Water Sustainability and International Innovation

The Baltimore Charter – A Transformation in Managing Water

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acknowledgements

The editors of this report wish to thank all the speakers and participants in the 2007 Baltimore Conference, *Water for all Life: A Decentralized Infrastructure for a Sustainable Future*, which was co-sponsored by the National Onsite Wastewater Recycling Association (NOWRA), the Water Environment Research Foundation (WERF), and the International Water Association (IWA). The two and a half days of plenary sessions and workshops were the foundation for the WERF-sponsored Long-Range Planning Retreat on the third and fourth day, at which the Baltimore Charter for Sustainable Water Systems was drafted.

We appreciate the willingness of eight key speakers in the Baltimore Conference to update their conference presentations for this report. In addition, Professor Vladimir Novotny researched and wrote a chapter on eco-cities, and Steve Moddemeyer provided a resource directory of international experts. A final chapter on prospects for innovation in the United States was prepared by the editors of this report. Lee Roberts compiled and formatted the final report.

introduction

On March 15, 2007 the Baltimore Charter for Sustainable Water Systems was drafted at a long-range planning workshop convened by the Water Environment Research Foundation (WERF). This workshop followed the international conference, Water for All Life: A Decentralized Infrastructure for a Sustainable Future, which met from March 12-14 in Baltimore, Maryland, USA. The conference was convened by the National Onsite Wastewater Recycling Association, International Water Association, and WERF.

Baltimore Conference: Water for all Life

The vision and commitment embodied in the drafting of The Baltimore Charter was a direct follow-on to the international conference on decentralized infrastructure held over the prior few days. The conference was convened at a seminal moment in water management, when there was a growing understanding that current methods and approaches are not sustainable into the future and that a "paradigm" shift would be required in technologies, practices, institutions, policies, and behaviors. However, the outlines of the new paradigm were at best murky.

The design of the conference was to bring visionary leadership from around the world to speak about their varied insights and perspectives, and to include a wide cross-section of stakeholders and participants in the water sector, including engineers, architects, biologists, researchers, investors, manufacturers, environmental activists, and government officials. Speakers were from both water-rich areas, including Canada, Japan Germany, and the western United States, and from drought-prone areas, including Australia, China, and the eastern United States. This diverse mixture of backgrounds and experiences was the backdrop for much intense and fruitful discussion and debate during the conference.

The Baltimore Charter
For Sustainable Water Systems

Water is at the heart of all life. In the past, we built water and wastewater infrastructure to protect ourselves from diseases, floods, and droughts. Now we see that fundamental life systems are in danger of collapsing from the disruptions and stresses caused by this infrastructure.

New and evolving water technologies and institutions that mimic and work with nature will restore our human and natural ecology across lots, neighborhoods, cities, and watersheds. We need to work together in our homes, our communities, our workplaces, and our governments to seize the opportunities to put these new designs in place.

Our group of scientists, engineers, environmentalists, government officials, manufacturers, and members of the private sector are part of the solution. We have both the opportunity and obligation to participate with others on this task of transforming how we think and act in relation to water.

We commit to implementing more sustainable water systems by expanding uses and opening new markets for small-scale treatment processes, advancing research on micro-biological and macro-ecological scales, inventing new technologies based on nature's lessons, creating new management and financial institutions, reforming government policies and regulations, and elevating water literacy and appreciation in the public.

Two key questions framed the conference presentations. The first day of the conference focused on the drivers for change and case studies from around the world, while the second day centered on strategies and dynamics for a paradigm shift. There may be a need for change, but unless there are successful efforts to break down barriers and implement new solutions, there will be continuing drift in a suboptimal, conventional approach. Topics in the plenary sessions about the need for and potential organizing efforts for change included research and new technologies, green building and eco-villages, watershed management, and global competition and new markets.

Out of these sessions and workshops emerged a clearer picture of the design of a new infrastructure, which would include the following innovations at various scales:

- Onsite and neighborhood treatment – small-scale technologies that mimic natural membranes and filters and that utilize soils and smart localized controls
- Onsite and neighborhood reuse -- Closed-loop water systems in residential and commercial buildings, where stormwater and wastewater are treated and reused for landscape irrigation, toilet flushing and cooling, and where minimal waste leaves the site
- Green infrastructure -- Rain gardens that trap stormwater and sustain trees and plants. These plants restore beauty and improve air quality in cities, moderate energy flows, and provide potential food sources
- Smart Growth -- Patterns of neighborhood development that interconnect nature and the built environment, preserve open space and respect natural drainage flows
- Green Cities -- Restoration of natural cycles of water infiltration and evaporation in cities and towns, through localized treatment and groundwater recharge, trees, parks and roof gardens, and stream daylighting and restoration
- Watershed restoration -- Restoration of natural watershed flows and functions, through localized water use and recycling into natural wetlands, groundwater, and air. These systems will restore and preserve vegetation and wildlife, and minimize climate changes and warming.

This report presents the updated work of eight of the key speakers at the Baltimore Conference. Each chapter represents a major thread in the new fabric of understanding of water sustainability that became embodied in the Baltimore Charter. We invite the reader to reflect on the messages of the Charter and to weave their own conclusions and insights into the evolving international conversation about the transformational changes needed in water management.

A New Water Management Paradigm

The first section of this report, presents key ideas incorporated into the new water management paradigm. Goen Ho and his colleagues from Murdoch University in Perth, Western Australia describe the shift from siloed, linear, and centralized infrastructure, which is wasteful and disruptive, to closed-loop water, energy, and nutrient infrastructure. Ho also describes a sustainability rating system for green builders in Australia, which incorporates goals for a lighter water footprint. Cori Barraclough and Patrick Lucey, from Aqua-Tex Scientific Consulting in Victoria, Canada, elaborate further on case studies for green development and closed-loop systems.

New Technologies and Tools for Sustainability

The second section of the report includes chapters on specific technologies and tools that are pieces of the larger paradigm shift. Ed Clerico from Alliance Environmental in the U.S. describes openings for reuse of rainwater and wastewater. Marco Schmidt from the Technische Universitat in Berlin, Germany describes a variety of green infrastructure approaches to stormwater management and energy controls in buildings. Prof. Xiaodi Hao of the Beijing University for Civil Engineering and Architecture presents work in China on eco-sanitation technologies and practices.

Change: Institutions and Barriers

The third section of this report includes chapters on drivers for and processes for change in water management. Glen Daigger from CH2M Hill presents innovation theories and their application to water utilities and policies. Cynthia Mitchell and her colleagues from the Institute for Sustainable

Futures in Sydney, Australia, applies theories of transition management to the unrecognized need for phosphorus recovery from wastewater back into agricultural use. Carol Howe from the SWITCH program in the Netherlands describes learning alliances in major cities around the globe.

Eco-Cities: An Update

An additional paper was prepared by Prof. Novotny of Northeastern University in the United States, which summarizes case studies in China and the United States.

Postscript: Applicability to the U.S.

The final chapter of this report is a 2010 postscript, where the editors reflect on the changing conversation and prospects for implementation of the principles of the Baltimore Charter in the United States. Using the work of Daigger, Mitchell, and Howe, the conclusions is that there is reason for hope.   There is an increasingly intense multi-stakeholder conversation about the problems with current water management approaches, an interest in integrated, green, and decentralized solutions, and an openness to demonstration projects and regulatory reform.

a new water management paradigm

Paper Abstracts

Sustainability Rating For Decentralised Water Systems

Goen Ho, Martin Anda, John Hunt

Decentralised water systems can readily contribute towards water environmental sustainability. It is important to be able to rate environmental sustainability of decentralised systems so that home buyers can have confidence on claims of water sustainability, builders can have guidance on how to improve sustainability, land developers can justify their marketing claims and regulators can assess and regulate promotion of water sustainability of decentralised water systems. The Environmental Technology Centre has developed a rating tool for such a purpose. The rating tool quantifies the volumes of water drawn from all sources and wastewater disposed or reused through all routes, compares these with best practice water use volumes for a decentralised system and arrives at a score out of 10 (equivalent to best practice). The algorithm for the rating tool is implemented using Excel workbook/ worksheets prompting users to enter required input values. Application to four case studies is presented.

Green Development and Closed-Loop Water Systems: A Restoration Economy Approach to Urban Watershed Regeneration

Cori L. Barraclough, Wm. Patrick Lucey

Natural systems operate in closed loops where water, energy and nutrients are constantly recycled and reused close to source. Modern infrastructure opens these loops and creates largely one-way open-flow systems. This has led to the simplification of the water and energy flows, a loss of ecological function, and a loss of ecological and economic value. In order to restore ecological function, and once again derive value from ecological services, we must restore the complexity of our urban ecosystems; in particular, the micro water cycles. Regeneration is especially critical in the face of a changing climate, because healthy ecosystems have the resilience to buffer communities from extreme weather events. While the cost of regenerating function may appear prohibitive, it can be accomplished simultaneously with development. This paper summarizes four case studies in Victoria, BC, Canada, that demonstrate how new and redevelopment projects can be used to restore ecological function and derive considerable value for the developer and the community without additional funds.

Sustainability Rating For Decentralised Water Systems

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Abstract

Decentralised water systems can readily contribute towards water environmental sustainability. It is important to be able to rate environmental sustainability of decentralised systems so that home buyers can have confidence on claims of water sustainability, builders can have guidance on how to improve sustainability, land developers can justify their marketing claims and regulators can assess and regulate promotion of water sustainability of decentralised water systems. The Environmental Technology Centre has developed a rating tool for such a purpose. The rating tool quantifies the volumes of water drawn from all sources and wastewater disposed or reused through all routes, compares these with best practice water use volumes for a decentralised system and arrives at a score out of 10 (equivalent to best practice). The algorithm for the rating tool is implemented using Excel workbook/ worksheets prompting users to enter required input values. Application to four case studies is presented.

Keywords

sustainability, decentralised water system, best practice, rating tool

Introduction

A number of challenges face the water industry and the professionals working in the water services sector. These challenges range from coping with increasing water demand from population growth and industrial development, rainfall variability and in many cases decreasing amounts, to aging water infrastructure. The latter is a problem of the developed world, whereas in the developing world there is the problem of inadequate water infrastructure and deteriorating environmental water quality.

Sustainability has also been an issue, and the question that the community has been asking is whether we will be able to maintain the supply of water to meet the demand, if we continue to develop our water services in the way we have been doing for at least the past half a century.

It is imperative therefore for us to consider current water management practices, particularly in urban areas, to examine whether they are sustainable, and how we can make them so. This is outlined below, followed by consideration of the contribution of decentralised systems to sustainability. It is important to be able to quantitatively rate how well a decentralised water system is in achieving sustainability, and a sustainability rating tool is described. Application of this rating tool is illustrated.

Water Management And Sustainability

Water services in an urban area usually consist of supplying drinking quality water, collecting wastewater, treating and disposing of it safely to the environment, collecting stormwater run-off and directing it to a receiving water, controlling flooding, and preserving amenity and water quality of surface and groundwater. These services may be the responsibility of several government agencies or corporations.

In an urban area with centralised water and wastewater systems, each area of responsibility is generally substantial enough to be handled by a single agency. Water supply service involves construction and operation of a surface water reservoir (dam) and its management, pumping it the city, treatment and distribution. Wastewater service involves building a sewerage system, pumping station, treatment plant and an effluent outfall. Even when water supply and wastewater services are handled by one agency, they are located in different sections within the organization. In general the provision of water supply service precedes that of wastewater sewerage service, and it is only in recent decades that provision of both is required during land development. The two services are in a sense completely different in nature, such that there is little need for the service providers to talk to each other.

Similarly stormwater drainage is a substantial responsibility. It involves the collection of stormwater run-off from urban surfaces that are impermeable (roof, driveway, road, car park) and directing it away to minimise the risks of flooding in the city. Stormwater may be collected in the same sewerage system as wastewater or separately, and responsibility is with usually with same agency as for wastewater.

Amenity provided by water environments (streams, lakes, wetlands) is usually looked after by local government or more recently a government agency responsible for the environment. Water quality of water environments is invariably affected by wastewater and stormwater that are discharged to them.

The centralised urban water infrastructure, particularly wastewater infrastructure, has been very effective in protecting public health in the developed world. The investment for water supply, wastewater and stormwater infrastructure is estimated to be between $5,000 to $10,000 per housing lot for new land development. This may appear to be considerable, but is a small fraction of the cost of land and building (less than 4%), and furthermore the direct (medical treatment) and indirect (loss of income) public health costs of not having the infrastructure may be 5 to 25 times.

The centralised water systems in the developed world are generally well managed with well established institutions, trained personnel and regulatory framework. The assets managed by centralised systems institutions are considerable, of the order of $10billion per million of population served. The direct costs or rates payable by householders for operation and maintenance is estimated to be $500 per year per household.

The centralised water systems can be depicted as in Figure 1. Despite the excellent management of the individual systems the impact of these systems on the environment is significant. The impact is in three areas.

Water is imported to the city for water supply. If the source is surface water it may involve building a reservoir (dam) across a river. The river downstream of the dam does not receive water in amount and variability as before the dam was built. At the same time impermeable surfaces in the city results in more rapid and greater amount of stormwater run-off in the stormwater sewer, which may increase the risks of flooding where the run-off is discharged.

Because not all pollutants are removed from treated wastewater that is disposed to a receiving water environment (river or ocean), the receiving water

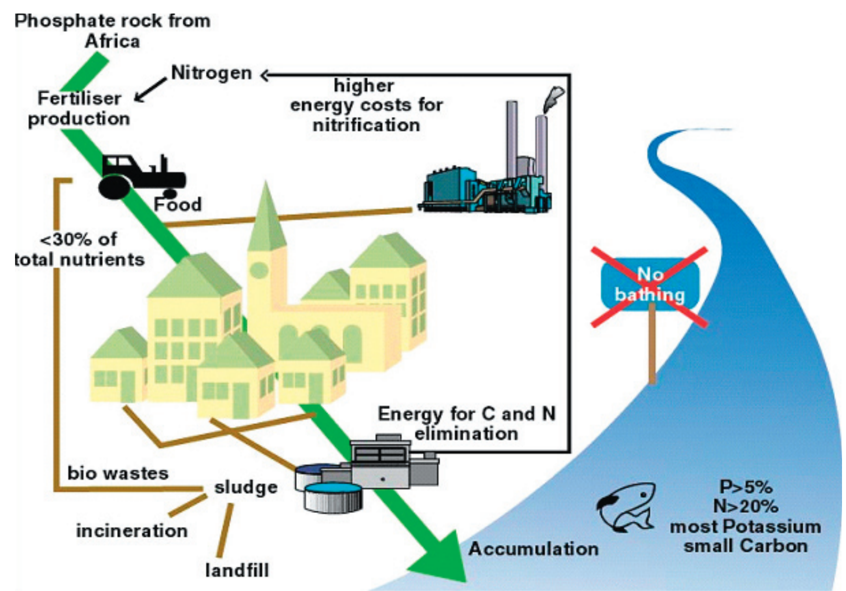

Figure 1. Unsustainable urban water management (UNEP, 2002)

environment is polluted. This pollution is exacerbated if industrial wastewater is collected with domestic wastewater. Wastewater and stormwater when collected in the same sewer also causes combined sewerage overflow during heavy rainfall periods, which generally bypasses treatment altogether.

There is loss of opportunity for the nutrients in wastewater (nitrogen and phosphorus) to be recycled on agricultural land. In fact nutrients are removed in many wastewater treatment plants, which adds to treatment costs to meet effluent discharge standards. The latter have become more stringent as regulatory authorities attempt to control and reduce pollution of receiving water environments. There is also the need to synthesise nitrogen fertilisers and mine phosphate rock to supply the fertiliser need of agriculture.

To overcome the environmental impact there have been efforts made to reuse wastewater, recycle stormwater and to return nutrients to agricultural land through recycling biosolids recovered from wastewater treatment. Integrated urban water management was introduced to ensure that planning for water supply, wastewater and stormwater is coordinated.

To reuse wastewater from a centralised system generally requires treated water to be piped and pumped to where large scale wastewater reuse can be applied, for example for replenishment of over-extracted groundwater, for agricultural or industrial purposes. The need for another water distribution system and the necessary large amount of investment is a challenge facing centralised water systems if sustainability is a desired outcome.

Sustainable water management

To achieve environmentally sustainable water management the undesirable environmental impacts have to be overcome. Figure 2 shows a possible scenario to achieve sustainability.

Industrial and domestic wastewaters are separately treated and collected. Industry is currently required to pre-treat its wastewater prior to discharge to the sewer. This is to protect the sewer and the treatment plant. This requirement can in the future be extended so that industry can also achieve sustainability objective by not discharging pollutants to the environment.

Future planning may include co-location of industry so that there will be opportunity for common treatment of industrial wastewater and its reuse. Industry with wastewaters that have similar characteristics to domestic wastewater (e.g. abattoir, food processing) can still discharge their wastewater to the domestic wastewater sewer. As a result domestic wastewater is not contaminated with industry wastewater, such as heavy metals, so treated domestic wastewater is suitable for reuse.

Stormwater run-off is infiltrated to the ground as much as possible through permeable pavements, infiltration strips and swales, constructed wetlands, ponds and lakes. Flow of the stormwater is slowed down and brought back as far as possible to the pattern before land clearing. Pollutants in the

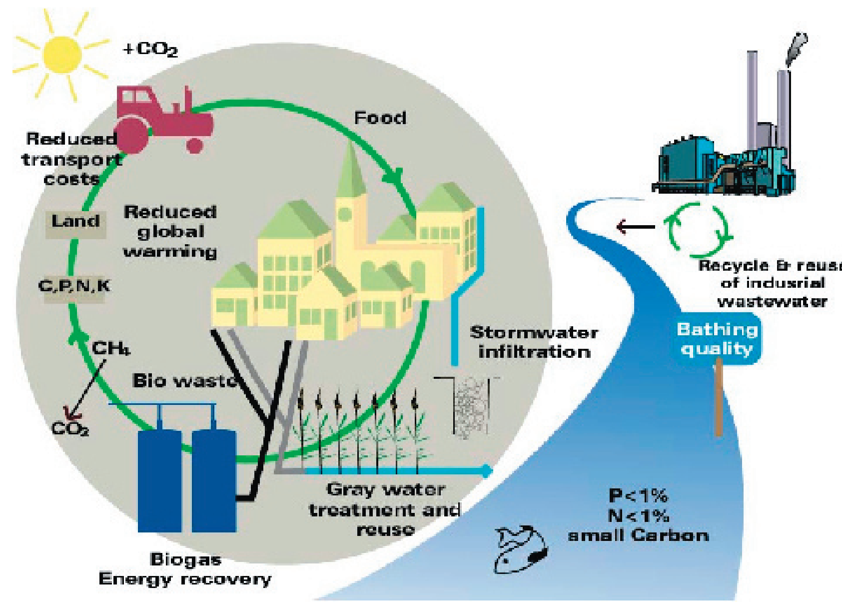

Figure 2. Sustainable urban water management (UNEP, 2002)

stormwater are also filtered by soil and plants. The wetlands, ponds and lakes provide environmental amenities and habitat for wildlife. There may also be opportunities to return streams that have been covered in the process of urban development to be restored to a condition closer to their natural state prior to development.

In the example shown in Figure 2 greywater, which is water from the bathroom and laundry, is separately collected and used for irrigation of garden or public open space. Blackwater, which is water from the toilet and kitchen, containing most of the solids and nutrients, is treated to extract methane. The nutrients are then recycled back to agricultural land. The nutrient cycle is then closed and no or less nutrients need to be imported. Little nutrients and pollutants are intentionally discharged to water environments, so that water quality in these environments is protected.

The use of greywater and stormwater for irrigation of garden and public open spaces means less scheme water is required. Less surface water is drawn for water supply and more environmental flow is restored to the river.

Decentralised water system contribution to sustainability

Closing the water and nutrient cycle for decentralised water systems is generally more feasible to achieve, because of the small scale nature of single dwellings, cluster of buildings or even village scale development. For a single dwelling, for example, roof rainwater can be harvested and stored for potable water and in-house uses (Ho and Anda, 2006). Wastewater can be treated to secondary standard using an aerobic treatment unit and the treated wastewater can be used for garden irrigation. The water and nutrient cycles can be more readily closed on-site without the need for piping and pumping water over long distances.

Progress in green building design has also facilitated the reuse and recycling of water. Stormwater run-off can also be infiltrated on-site and if desired stored under permeable pavements for use during long periods without rainfall, such in a Mediterranean climate. Green building design also facilitates integration between water and energy sustainability.

There is an advantage with cluster of dwellings or village scale development. There is an economy of scale, because one wastewater treatment plant instead of for each building is required, and there is public open space that can be irrigated with treated wastewater, instead of only gardens within property boundaries.

There is evidence of a growing desire by home buyers to have a home with water sustainability features. This appears to be driven by a range of reasons including consciousness for reducing water consumption in areas with decreasing rainfall, the desire to be more self-sufficient in water supply or wanting to be or become green. There is usually also the desire to have more energy efficient home, so that both water and energy use will be less while still maintaining the same lifestyle.

Home builders and land developers have responded to the demand by incorporating decentralised water systems, and advertising the properties as having water sustainability features. It may be bewildering for a home buyer faced with a variety of environmental sustainability claims by land developers, and it may also be difficult for the government to assist with advice. It is desirable to be able to rate decentralised water systems for their sustainability.

Sustainability Rating For Decentralised Water Systems

We have developed a rating tool that consists of 3 main steps (Hunt et al., 2006; Ho et al., 2007), and these are described below.

1. Ranking and assigning weighting values for water flows into and out of a land development

Figure 3 shows the flows of water into and out of a land development. Three sources of water are available to supply water to the land development, and five means for wastewater disposal. Scheme water and reticulated sewer are options for a land developer if a centralised system is desired, and rainwater and rainwater recharged groundwater for water supply if a decentralised system is desired.

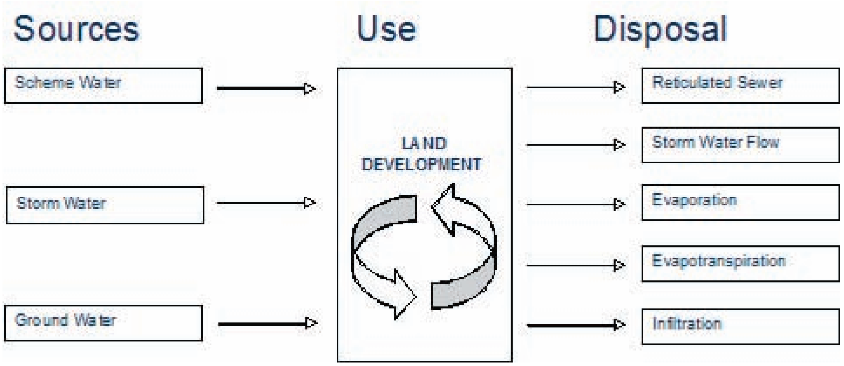

Figure 3. Water flow into and out of a land development

It may be necessary to draw water from scheme water if local rainfall, roof catchment or space for rainwater tanks is not adequate. Disposal of excess wastewater during the rainy season to a centralised sewerage system may also be necessary. If the objective of a decentralised system is to minimise impact outside the land development, then we want to minimise or avoid drawing water from scheme water or discharge wastewater to a centralised sewerage system.

For water supply we may give water from local rainfall the highest priority, followed by local groundwater which is replenished by rainfall and water from a centralised scheme the lowest priority.

For wastewater disposal our first priority can be evapotranspiration, because this is through plants and hence a means of maintaining a vegetated landscape (parks and gardens) or for growing food locally if desired. The next priority can be infiltration to the ground, because this is the means for recharging the local groundwater. Stormwater run-off can be next, because this will contribute to stream and river flow, although we may want to retain as much stormwater onsite, mimicking natural systems and may prevent

Supply streams		Disposal streams	
Ranking	Weighting (%)	Ranking	Weighting (%)
1. Rainwater	80	1. Evapotranspiration	75
2. Groundwater	70	2. Infiltration	55
3. Scheme water	50	3. Stormwater run-off	50
		4. Evaporation	20
		5. Reticulated sewer	10

Table 1. Supply and disposal stream ranking and weighting for land development

flash flooding in streams and rivers. Evaporation from excessive irrigation and disposal to a centralised reticulated sewer are least desirable when we wish to minimise impact on the environment and increase water use efficiency in a land development.

If we adopt the priority scheme as described above we can develop a weighting system that reflects it (Table 1).

Assigned values for the weighting of each stream should not only reflect our priority ranking (i.e. decreasing from ranking 1 to ranking 5), but also reflect local conditions. For example, if average local rainfall is relatively abundant and availability of land for rainwater storage tank is not limiting, then the weighting factor for supplying water through rainwater harvesting can be given a higher value, while for scheme water can be given a lower value. The weighting values shown in Table 1 reflect the local conditions in south west of Australia and in particular in the Perth metropolitan region and surrounding areas. The climate of the region is Mediterranean with four distinct but mild seasons. Rainfall is primarily in winter and long-term average rainfall is about 800 mm, although a significant decrease (-20%) has been noted in the trend over the past 20 years. There is a long dry period over summer and storing harvested rainwater for this period is an important consideration. Balancing this disadvantage is the existence of an unconfined aquifer beneath the predominantly sandy soils, acting as storage for infiltrated rainwater in winter that can be drawn in summer.

2. Determining best practice figures for volumes of water flows into and

out of a land development

Best practice volumes are estimated for each of the eight flow streams and they are discussed individually below as they involve quite a number of assumptions. Estimates will improve as we gain experience from application of the rating tool to real cases.

Rainwater

The best practice use of rainwater is determined by calculating the water that could be harvested and used in a home with moderate ease and cost. This usage is determined using standard household usage figures for the density of housing in the development. Different housing densities will have differing capacities to capture rainwater. For example if the development is high density the volume of water that could be captured per home is reduced as there is less roof catchment area per home than in a lower density development, and potentially less space for a rainwater tank.

The household usage is based on a tank size ranging from 2kL to 10kL. The water usage is for laundry, toilet flushing and a garden tap. Table 2 details this household (or indoor) usage further.

Groundwater

Zoning R-value*	m^2/dwelling unit	% of land under roof	Roof catchment area**, m^2	Tank size, kL	Max indoor use***, L/p/day
20	500	60%	150.0	10	36.5
40	250	70%	87.5	5	37.5
80	125	70%	43.8	2	36.2
160	63	80%	25.0	2	32.1

* Zoning R-value of 'n' refers to n dwelling units per hectare
** Roof catchment area for rainwater harvesting = half roof area
*** Takes into account rainfall pattern and size of tank

Table 2: Calculation of rainwater best practice usage

Best practice groundwater usage is determined by the volume of water required to irrigate household and public open space areas using average areas and efficient irrigation systems. Average areas of public open space and of household gardens for Perth developments were used. These averages were determined from a survey of land developments and are dependant on zoning density. The irrigation water required for these areas was calculated assuming efficient irrigation systems (90%), low crop factor plants (0.5) and improved soil. Table 3 outlines this information further. Washing machine used-water is assumed to supplement groundwater for irrigation of private garden.

Scheme Water

The best practice scheme water use is determined by subtracting the best practice rainwater use from the Perth average indoor water use. Water for indoor use is therefore from rainwater harvesting, and only when this is not sufficient that scheme water is used.

Evapotranspiration

The best practice volume of water that evapotranspires is determined by a percentage of the best practice groundwater use. That percentage is determined by the efficiency of the irrigation system. For an irrigation installed professionally a value of 80% groundwater used can be assumed.

Infiltration

Zoning R-value	m^2/ dwelling unit	Area of private garden m^2	POS* /dwelling unit m^2	Occupancy Rate	Dwelling units full irrigation requirement kL/ha/yr	POS Full irrigation requirement kL/ha/yr	Washing machine water kL/ha/yr	Ground water usage kL/ha/yr
20	500	175	100	3.4	1600	850	700	1750
40	250	50	44	2.6	3200	700	1400	2500
80	125	18.75	22	2.0	4600	700	1890	3410

* POS = public open space

Table 3: Minimum Irrigation Use

The best practice volume of infiltration is the sum of three infiltration flow paths. They are the infiltration from rainfall, the infiltration from irrigation use and the infiltration from seepage of any open water body. The infiltration from rainwater is the total rainwater falling on the development minus the volume of water harvested in the rainwater tanks and minus the volume of water leaving the site from runoff.

Storm Water Surface Runoff

The volume of surface water runoff is related to the volume of water infiltrated to the ground. Because of the sandy soils and the presence of unconfined aquifer in Perth, maximising infiltration of rainwater in winter and storing it in the unconfined groundwater for withdrawal in summer when there is little rainfall is the preferred option. In this case best practice means zero surface water runoff.

Evaporation

The best practice volume of water evaporated is determined by a percentage of the best practice volume of groundwater use, because groundwater is used for irrigation and excess irrigation should be minimised under best practice. That percentage is determined by the efficiency of the irrigation system. Assuming that the irrigation is installed professionally a value of 7% evaporation is assumed.

Reticulated Sewer

This volume of water is calculated from the Perth average in-house water use subtracting the volume of water used by the washing machine (this volume is used for garden irrigation, see above).

3. Determining actual values of volumes of water flows into and out of a land development and assigning a score compared with best practice.

For all flow streams the score of the development is determined by the difference between the actual quantity of water used by the development and the best practice volume for each flow stream. The higher the difference (deviation) the lower the score and vice versa. Differences can be negative and this results in the maximum score. The deviation calculation is given below for the eight flow streams. The equation is for Rainwater and Evapotranspiration

Deviation = (best practice volume – actual volume)/reasonable maximum difference

and for the other flows

Deviation = (actual volume – best practice volume)/reasonable maximum difference.

Score Calculation

To obtain the score for each flow stream the compliment of the deviation percentage for that flow stream is multiplied by the stream weighting. This number is then normalised so that the final score is out of 10.

Flow stream score = (1 - deviation) x weighting x normalising factor

The closer the actual is to the best practice, the lower the deviation resulting in a higher score. If the deviation is negative it is set to zero resulting in the maximum score. A reasonable maximum difference is set that corresponds to a likely worst scenario if no effort is made, e.g. reliance on scheme water only and disposal of wastewater through a centralised sewer. For deviations greater than 1 a score of 0 is assigned.

The algorithm for arriving at the final score as described above is set out in an Excel workbook. Inputs as required by the algorithm are requested at appropriate points in the relevant worksheets. An example of a score calculation is shown in Figure 4.The flow stream scores for the three supply flow streams are then added to give a total score for the supply flow streams out of five. The same is done for the five disposal flow streams. These two scores are then added together to give a total score out of ten.

Application To Case Study Land Developments

Score

Inflows

	kL/dev/yr	L/p/day	% deviation	Stream weighting	Score
Rainwater used actual	719	4	89.5%	80%	0.21
Rain water max use (HH)	6844	38			
Ground water actual	21236	116	-52.8%	70%	1.75
Ground water min	45000	247			
Scheme Water actual	31603	173	46.1%	50%	0.67
Scheme Water min	21626	119			
			Inflow Score		2.6 /5

	kL/dev/yr	L/p/day	% deviation	Stream weighting	Score
Evapotranspiration actual	28107	154	21.9%	75%	1.5
Evapotranspiration min	36000	197			
Infiltration actual	106107	581	13.4%	55%	1.2
Infiltration level	122551	672			
Storm outflow actual	21119	116	115.7%	40%	0.0
Storm minimum	0	0			
Evaporation actual	8825	48	180.2%	20%	0.0
Evaporation minimum	3150	17			
Sewer actual	28470	156	129.2%	10%	0.0
Sewer min	12421	68			
			Outflow Score		2.7 /5
			Total Score		5.3 /10

Figure 4: Example Score Calculation

The rating tool was applied to land developments in south west of Western Australia. Three actual case studies (South Beach, Bridgewater and Timber's Edge) were chosen not only for their innovative water systems, but also because these systems meant there was accompanying documentation. These included water balance audits, nutrient and irrigation management plans and Water Sensitive Urban Design and Integrated Urban Water Management plans. Much of the case study data was obtained from these documents produced by the developer or by consultants on behalf of the developer. A hypothetical case study considered a development in Perth that reflects current practice in the city. Pertinent characteristics of the case studies are shown in Tables 4 and 5.

The case studies have differing water regimes. Bridgewater has 100% onsite recycling of greywater for each house as its key feature, Timber's Edge has centralised grey water recycling and South Beach Village has no recycling system. The Perth average case study has no innovative water systems representing current practice in the Perth metropolitan area. The three real case studies have efficient irrigation systems, water-wise landscaping, promote efficient in-house water use and good storm water management.

Table 5 shows the rating scores for the case study land developments. The table also shows water saving features of the land developments. The rating score correlates well with increased use of water saving or efficient appliances, techniques or design.

	Perth*	South Beach Fremantle	Bridgewater Mandurah	Timber's Edge Mandurah
Parameters				
Number of houses**	280	300	389	260
Occupancy/ house	3.35	3.3	1.6	2.0
Land Area	20 ha	22.1 ha	13.7 ha	18.0 ha
Land area/ house	600 m^2	370 m^2	230 m^2	540 m^2
Roof area/ house	214 m^2	180 m^2	132 m^2	150 m^2
Land Use Classification^	Urban – Green Title	Urban - Green Title	Caravan Park & Camping	Urban – Strata Title
Greywater reuse#	0%	0	100%	100%
Rain water reuse	Some rain tanks	none	Unplumbed rain tanks	Some rain tanks

* average or typical values for Perth, ** detached dwellings in all cases, # blackwater to sewer in all cases, ^Green title = individual title for each land lot, Strata title = common title for land development.

Table 4. Characteristics of land development case studies

Discussion

Accurate estimates of water inflows and outflows are important in using the assessment tool. An indicator for the accuracy of the estimates is the difference between the total of the inflows and outflows, called the water balance closure. A closure of less than 10% is generally considered good, and this was the case for the estimates for the case studies (Table 5), except for Bridgewater. Further metering of flows can achieve better water balance closure.

Quite a number of assumptions are made in deriving the final rating score for a land development. In particular the derivation of the best practice figures for each flow stream can be refined to reflect improvements or advances in technologies, and will therefore change with time. The rating score values will correspondingly change with time (decrease with advances in technology and practice for the same land development unless a retrofit or better management practice is implemented). Viewed in this way the score should be regarded as an indication of the water use performance efficiency and not an absolute value. Its utility is in comparing between land developments and for a particular land development the relative improvements in overall water efficiency when different techniques, measures or management practices are adopted.

Land development	Water efficient appliances	Greywater reuse	Drip irrigation	Rainwater tanks	Water efficient landscape	Water balance closure*	Rating score (10)
Perth average	-#	-	-	-	-	2%	2
South Beach	Y#	-	-	-	-	3%	3
Bridgewater	Y	Y	Y	Y	Y	12%	6.5
Timber's Edge	Y	Y	Y	-	-	8%	5

- = no, Y = yes

* Closure = difference between total inflows and total outflows

Table 5. Rating scores for case study land developments

Utility of the rating tool

As indicated above the rating tool will be useful for a land developer to assess the water use performance efficiency of a land development, to compare alternatives for improving the efficiency and assist with choosing alternatives which are more cost-effective.

The rating tool will be useful to regulators who want to promote the efficient use of water. Appliances are now star rated for their water (and energy) use efficiency. The higher the number of stars the higher the efficiency, and the rating will assist consumers in choosing the appropriate appliance taking into account not only price but efficiency, with the former affecting investment cost and the later operating cost. In the same way land developments can be rated. This rating can be employed by land developers to market their land developments to home buyers. They are currently doing this, but their claims are not supported by a rating scheme.

Land developers in Perth are currently required to prepare a water management plan and in some cases a nutrient management plan. The former is largely driven by the decreasing amount of rainfall and hence less scheme water supply and availability of local groundwater, while the latter by the desire to protect surface and groundwater from nutrient pollution. The next logical step is for regulators to establish a land development water use performance efficiency rating that will facilitate both land developers to market their land developments and consumers to choose which land development to live in.

Refinement to the rating tool

The rating tool provides flexibility for assigning ranking for preferred use of sources of water and preferred route of disposal of wastewater. While the ranking as proposed is robust, the assignment of weighting factors relies on local factors. These include whether rainfall is relatively abundant, whether there is groundwater that is naturally recharged by rainfall and ease of withdrawal of the groundwater, the slope of the landscape that will govern how easily stormwater is retained on site, the nature of the soil and underlying materials that may or may not allow rapid infiltration, and thus local climatic, physical and geological features, and of course existing water supply and wastewater sewer infrastructure. Refinement of the rating tool could provide guidance on allocating weighting factors that will remove much of the subjectivity involved.

The rating tool requires that best practice water use and wastewater reuse and disposal be quantitatively determined. As discussed above best practice will continue to improve. What is considered best practice now may not be best practice in the future. Furthermore local best practice may lag behind international best practice. Using local best practice is preferred if the rating tool is to be used to rate local land developments and how future developments can be improved. Using international best practice may not provide a fair comparison because best practice is affected by local factors (climatic, physical and geological factors cited above), so that any comparison should select similar local factors.

Having discussed possible refinements to the rating tool we must not forget that the purpose of the rating tool is to provide a guide for comparing land developments and not absolute score values for the land developments. Precise values are therefore not needed, but only good estimates to allow comparison of land developments to be made by land developers, consumers and regulators.

Measuring progress towards decentralised water systems using the rating tool

The rating tool provides a means of measuring progress from a centralised water system to a decentralised water system. If the best practice conditions for a land development are set with zero flow of water from scheme water and zero flow of wastewater to a centralised sewerage system, then the score will indicate how well the land development is in performing as a decentralised system. The score is a quality measure with the higher score indicating better achievement.

The rating tool highlights the need to consider the broader questions of whether it is realistic to set best practice as equivalent to disconnecting to (or independent of) a centralised water and wastewater systems. In water deficient areas rainfall precipitation on the land development may not be sufficient, and water will have to be imported. Even in areas where rainfall is adequate there is the question of how much water should be retained within the land development area, and whether water is released through run-off to local stream outside the land development or through groundwater flow. In this regard there is an imperative in mimicking nature, i.e. how water would have behaved in the natural uncleared area prior to any development.

As the rating tool is applied to more case studies with differing local conditions we will gain greater experience that will provide guidance on how to apply it to general and particular situations.

Application to developing countries

Developing countries do not usually have adequate water infrastructure, but they endeavour to provide safe drinking water and adequate sanitation provision. Centralised water infrastructure is generally not affordable by developing countries, if wide spread coverage of water and sanitation services are to be provided to as many people as possible. The high upfront investment costs are the main deterring factor.

It can be argued that decentralised water systems could be more appropriate, because there are low cost systems for harvesting rainwater for potable use, and for sanitation. Information on these should be provided. The Environmental Technology Centre has developed monographs, training materials including eLearning packages in Rainwater Harvesting, Water Demand Management and Wastewater Reuse (Ho and Priest, 2005). The training materials can be used for face to face training workshop, whereas the eLearning packages for distance learning. Both should ideally be used at the same time.

Conclusions

A rating tool has been developed to assess the water use performance efficiency of land developments. The rating tool provides a structured, systematic and quantitative way all to assess the water flow streams into and out of a land development. It is a quantitative tool that gives a quality rating of not only water use efficiency of a land development, but also progress towards best practice decentralised systems. The rating or score is also a measure of attainment towards water sustainability of the land development, because the smaller the import of water and the export of wastewater the smaller the environmental impact outside the land development.

It will be useful for land developers to assess and promote its land development water sustainability, for consumers to choose alternative land developments and for regulators to facilitate more efficient water use at the land development scale.

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Green Development and Closed-Loop Water Systems: A Restoration Economy Approach to Urban Watershed Regeneration

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Abstract

Natural systems operate in closed loops where water, energy and nutrients are constantly recycled and reused close to source. Modern infrastructure opens these loops and creates largely one-way open-flow systems. This has led to the simplification of the water and energy flows, a loss of ecological function, and a loss of ecological and economic value. In order to restore ecological function, and once again derive value from ecological services, we must restore the complexity of our urban ecosystems; in particular, the micro water cycles. Regeneration is especially critical in the face of a changing climate, because healthy ecosystems have the resilience to buffer communities from extreme weather events. While the cost of regenerating function may appear prohibitive, it can be accomplished simultaneously with development. This paper summarizes four case studies in Victoria, BC, Canada, that demonstrate how new and redevelopment projects can be used to restore ecological function and derive considerable value for the developer and the community without additional funds.

Keywords

Integrated Design and Planning (IDP), Integrated Resource Management (IRM™), Proper Functioning Condition (PFC), closed-loop water system, ecological function, adaptive regenerative design, restoration economy, urban stream, wetland, stormwater.

Introduction

Our understanding of the way water moves across the landscape has changed substantially in recent decades; however, many schoolchildren are still taught the "classic" hydrologic cycle. In this model, water evaporates from the oceans to form clouds, moves inland toward the mountains, condenses to form rain and snow, and then flows once again toward the ocean in streams and rivers. While not actually incorrect at a gross scale, this model is essentially incomplete. Within the large hydrologic cycle there are many smaller "micro-cycles". It is the understanding and replication of these micro water cycles that is necessary to restore the function of aquatic systems and allow us to derive value from healthy watersheds.

Prior to European settlement, the North American landscape looked very different. Vast expanses of wetlands, beaver swamps, ponds, and lakes dominated the landscape. Beavers, nature's finest hydrological engineers, were present in all but the coldest parts of the north and the driest desert regions. Their ability to capture water in shallow ponds and wetlands allowed soils to remain saturated, provided summer baseflow to streams, captured sediment, built new soils and provided vast expanses of aquatic habitat for fish, amphibians and insects. Zooplankton and insects fed on the planktonic and attached algae within the ponds, which, in turn, derived their energy from sunlight while capturing and sequestering carbon and nutrients.

The prairies were home not only to beavers, but also to prairie dogs and bison. The prairie dogs created an underground network of tunnels, connected to the surface, which allowed rainwater to penetrate the tough layers of prairie grass and be stored deep within the groundwater table. The bison also did their part to recharge groundwater by creating shallow dust wallows to ward off biting insects. These wallows acted to trap rainwater and allowed it to slowly seep into the soil (Outwater, 1996).

Humans have interrupted the natural soil processes of "capture, store, and beneficial use" by eliminating many of the animals who performed these tasks, and by creating impermeable surfaces through which no water can penetrate (Barrett in: Buckhouse, 1999). While we now store more water in our artificial reservoirs than the beavers did in their natural ponds, our reservoirs are in a few key locations and are not evenly distributed across the landscape. The reservoirs are generally deep, with comparatively little surface area exposure to the sunlight that drives photosynthesis, and they are generally permanent. Whereas beaver dams would regularly be breached, allowing captured sediment to continuously feed the streams and rebuild the stream banks, reservoirs capture vast quantities of sediment permanently behind the dams, starving the rivers of their source for new soil and simplifying both their hydrology and morphology (Vorosmarty and Sahagian, 2000; Naiman et al., 2008). The phenomenon of "clear water erosion" then eats away streambanks and further exacerbates the degradation of streams.

As stream banks degrade, so too does their ability to store water. A healthy riparian zone can store many times more water than a degraded one (Prichard, 1998). Loss of riparian zones in turn, causes loss of base flow and creeks that are dried up in summer. Without the plants, the creeks cannot withstand the high flows brought on by snowmelt or rainy periods, and the banks erode. Fish habitat is lost, drinking water quality is compromised, and supplying enough water for irrigation becomes difficult. As water tables drop, riparian communities (amongst the most biologically diverse ecosystems and crucial storage reservoirs of fixed carbon) shift to dry soil 'upland' plant communities, resulting in carbon release and soil erosion. This drying of the landscape may then, in turn, exacerbate the effects of climate change through shifts from latent heat (seventy to eighty percent of solar radiation dissipated by vegetation, via evapotranspiration and photosynthesis) to sensible heat where sixty to seventy percent of energy is redirected to the atmosphere by a devegetated landscape and through extensive heat islands (Townsend, 2009).

Riparian systems are also critical for their ability to capture and recycle nutrients. Nutrient-rich runoff from our cities, including stormwater and wastewater, and fertilizer-laden agricultural runoff is intensifying eutrophication of estuarine and coastal waters and creating oxygen depleted 'dead zones'. "The continued and accelerated export of nitrogen and phosphorus to the world's oceans, even without climate change, is the trajectory expected unless social intervention in the form of controls or changes in culture are successfully pursued… As a result, the symptoms of eutrophication, such as noxious and harmful algal blooms, reduced water quality, loss of habitat and natural resources, and severity of hypoxia (oxygen depletion) and its extent in estuaries and coastal waters will increase… In anticipation of the negative effects of global change, nutrient loadings to coastal waters need to be reduced now, so that further water quality degradation is prevented" (Rabalais, et al., 2009). With social will however, this trend can be successfully reversed, as demonstrated in the Hudson and East Rivers of New York and the Thames River in England (Diaz and Rosenberg, 2008).

In order to reverse the drying trend, reclaim energy and nutrients, and restore ecological function, we must restore complexity. Nature derives value from complexity - the "waste" from one organism or process becomes food for another. If we follow this principle of microrecycling, be it for water, energy, or nutrients, we reduce the amount of energy needed for transport, minimize the amount of storage required, increase the resilience of the system, and reduce the effects of climate change, natural disaster and dependence on outside sources. We must, however, find a way to pay for this restoration of complexity. One solution is to incorporate a program of adaptive regenerative design into all new and redevelopment projects.

This program must have, at its core, six elements. It should:

- use a 'fit-for-purpose' approach to water use;
- reclaim and recycle water in many micro-cycles;
- mimic nature by keeping water on the land as long as possible (Doncaster, 2001);
- use a 'Design with Nature' approach (McHarg, 1969) (e.g. Engineered Ecology™);
- use an Integrated Design Process (IDP); and
- incorporate an Integrated Resource Management (IRM™) design philosophy.

The following case studies provide real examples of how adaptive regenerative design can be implemented to restore the water balance of our cites, regenerate habitat, reduce infrastructure costs, generate value, and restore the health and function of our watersheds and the people that live within them. These case studies, all projects undertaken by Aqua-Tex, represent a progression in scale and scope, and an evolution in thinking and complexity, from a simple subdivision to a city-wide program.

Case Studies

The Watershed and Community Context

The case studies presented here are all in the Greater Victoria area of Southern Vancouver Island, BC. This region receives approximately 608 mm (24 inches) of rainfall per year, primarily in the winter months from November through March, and rarely receives significant snowfall (Environment Canada, 2009). Due to its moderate climate, the Victoria area is a very popular place to live and demand for new housing is strong. Fertile soils and a long growing season have historically made this a successful agricultural area, but pressure from urban development and offshore competition in agricultural products has forced agriculture away from the city core and reduced its financial viability. As with many urban and semi-urban centres, an increase in the total impervious area (TIA) has resulted in flashy stream flows, reduced groundwater recharge, degradation in stream water quality and an overall reduction in both terrestrial and aquatic habitat. Anadromous salmon are still present in the Colquitz River system, and many streams support small numbers of trout. Within Saanich, many of the streams remain above ground; however, in Oak Bay and the City of Victoria, most of the streams have been culverted and buried.

Case Study 1: Blenkinsop Creek Relocation and Restoration

Project Description

This project was undertaken on Galeys' Farm which is located in the Blenkinsop Valley, Saanich BC. The site is situated between a former railway (now a rails-to-trails project known as the Galloping Goose Trail) and Blenkinsop Road (Figure 1). Land in the valley consists of small agricultural operations and hobby farms, with most of the agricultural lands being classified as Agricultural Land Reserve (ALR) (in BC, ALR lands are legislated for agricultural use only). The rich agricultural soils were laid down when the site was part of Blenkinsop Lake. In the early 1900s, a ditch (Blenkinsop Creek) was blasted to drain a portion of the lake south towards Swan Lake. The newly drained land was slated to be a residential subdivision, but was never developed due to the outbreak of World War I. The land was eventually sold for agriculture and its rich soils still produce high quality fruits and vegetables today.

Until its relocation, Blenkinsop Creek ran in a straight ditch north-south through the Galeys' field. Approximately one-sixth of their field was separated from the larger portion, necessitating bridges, a separate irrigation system, extra roads along each side of the ditch, and extra time and resources to

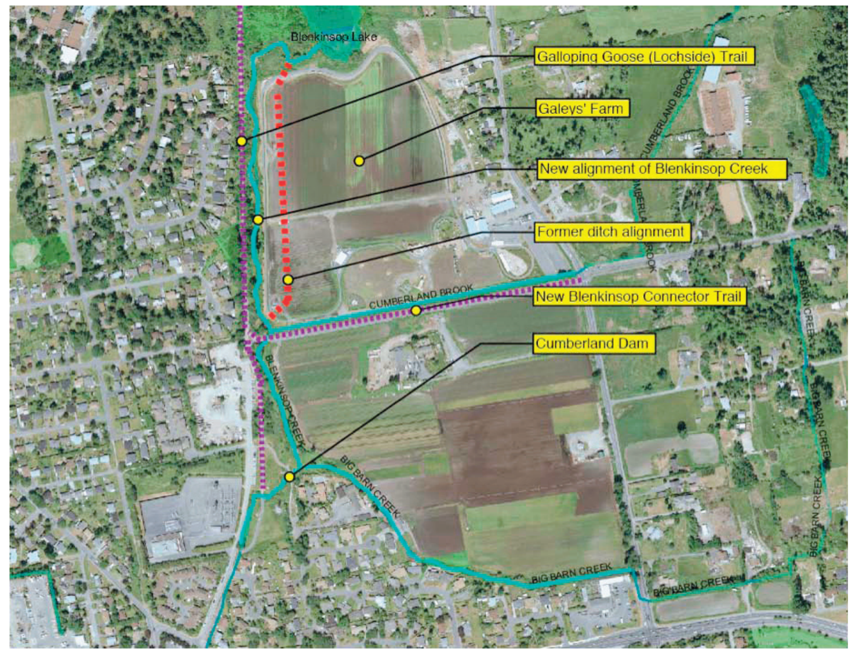

Figure 1. Site plan of Galeys' Farm and Blenkinsop Creek.

manage this narrow strip of land. The conversion of the neighbouring rail line to the Galloping Goose Trail created a secondary agricultural hazard: that of vandalism to the crops and the equipment. Since there was no direct trail or access to Blenkinsop Road from the Galloping Goose, large numbers of cyclists, hikers, and passersby accessed Blenkinsop Road via the field. In the process, both crops and farm equipment were regularly damaged, at an estimated cost of $100,000 a year (Galey, pers. comm. 2007). At this time, farming in the region had become gradually less viable, owing largely to competition from overseas markets. Pressure to improve farm efficiency had resulted in the Galeys seeking to diversify into agritourism. Success with small ventures such as corn mazes and similar attractions suggested that the creek restoration could create additional interest. For all these reasons, relocation of the ditch was very desirable from a farming perspective; however, it was costly and required a significant number of regulatory approvals.

Figure 2. Top Left: The ditch prior to relocation and restoration in 1999. Top Right: The field prior to reconstruction of the creek. Note the ditch on the right side of the hydro tower. Bottom Left: Blenkinsop Creek in May 2006, four years after construction. Bottom right: Blenkinsop Creek June 2009. (Aqua-Tex photos).

As noted above, Blenkinsop Creek drains into Swan Lake, which, in turn, drains into the Colquitz River. Owing to the fact that it drains agricultural fields and urban hard surfaces, the water quality of the creek was very poor. The managers of Swan Lake, concerned about the lake's water quality, approached Aqua-Tex with an idea to remediate a portion of Blenkinsop Creek in an attempt to reduce nutrient loading to the lake and restore fish and bird habitat. A project plan was developed and funding and in-kind support was drawn together from many different sources. These sources included: Natural Sciences and Engineering Resource Council of Canada (NSERC), Galey Bros. Farms, Swan Lake Christmas Hill Nature Sanctuary, the District of Saanich, Goodwin Farms, Eco-Action Canada, South Island Aquatic Stewardship Society, Capital Regional District Forestry Division, Ministry of Environment (E-Team), St. Michael's University School, Pacific Christian Academy, Katimavik, Royal Oak Burial Park, Royal Colwood Golf and Country Club, Victoria Natural History Society, Aqua-Tex, LaCas Consultants, Joseph Brown Contracting and Victoria Geomatics (Malmkvist, 2002). While the list is lengthy, it demonstrates the extensive community support necessary to undertake such a project.

The main objective of the project was to restore ecological function to a 650m length of the creek, and apply the Proper Functioning Condition (PFC) assessment method as design criteria (Prichard, 1998). By removing the ditch and rebuilding it as a creek in a more efficient location, it was felt that farming efficiency and water quality could be improved and habitat regenerated.

The project was completed in 2002. Aqua-Tex sponsored a graduate student to study and participate in this project and details can be found in her master's thesis (Malmkvist, 2002). Though there was no question that the project was an ecological success, as evidenced by the return of many raptors, herons, and other wildlife, at the time the project was completed it was unclear whether the objective of water quality improvement had been achieved, or whether the investment was financially sound. Two related, but separate, studies were therefore undertaken to examine the water quality in the creek and to assess the economic value of the project (Barraclough and Hegg, 2008; Barraclough and Hegg, 2008a).

Water Quality Benefit

In summary, the water quality improvements resulting from the channel restoration were significant. The channel removed between -1.2% and 38.9% of the total nitrogen with an average removal efficiency of 18.8%. On average, the ammonia was reduced by over 55.6%, the nitrate by 20.15% and the nitrite by 13.9%. The ortho-phosphorus was reduced by an average of 20.1%. The restored channel reduced Total Suspended Solids (TSS) more than 50% of the time. The effective removal of arsenic was 44.7%, cadmium 83.4%, chromium 19.8%, copper 39.9%, lead 90%, mercury 58.3% and zinc 64.7% (Barraclough and Hegg, 2008). It is important to consider how the change in channel morphology, from a ditch whose function was to convey water quickly, to a sinuous stream channel intended to slow the water and create complexity, might have assisted in removing these nutrients and heavy metals from the water column by providing extended residence time, allowing nutrient uptake by plants and settling of particulates to which the heavy metals are bound. This ability of riparian zones, in a state of proper functioning condition, to capture nutrients and heavy metals, and nitrogen in particular (Johnson, 2009), is critical to addressing the grave issue of “creeping dead zones” in the ocean.

“Dead zones in the coastal oceans have spread exponentially since the 1960s and have serious consequences for ecosystem functioning. The formation of dead zones has been exacerbated by the increase in primary production and consequent worldwide coastal eutrophication fueled by riverine runoff of fertilizers and the burning of fossil fuels. Enhanced primary production results in an accumulation of particulate organic matter, which encourages microbial activity and the consumption of dissolved oxygen in bottom waters. Dead zones have now been reported from more than 400 systems, affecting a total area of more than 245,000 square kilometers, and are probably a key stressor on marine ecosystems” (Diaz and Rosenberg, 2008). The health of freshwater systems thus directly influences the health of near shore marine ecosystems; a further example of the vital need to re-establish water and nutrient micro-cycles.

Economic Value

While the details of the economic analysis can be found in Barraclough and Hegg (2008a), the key findings are:

- Restoration increased arable land by approximately 1.5 acres. This was accomplished by eliminating two roads and reconnecting the two fields. Based on land sales at 2007 values, this suggests a net benefit to the land of $75-90,000. Agricultural land values do not appreciably fluctuate in this location.
- Pesticide use halted as a result of habitat restoration. The newly planted riparian zone provided significant bird habitat (Malmkvist 2002) and the birds were observed eating pests on the crops. This additional “support” enabled the Galeys to implement Integrated Pest Management without herbicides. This affected fields totalling approximately 21.4 acres on the Galeys’ farm. The savings amounted to approximately $1,650 per acre per year. The present value (PV) of these savings discounted at 5% over 25 years amounted to a savings of $497,657.
- Galeys were able to use (licensed) stream water to sub-irrigate their crops as a result of the drainage system that was expanded during the restoration project. Previously, they irrigated with potable water. The present value of this benefit was $8,548.
- Prior to commencement of the project, vandalism costs averaged approximately $100,000 per year. If the project had not been completed, vandalism costs would have continued to mount; this yearly cost discounted over 25 years would be $1,409,394.
- As the climate changes and storm events increase in frequency and magnitude, downstream flooding may become more of a political issue than it is today. Using proxies to estimate the value (or cost) of flood protection, the discounted value of flood protection is $765,484. Upon comparison to actual flooding costs that occur (i.e., in the millions), such an insurance value paid to a landowner would be relatively cheap in comparison.

- The present value of ecological benefit that resulted from the restoration of Blenkinsop Creek and riparian area was estimated at $12,006.
- The present value of carbon storage and sequestration for 650m of restored creek amounted to $496.13. Although, this value is small, carbon sequestration aggregated over the entire municipality would result in quite a large value ($1,113,869.00) (Blyth and Laing, 2008).

The financial summary below shows that this was a viable project for the farmer. This is an important point to note since the farmer or land-owner would likely be burdened with the cost of the project, and rarely do farmers have enough capital to undertake such projects. In total, the costs to the farmer prior to the restoration of the creek exceeded $1.4 million over 25 years, with little value accruing to either the municipality, farmer, or those affected by water flows downstream. By comparison, by taking into account the cost of the project as well as a conservative loan (although one was not required as this project was publicly financed and no finance rate applied), the estimated net benefit (PV) to the farmer from the realignment and restoration of 650m of Blenkinsop Creek was $1.6 Million. In addition, there was a net benefit to the municipality and surrounding community. The expected net present value of their benefit was estimated to be $4.0 million.

In summary, the Blenkinsop Creek project began as an ecological restoration project with significant costs, but no apparent economic value. Upon review, the project not only had substantial economic value to the farmer, but also to the municipality and broader community. In hindsight it is therefore appropriate and fitting that the project was funded through community collaboration. This project reinforces the ecological science that repeatedly demonstrates the value of complex ecosystem services, particularly in riparian areas. The simple act of increasing the complexity of the channel for example, had immediate water quality and habitat benefits. The Blenkinsop project was not designed with a future economic study in mind; therefore many of the data needed to complete a thorough analysis were not available. Were these data available, it is anticipated that many more benefits could be quantified including the value to air quality, human health, safety (for example to cyclists using the trail rather than congested streets), increased quality of produce (without pesticide) and capacity to reallocate existing water from a public reservoir, thereby postponing expensive infrastructure upgrades.

Table 1. Blenkinsop Creek Financial Summary

Blenkinsop (Traditional)	**Municipality**	**Farmer**
Installation of Ditch		($5,200.00)
PV of Ditch O&M		($6,631.69)
PV of Vandalism Costs		($1,409,394.46)
Total Present Value	$0.00	($1,421,226.14)
Blenkinsop (Sustainable)	**Municipality**	**Farmer**
Cost of the Restoration		($375,000.00)
Cost of the Connector Trail	($500,000.00)	
PV of the Cost of Financing		($26,607.17)
PV of Pesticide Savings (adjusted for the cost of integrated pest management)		$497,657.18
Increased Value of Land		$75,000.00
PV of Potable Water Savings		$8,548.33
PV of Flood Cost Avoidance to the Municipality	$765,484.59	
PV of Ecological Benefit	$12,006.19	
PV of Value of Carbon Stored and Sequestered	$496.13	
PV of Trail Connector Benefit	$3,302,784.65	
Total Present Value	$3,580,771.55	$179,598.34
Net BENEFIT	**$3,580,771.55**	**$1,600,824.48**

Table 1. Blenkinsop Creek Financial Summary

Case Study 2: Willowbrook Subdivision and Glanford Station Subdivision, Saanich BC (Neighbourhood/ Subdivision Scale)

Project Description

Willowbrook Subdivision was developed by Cadillac Homes Ltd. and is an urban in-fill development of thirty-one single family detached residences on former agricultural land. It is partially within the 200-year floodplain for Swan Creek in Saanich BC, which is a tributary of the salmon-bearing Colquitz River. During the construction of the Willowbrook Subdivision, Swan Creek was upgraded from an agricultural drainage ditch, relocated, and restored through the site (Figure 3). Seventeen percent of the property was dedicated to the municipality of Saanich as an addition to a neighbouring linear park. Six wetland ponds were created to manage stormwater, extend wildlife corridors, connect local public walking trails and provide habitat. A 750-meter section of the fish-bearing creek was rehabilitated to approximate its condition in the 1930's. A sewer right-of-way was used as a space to provide additional wetland stormwater treatment and to construct a walking trail, thus adding functionality to otherwise unused space and retaining full access for repair and maintenance.

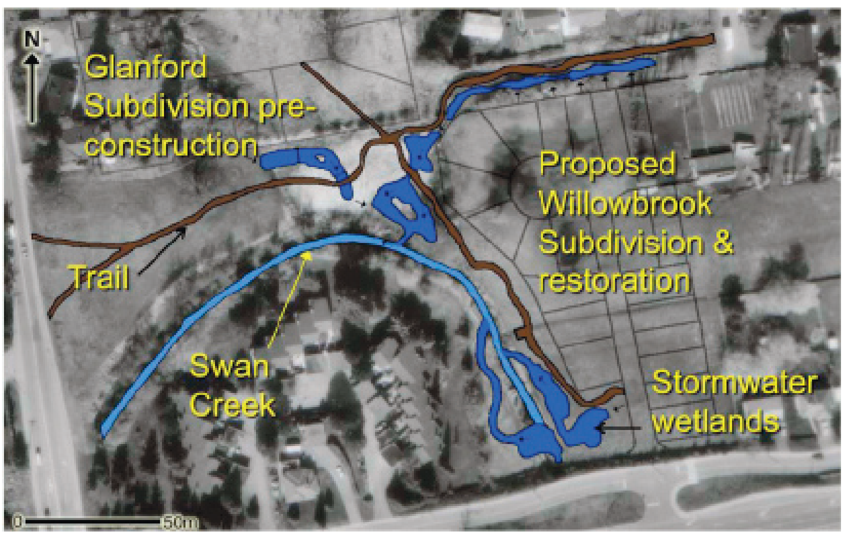

Figure 3. An aerial photo of Willowbrook Subdivision site, prior to development, showing the proposed wetland construction and trail network (after Malmkvist, 2002).

Two different developers had previously approached the municipality with development proposals that included traditional engineered solutions to stormwater management and flood control. These failed to obtain requisite approvals as their conventional methods did not meet City bylaw requirements or sufficiently address floodplain liability and were unable to garner local neighbourhood support (a common challenge to developers). In the Cadillac Homes project, the new 200-year floodplain was determined by hydrological modelling of the flows in Swan Creek. This approach was essential to address due diligence with regard to flooding. Aqua-Tex designed the urban stormwater treatment ponds and wetlands based on the Proper Functioning Condition (PFC) criteria (Prichard, 1998), and also used them to define how the subdivision and road layout would be developed given the ecological need to keep water on the land as long as possible. The design also incorporated public safety requirements, wildlife habitat enhancement, as well as aesthetic and recreational benefits from the new park. The neighbourhood thus actively supported this proposal when it was presented to City Council for approval.

Glanford Station, adjacent to the Willowbrook Subdivision, is a single-family residential subdivision of twenty-two homes including a pre-existing subdivision of six homes. Stormwater from both subdivisions is managed using wetlands constructed between Swan Creek and an adjacent Garry Oak preservation area. The stormwater drains from the subdivisions into a cascading series of ponds and wetlands, constructed by the developer, before entering Swan Creek. For the purposes of this paper, these two adjacent projects were considered as a single whole.

The Willowbrook project was the subject of an intensive year-long stormwater study. This study demonstrated that the ecologically designed wetlands were effective at improving stormwater quality, but, like any managed system, required a small amount of maintenance to optimize their function. The results of the stormwater study can be found in Barraclough and Hegg (2008).

The Value of an Ecological Approach to Infrastructure

Construction of the Willowbrook Subdivision began in the summer of 2000, following regulatory approvals at the municipal, provincial and federal level. Federal (Fisheries and Oceans Canada) approval was required because Swan Creek is a tributary to a salmon-bearing stream. Complex approvals can cause developers to incur major delays and borrowing costs on their land and construction loans. In this case, support for an ecological approach to stormwater infrastructure and stream restoration, meant that all approvals were received inside of three months. This saved the developer a significant amount of money that he then put toward ecological restoration on the site. In order to maximize the land available for park dedication, and to encourage similar ecologically-based projects, the municipality enacted a new subdivision bylaw to accommodate small lot sizes of +/-290 m^2 (3,000 sq. ft.) with reduced setbacks. While the lots were up to fifty percent smaller than the traditional lots in the neighbourhood, the impact was only a fifteen to twenty percent reduction of traditional lot values. The smaller lots required less site servicing (shorter roads and pipes) and the donation of seventeen percent of the land enabled the developer to achieve fourteen additional lots through density bonusing to bring the lot count from seventeen to thirty-one (Barraclough and Hegg, 2008a). The municipality also agreed to permit the developer to utilize an adjacent sewer right-of-way as the location for several stormwater wetlands and a trail. This further enhanced the stormwater treatment capacity of the site, allowed stormwater from adjacent existing subdivisions to be treated at no additional cost, enhanced the profitability of the project by increasing the lot yield, connected the site to adjacent trails, and restored ecological function to an otherwise depauperate area of land (Malmkvist, 2002).

The Willowbrook Subdivision was included in the same economic valuation study undertaken for Blenkinsop Creek (Barraclough and Hegg, 2008a).

The summarized results are presented in Table 2 below. The implemented ecological stormwater solution was found to be cheaper than a traditional pipe solution would have been, if allowed. The estimated cost of construction for the entire stream and stormwater project for Willowbrook was $120,000 for construction and consulting fees. The hydrology modelling costs represented approximately half of that total. Due to the proximity of the subdivision to Swan Creek, an alternative solution would have required a traditional stormwater management system that would control discharge. One solution would have been to construct a stormwater holding tank under the street with a pump system, at a cost estimated at $260,000 to $300,000. Although expensive, it would not have achieved the same degree of particulate and contaminant treatment achieved through the ecologically restorative method. It would also have failed to contribute to the habitat or visual amenity of the community, as the creek would not have been restored and the extensive complex of public trails would not have been constructed.

Table 2. Willowbrook Financial Summary (red numbers in parentheses are negative *i.e.* a cost)

Willowbrook/Glanford (Traditional)	**Municipality**	**Developer**
Cost of the Traditional Stormwater System		($260,000.00)
PV of Ditch Maintenance	($7,651.95)	
PV of Costs for Future Capital Replacement of Stormwater Infrastructure	($9,908.03)	
Total Present Value	($17,559.97)	($260,000.00)
Willowbrook/Glanford (Sustainable)	**Municipality**	**Developer**
Cost of Restoration		($120,000.00)
Increased Lot Yield		$825,000.00
PV of Wetland Maintenance	($4,057.28)	
PV of Educational Value	$34,344.83	
PV of Ecological Benefit	$12,470.09	
PV of Value of Carbon Stored	$515.30	
Total Present Value	$43,272.94	$705,000.00
Net BENEFIT	**$60,832.91**	**$965,000.00**

Table 2. Willowbrook Financial Summary (red numbers in parentheses are negative i.e. a cost)

The Willowbrook Subdivision demonstrated that it is possible to improve the ecological health of an aquatic system through the use of regenerative design and to make it profitable to both the developer and the community. While the residents of the neighbourhood initially resisted the loss of the small field, the habitat, views and trail network created as part of the development have made the new neighbourhood, and the existing homes that surround the site, highly desirable (Figure 4).

With time, it is possible to regenerate ecosystem function throughout many urban streams and improve their ecological resilience. Development does not have to mean a loss of ecological function. The key is to focus on function first, not values, and then to demonstrate that the function is what provides the values we all want and need.

Figure 4. Swan Creek in 1999 (top) prior to the development of Willowbrook Subdivision and again in 2006 (bottom), following rehabilitation and subdivision construction.

Case Study 3: University of Victoria, Saanich and Oak Bay BC (Campus Scale)

The University of Victoria (UVic) is a campus of 162.7 ha (402 acres) that straddles the border between the municipalities of Oak Bay and Saanich (UVic, 2002). Due to its location at the height of land, the campus is the headwaters for three streams: Bowker Creek, Hobbs Creek and Finnerty Creek. In the fall of 2002, as an outcome of its Strategic Plan, UVic proposed to develop the first Integrated Stormwater Management Plan (ISMP) of its kind in Canada, for a university campus. Upon discussion with the authors and other colleagues, UVic staff agreed to visit the above-mentioned Willowbrook Subdivision and several other local stream restoration/stormwater management projects, undertaken by Aqua-Tex, prior to finalizing the ISMP terms of reference. Following the field trip, and the recognition that a focus on "stormwater" was too limiting, the scope of the proposal was broadened to include elements of watershed management, in addition to stormwater management.

The project was awarded to an interdisciplinary team consisting of engineers (RCL Consulting Ltd. and Komex International Ltd.), an architectural firm (Terrence Williams Architect), a green building consultant (Joe VanBelleghem of Build Green Consulting and now the creator of Dockside Green), aquatic ecologists (Aqua-Tex Scientific), a vegetation specialist (Dr. Vivienne Wilson) and a landscape architect (Dr. Will Marsh). This simple act of selecting a diverse, integrated design team fundamentally changed the outcome of the project and was instrumental in its success. While the final stormwater management plan was successfully delivered, it is the process that occurred during its development, and the subsequent outcomes, that are of interest to this paper.

UVic was undertaking several significant building projects on campus at the time the ISMP was being developed. No less than eight buildings were in design or construction during the January 2003- May 2004 period of the ISMP study. As a courtesy to UVic, the ISMP design team was asked to review the designs for the new buildings and suggest where water savings might accrue. The notion of double-plumbing the buildings to use reclaimed water and/or rainwater to flush toilets or for irrigation was introduced by the team (although it was later discovered that one of the construction companies had been quietly double-plumbing its buildings, without connecting the second set of pipes, in the belief that it was the right adaptive design decision). It was noted that a new building (the Engineering Computer Science Building) was slated for construction adjacent to the Aquatic Facility of the Biology Department. This research facility used millions of liters of dechlorinated drinking water to house freshwater fish in a flow-through system. The "used" water was then dumped into the sewer. As a direct result of the design review (not part of the ISMP mandate) and having an integrated design team available to undertake the review, UVic embarked on a program of water reclamation and reuse. Wastewater from the Aquatic Facility was treated and used to replace potable water for toilet flushing in the Engineering Computer Science Building and the Medical Sciences Building. The link was thus made between a reduction in potable water use, reduction in wastewater volumes, and a "fit-for-purpose" approach to water management on campus. UVic became the first example of treated reclaimed water reuse in the Capital Regional District. The Engineering Computer Science Building (LEED™ Gold) recycles 2,716,441 L/yr while the adjacent Medical Sciences Building recycles in excess of 2,000,000 L/yr. The Engineering Computer Science building also benefits from a water-to-water heat pump that takes heat out of the wastewater to preheat water for use in the building at a savings of 350,000KwH/yr (UVic, 2006). This program has now expanded to include many more buildings and by 2010 up to seven additional buildings will be using treated wastewater for flushing purposes (UVic, 2006).

UVic has since expanded their water recycling and energy reclamation program. All new buildings are double-plumbed, and several have green roofs, porous paving and rain gardens to capture stormwater, recharge groundwater, and reduce flashy flows to neighbouring creeks. New buildings are being built on the footprint of existing parking lots, and a transportation demand management program has been implemented to reduce the number of cars, and parking spaces, on campus. A long-term restoration program is underway to rehabilitate Hobbs Creek and return its ecological function. The stormwater project has thus had far-reaching consequences and served to integrate many otherwise disparate elements of sustainable design and management at UVic.

Case Study 4: Dockside Green, Victoria BC (High Density Urban Scale)

Dockside Green is a brownfield redevelopment project in the heart of the City of Victoria. This 6.1 ha (15 acre) former industrial site is being transformed into a 120,774 m^2 (1.3 million ft^2) master-planned mixed-use development which showcases sustainable community design. In 2004, the City of Victoria issued a Request for Proposals to redevelop this site. A partnership group comprised of VanCity and Windmill Developments (under the leadership of Joe VanBelleghem) submitted the winning bid. This team proposed to remediate the brownfield site and build the entire project to a LEED™ Platinum standard. From the outset, Dockside's objective was ambitious:

> *"Vision Statement*
> *Dockside Green will be a socially vibrant, ecologically restorative, economically sound and just community. It will be a distinct collection of beautifully designed live, work, play and rest spaces designed to enhance the health and well being of both people and ecosystems, both now and in the future" (Dockside, 2008).*

The original design called for creating a green corridor that would run the length of the site. This would provide open space for the residents, a walking trail, and an attractive environment. Rainwater would be captured on green roofs with the excess water added to the stormwater system. Stormwater was to be routed through a series of swales and ponds in an open channel toward the ocean. This model proved to be very expensive and not viable.

The next design replaced the green corridor with a naturalized creek that would flow into the harbour. Water for the creek would be supplied by stormwater. Since Victoria gets very little rainfall in the summer months, this meant that the creek would be dry for several months of the year. The creek would therefore require supplementation from the City water supply. Underground tanks would capture rainwater from green roofs during the winter and store it for toilet flushing. This model had significant benefits in that it increased the value of the residential "streamside" units, reduced the potable water use, and created habitat. Complications arose in that potable

Figure 5. Dockside Green July 2009 showing central stream, green roofs, on-site sewage treatment plant and biomass plant (blue building) in the background (Aqua-Tex photo).

water would be needed to supplement the creek (which would have violated LEED™ standards and went against the principles of the project), the volume of rainwater storage needed was significant and therefore top-up of the rainwater tanks with potable water would be needed, and the cost was very high.

Rather than scaling back on the "green" features, which is a typical response of many developers when faced with high costs, the developers chose to move ahead with an even more ambitious design. The principles of this design were to use as little potable water on site as possible, treat, reclaim and reuse water wherever possible both inside and outside of the buildings, minimize the impervious surfaces on site to eliminate stormwater runoff, and use all water in a beneficial way to restore ecological function on the site. In the final design, currently entering phase three of construction, there are very few impervious surfaces on site. A combination of green roofs, porous paving, and bioswales limit runoff and any surface flow is directed toward the newly constructed creek (Figure 5). All the sewage is treated on site in a tertiary treatment plant that is located right in the middle of the first two phases of development, under the creek corridor. Reclaimed water is UV disinfected and then either chlorinated and sent into the buildings for flushing toilets, or left unchlorinated and sent directly to outside non-potable hose bibs and irrigation systems. The unchlorinated water is also used to top up the creek, which is a recirculating system. The creek strips excess nutrients, and is home to fish, crayfish, ducks, and herons and is regularly visited by a river otter and deer.

The cost of the on-site sewage treatment plant was offset by the added value received from the sales of the housing units that faced the stream (VanBelleghem, pers. comm.). The stream is viewed as a very desirable amenity and therefore the units that front on to the stream sell for higher prices. The costs of the plant itself were minimized through the use of water efficient appliances. "This strategy of decreasing the water loads was an integral component in reducing the capital and operating costs of the sewage treatment plant" (Dockside, 2008). The residents of Dockside Green do not pay a sewer tax, because they do not use the City sewer. The Capital Regional District (CRD) is currently in the process of implementing region-wide sewage treatment and Dockside residents will not have to contribute towards this program either. Dockside residents have lower water bills because their potable water use is minimal. The developers are presently trying to obtain regulatory approval to use reclaimed water in washing machines, which will further reduce potable water use. Water use is presently 66.5% below baseline LEED™ standards. At full build out, Dockside will save enough potable water in one year to supply the entire CRD with water for one full day during the hottest part of the year (approximately 300,000+ m^3).

The sewage treatment plant was designed so that, in future, heat can be reclaimed from the sewage. At the present time this is not necessary, because Dockside has an on-site energy plant which uses wood waste to create syngas and heat water. All the energy required to heat the buildings and supply hot water is generated by the energy plant. There is presently a large amount of excess heat and plans are underway to supply heat to a neighbouring hotel. The Clinton Climate Initiative recently named Dockside Green one of sixteen international "Climate Positive" developments in the world.

Dockside Green is but one example of a strategy that could be used on a region-wide scale to recapture water and energy and begin to close the water and energy loops. While Dockside has the advantage of being a new project, it is possible to retrofit existing neighbourhoods, and use the cost-savings to offset capital costs of construction. Cities in Sweden, including Gothenburg, Linköping and Stockholm, have demonstrated the viability of such an approach (Min. of Environment, 2009). The next logical steps are to reduce solid waste generation, use the remaining solid waste to generate energy, shrink the ecological footprint of our cities, move toward regenerative design to restore ecosystem function, and improve resilience and adaptation to a changing climate.

Cities Of The Future

International agencies such as the World Bank, United Nations, UN Millennium Ecosystem Assessment, and World Business Council on Sustainable Development have all warned about the impending crises of global shortfalls in energy and water, as well as the serious threats from pollution, loss of ecosystem services and dramatic changes in climate. The implications of these global concerns threaten much of the past century's development. The absolute dependence upon meeting water and energy needs for continued urban development, and continued improvements in the well-being of the majority of the world's population, place a premium on changing the very nature of urban design and urban infrastructure.

At present, conventional infrastructure is reliant upon the notion that water and energy can be transported vast distances at great cost, and that wastes can be disposed of without consequence. We see the results of this type of thinking all around us: streams are buried or channelized to convey stormwater, fish stocks are depleted due to loss of habitat, oceans are dying from excess nutrients, energy costs are soaring, and many cities are becoming unlivable. The achievement of sustainable and healthy urban environments will require water, waste and energy infrastructure that mimics Nature's design through localized closed-loop systems that are localized. As demonstrated in the case studies above, there is enough money already in the system to pay for ecosystem regeneration, but we must rethink the way in which it is spent, and simultaneously reexamine our notions of "value".

How Do We Get There?

Integrated Resource Management (IRM™) is a new approach to liquid and solid waste management that optimizes value by recovering resources (e.g. water, heat, carbon) and generating energy from sewage and organic solid waste (Corps et al., 2008; O'Riordan et al., 2008). This approach mimics the closed-loop cycles present in all ecosystems, providing local sources of energy, water and other resources, to reduce demand from external or new sources thereby achieving, in part, the objectives of the Natural Step Framework (Robert, no date). It focuses on core urban infrastructure for water, wastewater, and solid waste and frees up resources, which can then be reallocated to regenerating ecosystems and the services they provide.

In IRM™, decentralized tertiary wastewater treatment produces heat, water, nutrients and biosolids that can be reused rather than discharged into the environment. "Waste" heat energy from sewage is captured to heat homes and businesses, and the resulting chilled water is then used for cooling. Organic waste is used to create syngas or biofuels, together with the solids from sewage. These "new" carbon neutral energy sources displace fossil fuels, saving money and reducing GHGs, while increasing energy supply flexibility and security. The revenue derived from recovering energy from solid waste is used to offset the costs of wastewater treatment. Just as in nature, the system therefore depends on the integration of all waste streams and water. By building capacity as and when it is needed, the system remains current and flexible, allows capacity to be increased as demand increases and defers capital expenditure until necessary.

Conclusions

Billions of dollars are currently being spent on new infrastructure, including water and sewer systems, across North America. Unfortunately, most of these 'shovel-ready' projects use old technology and outdated thinking. If even a small percentage of these projects implemented integrated water and energy design, coupled with resource recovery, we could perhaps begin to make meaningful change and regenerate the priceless ecological services on which our society depends.

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At every turn, people were generous with their time and knowledge, for which we are both grateful. Valerie Nelson (Coalition for Alternative Wastewater Treatment) and Jerry Stonebridge have been conductors and guiding lights, illuminating the entwined world of people, politics, legislation and regulation, keeping two views in perspective – vision and implementation. Paul Schwartz (Clean Water Action, Washington, DC) has provided insight into the inner workings of senior government and the vital need for community participation of affected interests if we are to begin to plan, design and build Smart, Clean and Green Cities and Towns of the Future; Becky Smith, CWA, Boston, has extended a special effort ensuring a broad public engagement. A special thank-you to Professor Vladimir Novotny, NEU, and Jeff Moeller, WERF, for their support of our IRM™ approach, to a new urban infrastructure concept and the adoption of Engineered Ecology™. In rounding up the usual group of suspects who have supported the work presented here we must include Sarah Buchanan, Daniel Hegg, Lehna Malmkvist, Rick Lloyd P.Eng., Les McDonald, the staff and designers of Dockside Green (especially Joe Van Belleghem), Ray and Judy and Rob Galey, Cam Pringle and Dave Slang (Cadillac Homes), University of Victoria senior staff (Gerry Robson, P.Eng., Tony James, Sarah Webb, and Bentley Sly), and District of Saanich senior staff (Adriane Pollard, Dwayne Halldorson, P.Eng. and Colin Doyle, P.Eng.).

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new technologies and tools for sustainability

Paper Abstracts

Water Reuse – New York City and Japan Experience and Future Prospect

Edward A. Clerico

Direct water reuse has been practiced in the United States for many years but only to a very small extent and in highly varied fashions which were the result of specific local conditions and goals. By its nature, the water resource industry in the United States is slow to innovate and deeply encumbered with massive infrastructure that is all configured in a linear manner whereby water flows toward a use, is used and managed in some fashion and then flows away, generally in a downstream direction taking advantage of the simple fact that water flows downhill. On the positive side, there are signs that public awareness and acceptance of water reuse and the overall importance of better water resource management are gaining momentum in certain key sectors which could escalate this transition. This is evident in the green building industry where sustainable infrastructure models are demanded, in developing arid areas where the risk of water resource depletion is becoming very obvious, in pristine rural areas where the discharge of contaminants must be avoided and in urban redevelopment areas where very old and often failing infrastructure cannot support the demands of redevelopment without significant conservation and reuse.

A New Water Paradigm For Urban Areas

Marco Schmidt

Global change in land use is characterized by daily deforestation rates of 350 km^2 and a desertification process of 300 km^2 daily. These developments are closely linked due to the impact on the water cycle. The global change in land use causes a huge impact on the hydrology by reduction in evaporation. Consequences are reduced precipitation rates and a release of heat.
Only water that has evaporated will cause rainfall, therefore a reduction in evaporation leads to a further reduction in precipitation. Contrary to the public opinion local precipitation rates are dominated by the small water cycle on land (Kravčík et al. 2007). Small water cycle means precipitation generated out of evaporation on land. This is a regional process. Evaporation of water is the largest hydrologic process on earth and also the most important component of energy conversion.

Practice of Ecological Sanitation in Beijing: a demonstration project

F.-G. Qiu, D.-Y. Zhang, J.-Q. Li, W. Che and X.-D. Hao

The concept of ecological sanitation (ECOSAN) is practiced in a deserted river-side area of 2 ha, which includes urine separation and utilization, biogas production from faeces, animal wastes and biomass, rainwater harvesting, ecological lake, wetland, etc., Within the practiced area, water cycle, nutrient cycle and energy cycle are simultaneously formed. In this way, a zero discharge of pollutants is realized. Such an ECOSAN concept is very close to the conventional farming and life style in China, and so the demonstration project is intended as a model for the future of villages in China. The article describes the details of the demonstration project.

Water Reuse – New York City and Japan

Experience and Future Prospect

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Introduction

All water gets reused eventually, some sooner than later. When rivers and other surface water bodies serve as the source of water supply and means of wastewater disposal for multiple cities, the timeframe between uses can sometimes be measured in days rather than years as a portion of the upstream disposal becomes the downstream supply. In remote rural areas where population density is very low and water is drawn from a protected underground aquifer it is possible that the most recent possessor of the water that comes from the tap today may have been a dinosaur, but as world population increases and luxurious water use spreads to developing nations, it is more likely that your next glass of water was last used by an upstream neighbor rather than a prehistoric species. In the natural cycle of water use, this reuse characteristic is inadvertent, unavoidable and almost entirely unintentional. On the contrary, intentional water reuse which is the subject of this paper is a relatively modern concept whereby water is used once, becomes contaminated to a certain degree, is then subsequently treated in some fashion to improve the quality and then is used again in a well planned and controlled manner. Although it is possible to treat used water adequately for purposes of drinking, the water use-reuse concept discussed herein is almost exclusively intended for nonpotable purposes.

Direct water reuse has been practiced in the United States for many years but only to a very small extent and in highly varied fashions which were the result of specific local conditions and goals. Regardless of a successful history, many newly conceived water reuse projects are still hailed as pilots or demonstrations intended to build understanding and acceptance by a public which remains skeptical. The water industry and the general population remain very comfortable with the current simple perspective which emerged in Roman times and embraces the notion that water supply should come from pure upstream sources, as though there remain such sources, and contaminated wastewater should be disposed of downstream, as though this would somehow keep everyone safe, including those who live downstream. The booming bottled water industry which portrays images of pristine protected sources as part of product marketing campaigns continues to bolster this public perception.

Public concern about the quality of water is increasing. There is also an awakening to the reality that water supply sources are severely limited in many populated locations and that wastewater contaminants are spreading everywhere posing a risk to all living things. This awakening is fueled somewhat by widely published images and facts from undeveloped nations that illustrate the connection between disease and the lack of adequate water supply and appropriate sanitation. But even though public concern is heightened, there is no perceived connection between these more obvious problems in undeveloped nations and the way in which water and wastewater are managed in developed countries. The linear Roman model of consume, use and dispose still prevails in the minds of most people as the preferred approach.

There is recent evidence however that this ancient perception may soon change. Through the successful application of water reuse in a growing number of both commercial and residential development projects the multiple benefits of water recycling are becoming too obvious to ignore. Unfortunately, a dramatic shift towards water reuse will be significantly complicated by a multiplicity of hurdles which must be overcome. Complications associated with existing regulations, short term economics, massive existing infrastructure needs and the fact that water is mostly a local issue will likely make the transition to water reuse much slower than comparable revolutions in the communications, information and renewable energy industries. Even though there is tremendous potential benefits to be gained, without significant policy changes, the shift to water reuse is only likely to occur in a gradual manner and where short term cost effectiveness can be realized or where local conditions are severe.

By its nature, the water resource industry in the United States is slow to innovate and deeply encumbered with massive infrastructure that is all configured in a linear manner whereby water flows toward a use, is used and managed in some fashion and then flows away, generally in a downstream direction taking advantage of the simple fact that water flows downhill. This linear configuration is not generally conducive to cyclical reuse approaches that require return loops for recapture, treatment and ultimate reuse. Lacking any widespread water supply shortages caused by major droughts or severe contamination, economics will still be the primary driver behind how people choose to manage their water resources. As a result, the current status quo "once used and through" linear model is likely to remain for some time. On the positive side, there are signs that public awareness and acceptance of water reuse and the overall importance of better water resource management are gaining momentum in certain key sectors which could escalate this transition. This is evident in the green building industry where sustainable infrastructure models are demanded, in developing arid areas where the risk of water resource depletion is becoming very obvious, in pristine rural areas where the discharge of contaminants must be avoided and in urban redevelopment areas where very old and often failing infrastructure cannot support the demands of redevelopment without significant conservation and reuse. Through a number of successful projects that are leading examples of water reuse, it is now possible that the interest and activity in this new water reuse model could increase dramatically and things could change more quickly than otherwise expected.

Early US Closed Loop Water Reuse

Nationwide in the United States, indirect water reuse for purposes mostly associated with irrigation (open loop) has been steadily increasing, but still remains a relatively small component of water resource management in total. The Water Reuse Association estimates that of 396 billion gallons per day of water extracted for use in the US, 2.6 billion gallons per day (0.7%) is reclaimed for some form of reuse and this reuse quantity is growing at a rate of 15% per year. (Metcalf & Eddie, 2007. pp. 46-47) California, Florida and Arizona are the states with the most water reuse in place and each are leaders in use of nonpotable water for irrigation of lawns, golf courses and crop land and for industrial purposes mostly associated with cooling. In 2004 Florida reported 54 percent of their total wastewater capacity being dedicated to reuse which illustrates the significant role water reuse can serve in the bigger water resource management picture. (Metcalf & Eddie, p. 54)

Early water reuse projects in the United States were generally driven by a particular local environmental concern or lack of adequate water supply. Most early projects did not return treated water directly back to a consumer for direct reuse in indoor building plumbing (closed loop) which would in turn yield new wastewater, but instead used the water for indirect outdoor purposes (open loop) such as irrigation or simply placed the water into the ground as a means of recharging the underground aquifer. Such practices, often referred to as indirect reuse, are almost always considered to be beneficial and were sometimes implemented as an alternate means of waste disposal as opposed to an alternate source of water supply. Whereas, groundwater recharge almost always helps maintain the local water balance by recharging aquifers, consumptive uses of reuse water for irrigation or evaporative cooling purposes convert the water to water vapor which is then subsequently lost from the watershed. Such indirect reuse approaches can have both positive and negative effects which can only be fully understood by completing a detailed water balance evaluation that depicts exactly where and how all local water flows.

Irrigation with treated wastewater effluent is arguably almost always better than irrigation with more precious potable water, but from a water balance perspective is less desirable than having no irrigation at all. Xeriscaping, a landscaping method which requires no irrigation, is the best approach for protecting water balance as would be non-evaporative cooling alternatives. In fact, in some surface water bodies the flow of wastewater effluent is so significant that diverting this flow to reuse for irrigation during low flow periods can actually decrease the water body quality. During drought periods, fish will often choose to reside close to the wastewater treatment plant discharge pipe because this is where the freshest and best water can be found.

Direct water reuse offers more significant benefits because the water is not discharged to the environment, but is instead returned directly to the consumer to be used again. For the purposes of this report, direct reuse of this nature is generally referred to as “closed loop”. The term “closed loop” sometimes is also used to signify the concept of continuous reuse with zero discharge. A zero liquid discharge closed loop system is technically possible, but not practical given the economics of water management that exist today. Only the International Space Station can afford an actual completely closed loop water system, simply due to the extreme cost of bringing fresh water into outer space.

Over the past 30 years we have seen a continuous gradual progression of water-wastewater approaches that begin with the linear “once through and used” traditional model to more creative “use it once then use it again” open loop models to the more significant “use it repeatedly for as many purposes as possible and only release what cannot be used” closed loop approach. Taken together, this represents a continuum of slow but steady progress heading towards a future, completely cyclical, closed loop system; a man-made water cycle if you will.

Beginning in the mid-1980’s there was a series of direct closed loop and indirect open loop water reuse projects developed in the northeast which serve as good models. These projects were driven mostly by lack of sewer capacity in suburban and rural communities. This is a region where rainfall is plentiful and water shortages generally only existed due to growth outpacing infrastructure development and the occasional drought that might occur. Whereas today the water supply picture has changed significantly due to over extraction of groundwater supplies, in the 1980’s, lack of wastewater infrastructure was often the most challenging development hurdle which limited growth in undeveloped areas. To a large extent, such infrastructure hurdles sometimes created convenient roadblocks which helped curtail rampant suburban sprawl as people chose to move out of the cities. In addition, the expansion of expensive regional infrastructure without government subsidies was not cost effective and was not in the best interest of the general public. During this era, creative direct water reuse projects where implemented to allow some development to occur in infill areas and where the economics justified the additional costs. All of these projects were created as on-site decentralized systems with the water reuse systems designed for the specific site characteristics and user needs and all were located on private property.

These northeast-based closed loop water reuse models applied a combination of direct water reuse and indirect beneficial reuse. In the simplest model, wastewater was treated for nonpotable use inside buildings for flushing toilets and excess treated water was recharged into aquifers. Over time, these systems advanced into a multiplicity of building types and the nonpotable reuses inside the buildings expanded to include laundry and cooling in addition to toilet flushing. Nonpotable reuse outside the buildings typically included irrigation and groundwater recharge.

To date these systems are all owned and operated by private interests or as privately held public utilities simply because public entities were not available or were not interested at that time, but there is no reason why they could not just as well have been owned by a public agency. Figure 1 provides an overview of the distributed water reuse systems that were built in the northeast, beginning in 1987 and illustrates the percent water reuse that was achieved.

The amount of water reuse varies from 95% for office uses that have a very high nonpotable consumption characteristic, down to 50% for residential high rise buildings that reuse water for toilet flushing, cooling, laundry and irrigation. The percentage of water reuse varies according to the specific user’s characteristics, plumbing fixture types and the nonpotable uses implemented.

Building Type	Date of 1st System	Water Reuse	Water Uses
Research	1987	95%	Toilet Flushing
Office	1989	95%	Toilet Flushing
School	1990	75%	Toilet Flushing
Commercial Center	1993	70%	Toilet Flushing
Stadium	1996	75%	Toilet Flushing
Urban Residential High Rise	2000	50%	Toilet Flushing, Cooling, Irrigation, Laundry
32 Systems	22 Years	80% Nonresidential 50% Residential	

Figure 1 – Distributed Water Reuse Systems in Northeast U.S.A.

Technology played an important role in the viability of direct water reuse in these facilities. The advent of the membrane bio-reactor (MBR) in the 1980's as a robust, highly automated biological wastewater treatment method helped to provide the dependability and advanced levels of treatment required to produce reuse quality water. Also, the steady improvement of ultraviolet light disinfection and ozone oxidation (ozonation) improved disinfection capability while advancements associated with programmable system controllers improved system automation and operability.

In the grand scheme of water resource management in the US, this pocket of decentralized direct water reuse systems represents a drop in the bucket with regard to the total quantity of water reused nationally. However, these systems represent a significant opportunity for future, lower impact development that actually consumes less and discharges less, therefore having direct water balance and water quality benefits. Whereas, this direct reuse closed loop model is new to the US, it has been used for many years in Japan where the need to conserve water arose earlier.

Water Reuse in Japan

Many countries have adopted water reuse practices which supplement water supply for nonpotable purposes. With an evolution similar to the water reuse systems in the US, the early entries into this arena were focused on irrigation demands and were in very arid locations such as Tunisia, Israel and Australia. Irrigation in these countries was critical to support food crop production and to help stem salt water intrusion from over pumping of groundwater. Thus, these early models were open loop indirect reuse style systems wherein treated wastewater was reused once before being dissipated back into the environment. Japan however stands out as a nation that adopted a mix of water reuse strategies that included closed loop type systems at a very early stage and in a more significant manner. Japan also utilized a blend of reclaimed water sources: municipal wastewater, greywater and rainwater. (Metcalf & Eddie) As a result of concentrated high density growth in post World War II Japan, urban areas that lacked adequate water resource systems were forced to find alternative solutions. As a result, Japan became the leader in urban water reuse, with 8% of the total reclaimed water being used for urban purposes through a number of mechanisms which includes decentralized closed loop and open loop systems. Because of Japan's focus on urban water reuse, it stands as a good model for other developing and developed countries that seek to establish water reuse systems as part of urban development and redevelopment.

The earliest designed wastewater reclamation and reuse project started in Japan in 1951 when reclaimed wastewater from a nearby wastewater plant was utilized to supply industrial water for a paper-manufacturing mill. (Yamagata, et al., 2002) In the 1960's there were severe droughts throughout Japan along with rising economic and population growth in the large cities and corollary contamination of surface water bodies. In 1978, citizens of

Fukuoka City were strained by accepting severe water supply limitations which lasted 283 days. These events eventually led to Japan taking great interest in urban water reuse and to the commissioning of the Water Reuse Promotion Center in 1973. Water reuse was further driven by the urgent situation of having no new source water available for growing cities coupled together with the occurrence of ground surface subsidence in areas where aquifers were being over pumped. The resultant multifaceted water reuse approach that ensued is therefore unique and includes the first indoor closed loop water reuse projects beginning in 1984, in the Shinjuku District of Tokyo.

Since that time, along with expansion of municipal and neighborhood scale systems (referred to as large-area reuse systems), many in-building closed loop wastewater reuse systems have been installed. These in-building systems represent a wide range of configurations with wastewater, greywater and rainwater being captured in the building or from neighboring buildings. Some systems are therefore very small but taken together this entire network of large area systems combined within building systems results in 61% of all nonpotable water demand being met with reuse water in Tokyo. It was reported in 1996 that there were a total of 2,100 buildings using some form of water reuse and that 130 new water reuse systems were being installed each year. (Yamagata)

In addition, of the 1,718 wastewater treatment plants that exist in Japan, 240 plants distribute water for reuse in various forms. Currently it is reported that 4.2 million gallons per day of reuse water for toilet flushing is distributed from the larger plants and 46 smaller plants provide 14.2 million gallons per day of reuse for various in-building uses, including toilet flushing, cooling and plant watering. (Nagasawa, 2009) Individual cities have adopted ordinances requiring all buildings over a certain size to include nonpotable water reuse. In Tokyo the requirement for water reuse is for all buildings over 10,000 square meters and in Osaka and Fukuoma the requirement for water reuse is for all buildings over 5,000 square meters. Additionally, nonpotable reuse water is utilized to supply fire suppression systems, thereby effectively using the fire system piping for dual purposes. Action was also taken to retrofit many existing buildings with dual plumbing, particularly multi-family buildings, commercial buildings and schools. In most cases, MBR technology was utilized as the means of treatment to provide adequate water quality.

In addition to the pressing social aspects of water reuse in Japan, the economics have been shaped to promote conservation and reuse. The national government has generally subsidized 50% of the capital cost for large scale water reuse facilities and the average cost for nonpotable reuse water is $\$0.83/m^3$ ($3.14/1,000 gallons) whereas potable water supply ranges between $\$1.08/m^3$ ($4.00/1,000 gallons) to $\$3.99/m^3$ ($15/1,000 gallons). The economics favor water reuse in all cases.

Japan therefore has created an optimized water reuse model for its specific climate, environment and social needs that includes several approaches and which mandates water reuse systems in many new buildings. The need for water reuse in Japan arose at a time when tremendous urban growth could not be completely supported by expansion of traditional centralized infrastructure that relied solely on natural sources of supply. As is often the case, urgency became the driving force behind innovative solutions and the result is that water reuse has become a basic component of the overall water resource management approach.

Battery Park City, New York

Battery Park City, New York, serves as a very recent urban water reuse model which was created under a different set of circumstances from those which exist in Japan, but which ultimately provides a similar illustration of the benefits of water reuse as a means of achieving growth with less impact on natural sources. Battery Park City is a redevelopment area located at the southwest tip of Manhattan which consists of 92 acres under the control of the Hugh L. Carey Battery Park City Authority (BPCA). This land was created from landfill and demolition of old, deteriorating piers which existed along the Hudson River waterfront, the full build out of which would include 14,000 residential units, 6 million square feet of commercial space and more than 27 acres of parks, plazas and waterfront walkway. Begun initially in the 1970's, the BPCA adopted a mission to demonstrate sustainable urban development for the redevelopment of this land and in 2000 issued its Environmental Residential Guidelines, which set forth goals and standards for environmentally responsible building. This was at the same time that the United States Green Buildings Council launched LEED® (Leadership in Energy and Environmental Design) Version 1. The two programs were closely aligned and both included water conservation objectives. The BPCA Environmental Residential Guidelines also included a water reuse component which was more advanced than the LEED requirements.

In order to win the rights for land lease development in Battery Park City, developers had to submit competitive bids which illustrated how the objectives of the guidelines would be fulfilled while offering their best bid price. The BPCA rated the developer proposals based on price and compliance with the guidelines. The first winning proposal was awarded to Albanese Development for a 27 story residential building to be named The Solaire which included water reuse as a component of a long list of other environmental features. The Solaire was completed in 2003 and it became the first residential project in the US to incorporate direct closed loop water reuse. The project went on to be awarded a LEED Gold certification for new construction and later a LEED Platinum for operation and maintenance.

Whereas, public water and sewer facilities were available in Manhattan, the sustainable development program helped to demonstrate how new construction could have a reduced impact on water resources and existing infrastructure. Sewer overflows are common in New York City during rainfall events and while overall water supply is adequate it lacks capacity for future growth due to limited transmission facilities. Deteriorating and inadequate infrastructure is a common constraint for urban redevelopment and growth in many older cities and the water reuse approach was established as a means of demonstrating how decentralized closed loop approaches could help overcome such barriers.

As a result of this initiative, there are now five existing residential water reuse systems in Battery Park City: The Solaire, Tribeca Green, Millennium Tower, The Visionaire and Riverhouse. One additional system is currently under construction at Liberty Luxe. All of these six projects include wastewater and rain water capture and reuse systems which utilize membrane bioreactor technology. The Solaire being the first, has been the most studied and reported on. It has consistently achieved a 48% water consumption reduction by comparison to a comparable base residential building in NYC and a 56% reduction in wastewater discharge. This water and wastewater reduction is achieved by a combination of wastewater reuse and water conservation where nonpotable water is distributed in closed loop systems for uses that include toilet flushing, cooling tower make-up, laundry and irrigation. Each building is unique and the exact components vary somewhat, but the overall program of wastewater and rainwater reuse remains the same.

The typical configuration for a closed loop direct water reuse system consists of holding tanks for wastewater and rainwater. In some buildings, greywater is used in place of wastewater as a source of supply for the water reuse system. Wastewater and rainwater are treated and placed into storage in a nonpotable water reservoir prior to distribution back to the nonpotable water uses in the building. As discussed earlier in this report, the percentage of nonpotable water varies with the use of the building and can be as high as 95% in dry type office uses. Figure 2 illustrates a typical configuration for a closed loop water reuse system as found in most modern buildings.

In Figure 3, all of the water is treated to the same quality prior to reuse. As water reuse standards evolve, there is likely to be some variability in quality requirements for specific uses and the treatment mechanisms would vary accordingly. The system depicted in Figure 2 is meant to achieve high quality nonpotable water that would generally meet all current standards for “unrestricted urban use”. Specifically for New York City, this unrestricted urban use would entail the performance outlined in Figure 4 which is similar to the nonpotable reuse water quality in a number of states in the US and in Japan.

New York City Planning and Economics

Battery Park City provided the groundwork for further water conservation and reuse projects throughout the City. PlaNYC 2030 was put forth in 2009 as a progressive growth planning document which adds 200,000 additional residents to the current residential project pipeline and anticipates adding another 700,000 residents between 2010 and 2030 while reducing total water

Figure 2. Membrane bioreactor in basement of The Solaire

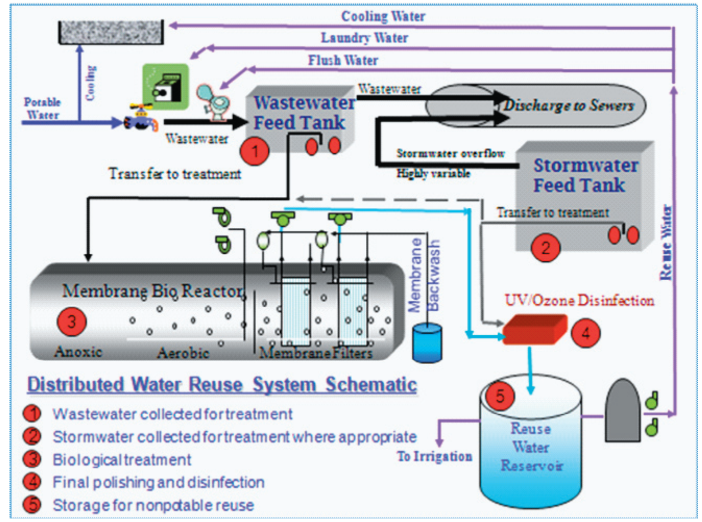

Figure 3. Typical Closed Loop Configuration

consumption by 5% overall. In addition, there are serious combined sewer overflow conditions that must be addressed in this timeframe and major infrastructure upgrades required to correct other existing problems as well as accommodate future demands.

Achieving such aggressive goals will require a multiplicity of approaches that include expanding and upgrading parts of the centralized water, wastewater and stormwater systems, implementing progressive water conservation, adopting best management practices to divert stormwater away from sewers and launching new water reuse efforts. In addition, incentives and rate structure changes may be used to help achieve some of these goals. The City had prior successful experience with incentive programs which offset the customer's cost of high efficiency plumbing fixtures and appliances. Additional incentive programs are anticipated to help achieve a reduction in consumption by approximately 60 million gallons per day over the next 20 years.

In 2004 New York City implemented the Comprehensive Water Reuse Program which provides a 25% reduction in sewer and water charges for buildings that achieve a minimum of 25% water reuse. Such incentives combined with rapidly increasing sewer and water charges provide considerable economic motivation for new developments and are beginning to attract attention within existing buildings as well.

Current water rates are $3.09 per 1,000 gallons and sewer charges are $4.91 per 1,000 gallons for a total water and sewer charge of $8.00 per 1,000 gallons. These rates are projected to increase at 15% per year for the next several years to help fund capital projects that are already under way. The New York City rates are at approximately the median for large cities in the US and similar water and sewer rate increases are occurring in most urban municipalities. It is clear that water and wastewater costs to the consumer are

Nonpotable Reuse Water Quality – Unrestricted Urban Reuse			
Parameter	Abbreviation	Numerical Limit	Units
Biological Oxygen Demand – Five Day	BOD	< 10	mg/l
Total Suspended Solids	TSS	<10	mg/l
Total Coliform Bacteria	TC	< 100	Counts per 100 ml
Escherichia coli	E.Coli	<2.2	Colonies per 100 ml
Acidity (or basicity)	pH	6.5 – 8.0	Standard units
Turbidity	Turb	<2.0 (95% samples) <5.0 (at all times)	NTU

Figure 4. Nonpotable Reuse Water Quality – Unrestricted Urban Reuse

going to increase almost everywhere and that these costs will become a much more significant concern to residents and businesses in the future.

Operating experience from the existing decentralized water reuse systems in New York City indicate that the costs for treating wastewater and producing nonpotable reuse water is in the range of $9.00 to $13.00 per 1,000 gallons depending on system size. The costs for building and operating such systems is very stable, and will probably decrease in the future as technology improves and systems become more efficient. Taking all of this into consideration, nonpotable water reuse is nearly cost competitive today. Considering the pending New York City rate increases and the 25% rate incentive, water reuse is actually a wise choice for all new construction. Certainly, given the life span of a building, not having water reuse capabilities included in the initial plumbing will become a considerable cost detriment in the future. This new age economics for water and wastewater is also spurring some existing buildings to consider retrofitting water reuse when the opportunities are readily available such as in supplying cooling towers or centralized laundries.

The initial pilot water reuse programs in Battery Park City were regulated by the Department of Health. As the need and desire for more water reuse grows, formal regulations are being developed within the building codes which will provide for a more comprehensive management program. Similar to the approach in Japan, the ultimate solutions for New York City water conservation will entail a combination of numerous approaches including rainwater reuse from green roofs, greywater reuse, condensate reuse as well as wastewater reuse. But unlike Japan where the need for reuse was driven by a lack of available resource, the future demand for water reuse in New York City will be more a case of simple economics.

Conclusion

In conclusion, the comparison of New York City and major cities in Japan illustrates how the local demands and drivers with regards to water resource management will make the transition towards water reuse occur at different paces in different places, but the trend will be inevitable and ultimately universal. Water reuse will be a key component for addressing water scarcity and quality issues in the future. There are some barriers to this approach because certain codes may restrict water reuse and the water/wastewater industry is not geared up presently to readily adopt decentralized approaches, but in the relatively short term these barriers will be removed as the economic landscape changes. Water and wastewater services have always been very inexpensive in developed societies and that picture is now changing as both capital and operating costs rise dramatically. The history of water reuse in Japan, one of the world's most densely populated countries, illustrates how mandates for conservation and reuse will come forth as social needs arise. The recent success of decentralized water reuse in New York City illustrates how green building practices and water conservation can play an important role in the US. Taken together, the experience of these water reuse examples provides clear evidence of the rationale that will drive the transition towards water reuse globally.

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A New Water Paradigm for Urban Areas

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Introduction

Global change in land use is characterized by daily deforestation rates of 350 km² and a desertification process of 300 km² daily. These both developments are closely linked due to the impact on the water cycle. We further lose large vegetation structures by urbanization. In Germany urbanization increases at a rate of 1.2 Mio square meters per day. If we take this rate into a global account, we lose mainly agricultural areas of about 150 km² daily for urbanization. Main reasons are increased settlement requests like in Germany and global population growth.

The global change in land use causes a huge impact on the hydrology by reduction in evaporation. Consequences are reduced precipitation rates and a release of heat. Only water that has evaporated will cause rainfall, therefore a reduction in evaporation leads to a further reduction in precipitation. This causes a chain reaction on land (Figure 1).

Contrary to the public opinion local precipitation rates are dominated by the small water cycle on land (Kravčík et al. 2007). Small water cycle means precipitation generated out of evaporation on land. This is a regional process. The proportion of local precipitation out of the large and the small water cycle differ largely depending on the local situation.

Evaporation of water is the largest hydrologic process on earth and also the most important component of energy conversion. Just as rainfall volume depends on the amount of water that has evaporated, so will a reduction in evaporation mean the increased conversion of short-wave global solar radiation to long-wave emissions and sensible heat. All components in which

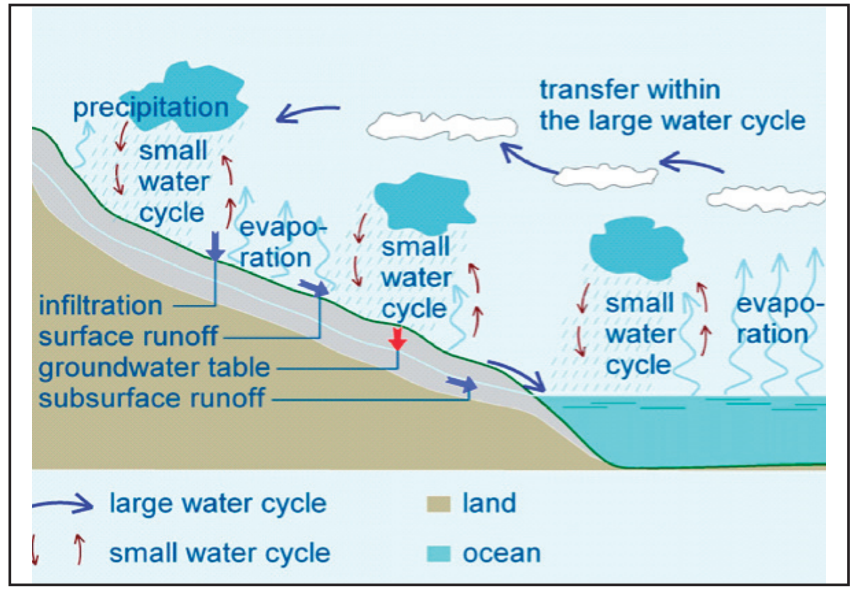

Figure 1. Local precipitation rates are dominated by the small water cycle of evaporated water on land, compared to the large water cycle between the oceans and land (Kravčík et al. 2007; www.waterparadigm.org)

global radiation is converted on the Earth’s surface are illustrated in figure 2, for a mean energy flux of one square meter per day. Of this, 7.3% of incoming solar radiation is reflected, and 38% is directly converted to thermal radiation due to the increase of surface temperatures. The total long-wave (thermal) radiation consists of atmospheric counter-radiation (7776 Wh/ (m²d)) and the thermal radiation of the surface of the Earth (7776 + 1724 Wh/ (m²d)).

Net radiation can be either converted into sensible heat (575 Wh/ (m²d)) or consumed by evaporation, a conversion into latent heat. With 1888 Wh/ (m²d), the energy conversion by evaporation is the most important component of all, even more than the thermal radiation converted from incoming short-

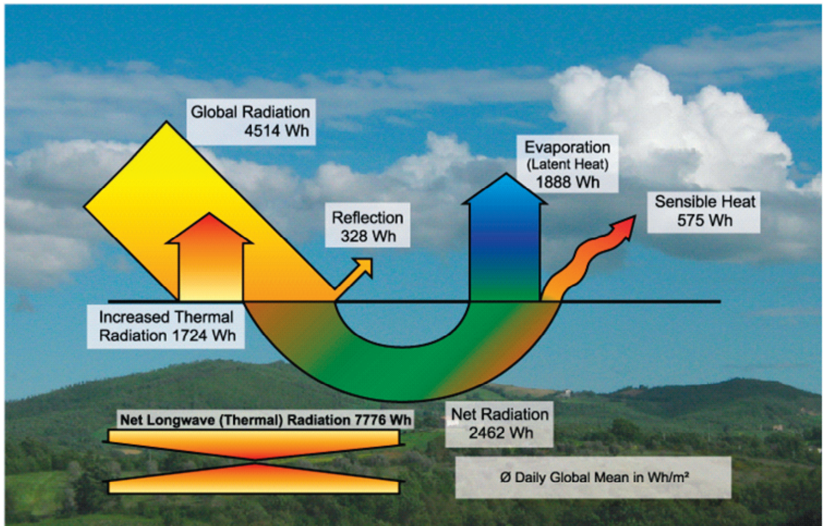

Figure 2. Global daily radiation budget as annual mean of one square meter. Energy data based on www.physicalgeography.net

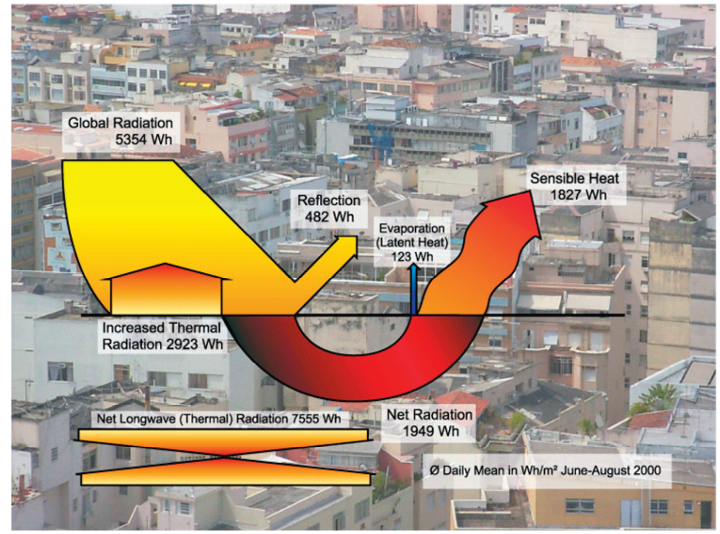

Figure 3. An urbanized landscape significantly alter a region's patterns of radiation and hydrology (here: Rio de Janeiro, Brazil). Radiation budget of a black asphalt roof as an example for urban radiation changes, measured at the UFA-Fabrik in Berlin-Tempelhof (Schmidt 2009)

wave radiation. Additionally, evaporation reduces the long-wave thermal radiation due to the decrease in surface temperatures. With consideration of figure 2, the entire global radiation budget is dominated by evaporation and condensation.

Urbanization results in a huge change to the small water cycle. Additionally, hard materials and surfaces in urban areas absorb and re-radiate solar irradiation and increase that area's heat capacity. Fundamentally, the main driving factor for the urban heat island effect is the lack of vegetation and absence of unpaved soils (Figure 3). Impermeable surfaces like roofs and streets influence urban microclimates through a change in radiation components. As an example of radiation changes in urban areas, figure 3 illustrates the radiation budget of a black asphalt roof. Compared to figure 2, most of the net radiation from the urban setting is converted to sensible heat rather than evaporation. Higher surface temperatures also increase the thermal radiation and change the due point, which results in a further reduction in precipitation.

The radiation budget in a desert is quite similar to the "urban desert" of concrete and asphalt. Compared to a desert precipitation still takes place, but instead of closing the water cycle by evaporation large water amounts are discharged into sewers. As a result of changes in the urban energy budget, air temperatures inside buildings also rise and lead to discomfort and/ or greater energy consumption by climate management. The use of electricity for cooling further worsen this situation in urban areas by increased heat release outside of the buildings. Instead, water should be used for climate management in evaporation processes (www.gebaeudekuehlung.de).

The chain reaction of reduction in evaporation, climate change and drought requests a new water paradigm. Until recently, evaporation has always been defined and understood as a loss. In fact, evaporation is the very source of precipitation. Drought is conventionally expressed as a result of rising global temperatures, but if we take this new perspective then increased aridity is the cause, not the result, of the global warming. Our intensive land use patterns are causing the planet to dry out (Ripl, Pokorny, Scheer, 2007; Kravčík et al., 2007).

Old cultures experienced the same. Once, whole north Africa was green. The Egypt's did not found their culture in the desert. Forests have been cut

Figure 4. Egypt several thousand years after deforestation, which influenced the small water cycle of evaporation and precipitation and caused an ecological chain reaction. Photo: Stefan Krauter

and used as building material and energy source (Ponting 2007). Once, deforestation took place, increase in precipitation intensities, soil erosion and following large drought periods were historically handed down. Decreased evaporation in the catchment area caused a climate change. Consequences in crop production first led to artificial irrigation systems, later whole areas and prosperous cities had to be abandon like Piramesse, the former capital of Egypt. About 3000 years ago the city was left after a massive climate catastrophe which caused an ecological chain reaction, known as nine of the "Ten Plagues of Egypt".

The same development occurred several thousand years ago at the landscapes near the cities Caral (Peru) and Uruk (Sumer, today Iraq). The remained artifacts of our ancient civilizations can be found in the desert. A later example as an obvious cause are the developments on the Easter Islands. Their civilization started with deforestation and ended in cannibalism (Ponting 2007).

Nowadays, the situation in land use and drought gets even worse. Portugal and Spain dried out, and regions like the northeast of Brazil suffer from missing precipitation and increased temperatures due to the deforestation of the Amazon. These developments endanger future crop production.

The new water paradigm includes fundamental changes in land use. Soil fertility, especially the storage capacity for water are essential for the small water cycle. In urban areas the priority for rainwater management needs to be shifted from sewer systems and artificial infiltration systems to evaporative cooling and vegetation.

The conventional principle of water discharge, which was implemented for over a hundred years, nowadays bears disastrous environmental effects on surface water quality and on the climate. The paradigm shift which must be implemented on the local level will require a complete rethinking of the existing urban planning and water management.

To prevent polluted surface waters due to combined sewerage overload and direct discharge of pollutants in separated sewer systems, rainwater infiltration has been a popular strategy in recent years. However, in spite of the great

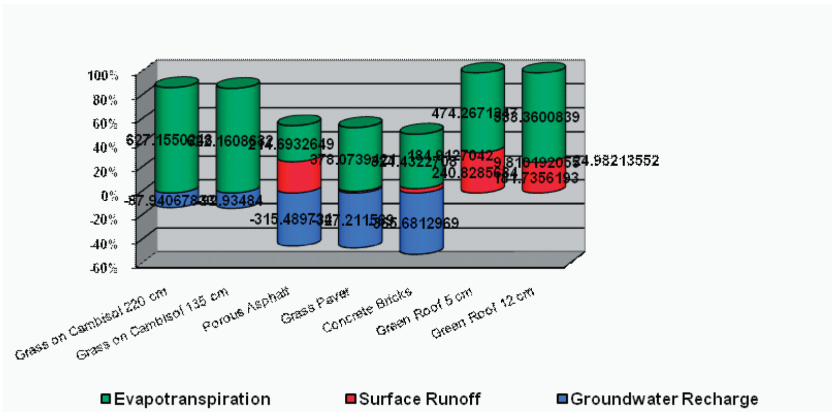

Figure 5. Hydrology of different urban surfaces in mm of precipitation (715 mm as annual mean 1.1.2001-31.12.2004), Technische Universitaet Berlin-Wilmersdorf

benefit of preventing negative impacts to surface waters, infiltration does not fully reflect the natural water cycle. Urban areas are not characterized by reduced infiltration rates, the missing hydrological component is evaporation.

In the catchment area of Berlin/ Brandenburg, about 80% of precipitation is converted to evaporation, while groundwater recharge and runoff together represent 20%. Urban areas are characterized by completely paved areas as well as semi-permeable surfaces with little to no vegetation. Semi-permeable surfaces allow much higher groundwater recharge compared to naturally vegetated areas (Schmidt et. al. 2005), as they over-compensate for infiltration with reference to completely paved surfaces. Therefore, in the interest of effective environmental priority, the provision for evaporation rather than infiltration needs to become a primary task.

At the Technical University in Berlin we monitor the hydrology of different urban surfaces. Main goal is to identify the reduction of rainwater runoff into

Figure 6+7. Lysimeterstation at the Technische Universitaet in Berlin-Wilmersdorf, measurement of precipitation, evaporation and percolation (groundwater recharge), surface (left) and balances in the underground (right, coloum 1+2 of figure 5)

sewer systems and the annual rate of groundwater recharge and evaporation to identify environmental influences on the urban hydrology. Column 1 and 2 in figure 5 represents the hydrology of a grass surface on a loamy soil. The artificial groundwater level was fixed at 1,35 and 2,20 m. Annual evaporation rates of 622 to 627 mm correspondent to 88-93 mm of groundwater recharge. Evaporation therefore dominates with 87% of the precipitation already on grass. Trees, supplied with additional water, would evaporate more than annual precipitation permits. Compared to grass common pervious pavements which are shown in columns 3 to 5 of figure 5 show a 3 to 4 times higher groundwater recharge due to reduced evaporation rates. Surface runoff is mostly overestimated and mainly related to precipitation events with high intensities. Most of the annual precipitation falls under low intensities, therefore 2-3 % of pervious gaps of concrete bricks are sufficient to reduce the surface runoff during a year to less than 5%.

Artificial infiltration systems became a popular strategy in Germany for the last years. They overcompensate missing groundwater recharge of completely paved streets and buildings as they manage an additional 6-10 times the surface of the infiltration area itself. This represents 500% - 900% of

Figure 8+9. Lysimeterstation at the same place for measurements of the hydrology of semi permeable surfaces (left, coloumn 3-5 of figure 5) and evaporation and runoff of extensive greened roof plots (right, coloumn 6-7 of figure 5), TU Berlin in Berlin-Wilmersdorf

natural precipitation as runoff from paved areas, and leads to 5 times more groundwater recharge compared to natural unsealed conditions or 40-50 times more at the infiltration area itself. For example, a park area in Berlin receives 700 mm of precipitation annually. A grassy area without any artificial irrigation would typically evaporate about 600 mm into the atmosphere, while 100 mm serves for groundwater recharge, mainly in the winter season. An infiltration system in the neighborhood receives the same 700 mm of annual precipitation, plus an additional 4800 mm surface runoff from paved areas adjacent (figure 10). Following the rates above, these 5500 mm of water would be converted into about 700 mm evaporation, while 4800 mm represent groundwater recharge. This level of recharge is 48 times higher than the natural water cycle would permit. Retention time in the soil surface is largely reduced and the cleansing capacity therefore minimized. To protect the groundwater quality, artificial infiltration systems are not the best practice.

However, infiltration can also lead to evaporation provided that vegetation and vegetated structures are constructed in the neighborhood. In such a case, infiltration systems must be supplemented with trees or façade greening systems. A discussion about the overcompensation of groundwater recharge by infiltration systems should not neglect the benefit of preventing rainwater from being discharged into sewers and surface waters. Nonetheless, we need to meet the natural water cycle and regard the groundwater quality in urban areas.

Figure 10. Trough infiltration system in Berlin, lacking vegetation

Green Roofs

A cheap and reliable measure to improve the urban environment by closing the water cycle is to green roofs. According to measurements taken at experimental plots (Figure 9) and large roofs at UFA Fabrik in Berlin 65-75% of annual precipitation is redirected to evaporation (columns 6 and 7 of figure 5). This unexpected high rate of evaporation of artificial soils with only 5 to 15 cm is affiliated to high radiation and wind speed rates on roofs, low humidity and increased temperatures of urban areas.

Another positive aspect of greened roofs is their capacity for stormwater retention. This capacity successfully reduces combined sewerage overloads (Knoll, 2000). The temporary retention rate of stormwater runoff is an independent value to annual retention rates for evapotranspiration and should not be confused.

Combined sewage overflows cause serious health problem. Eutrophication of surface waters and a decrease of oxygen content in the river in several cases reaches alarming proportions of fish mortality. Therefore the retention of stormwater is of high priority in urban areas. End of the pipe strategies are cost intensive and have to be constructed, operated and maintained by public authorities or the local water supplier. Decentralised measures on the other hand are established at the source of the problem and are mainly constructed with private money. Central retention measures as well are not able to consider the small water cycle and redirect rainwater into the atmosphere.

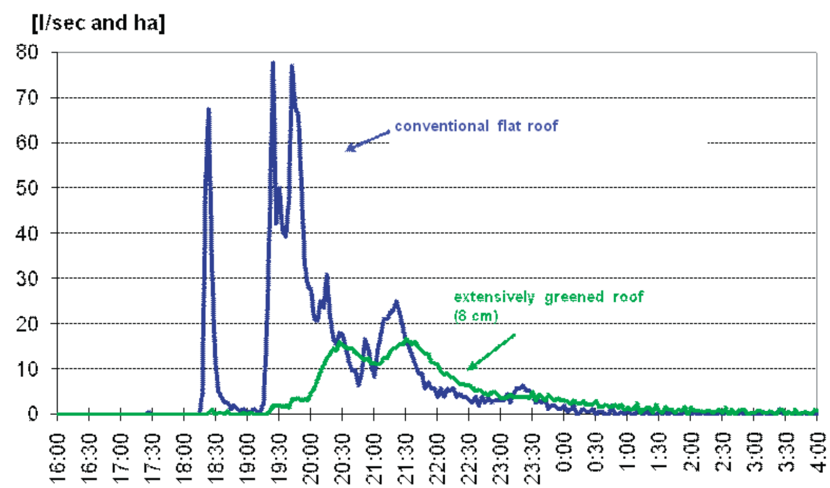

Figure 11. Reduction of stormwater runoff, an extensively greened roof compared to a conventional flat roof, 12.-13.6.98 UFA Fabrik Berlin Tempelhof.

Compared to annual retention rates by evapotranspiration, stormwater retention of greened roofs show results of up to 90 and 100%. Stormwater retention capacity consists out of the non saturated field capacity of the substrate and an additional temporary storage capacity above this field capacity. Figure 12 shows the overload of a greened roof during a stormwater in May 1997, expressed in millimeter of rainfall as a difference between precipitation and runoff (Bustorf, 1999). The temporarily overload showed a capacity of 10 mm of precipitation (hÜ in figure 12). A second important aspect is the time delay of the runoff. Figure 11 shows that runoff starts when the peak of the stormwater runoff of a conventional roof already ended. This benefit for combined sewer systems is largely underestimated as simulation software is not yet able to calculate evaporation and non saturated water flow in sloped artificial soils. Nevertheless it should be considered in wastewater fees to give a credit for a stimulation in construction.

Compared to combined sewerage systems a separated sewer impacts the

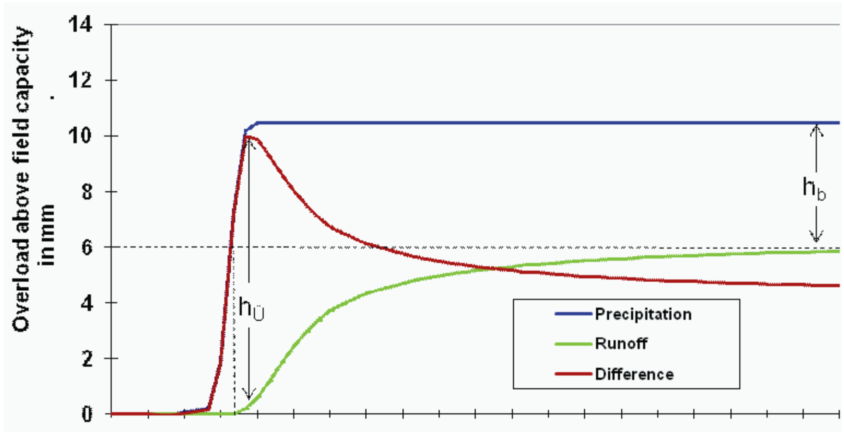

Figure 12. Reduction of stormwater runoff, an extensively greened roof compared to a conventional flat roof (UFA Fabrik, Bustorf 1999).

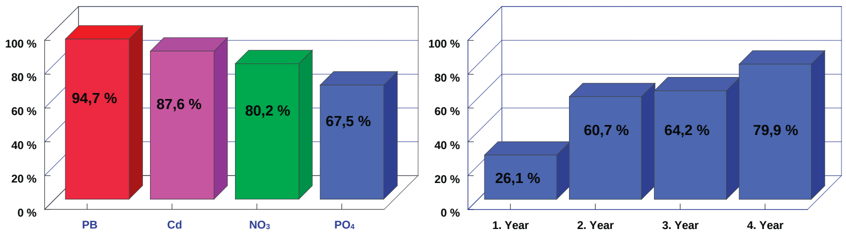

Figure 13 +14. Reduction of nutrients and heavy metals by greened roofs as percentage of influx [Schmidt, Köhler 2003]

surface water quality by direct effluent of harmful substances like nutrients, heavy metals and pesticides. In this case a green roof acts like a filter. Figure 13 shows the reduction of nutrients and heavy metals as percentage of influx as a three years average, measured on research plots of the Technical University of Berlin. Figure 14 demonstrates the increase of phosphate retention due to the establishment of plants over the years after greening. With 80-95% the retention of nutrients and heavy metals is large, and could be increased by a further selection of the substrate used. This was a main goal of the project "Potsdamer Platz" in the city center of Berlin, where 99% of the whole stormwater of 19 buildings had to be managed in a decentralized combination of rainwater management measures. Greened roofs together with rainwater harvesting for toilet flush and a large urban rainwater lake of 12.000 m² (Schmidt 2009) were build up in the new city center of Berlin. Up to now

Figure 15. Europes largest stormwater management project at Potsdamer Platz combines green roofs, rainwater harvesting and an urban rainwater lake with a total stormwater retention capacity of 4000 m³ additional to the green roofs

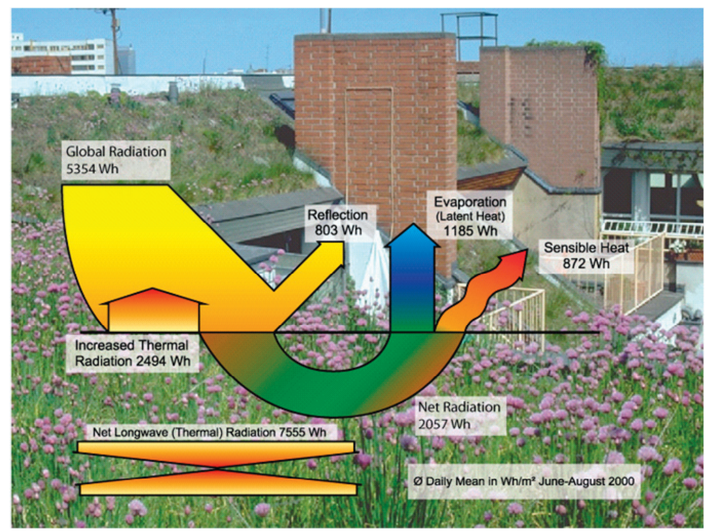

Figure 16. Extensive green roofs transfer 58% of net radiation into evapotranspiration during the summer months, UFA Fabrik in Berlin, Germany (after Schmidt, 2005)

this project remains unmatched in Europe.

Evaporation automatically translates to improved radiation and therefore climate values. Our measurements taken at the UFA Fabrik in Berlin showed, that a roof covered with 8 cm of soil transfer 58% of net incident radiation into evapotranspiration during the summer months (Figure 16). The annual average energy consumption is 81%, the resultant cooling-rates are 302 kWh/ (m^2*a) with a net radiation of 372 kWh/ (m^2*a) (Schmidt 2005). The roof in figure 16 was monitored parallel in the direct neighborhood to the asphalt roof in figure 3.

Due to lower surface temperatures (figure 17) the thermal radiation of a green roof compared to an asphalt roof is reduced, too. The mean difference of thermal radiation between both roofs was 429 Wh per day (figure 16 compared to figure 3).

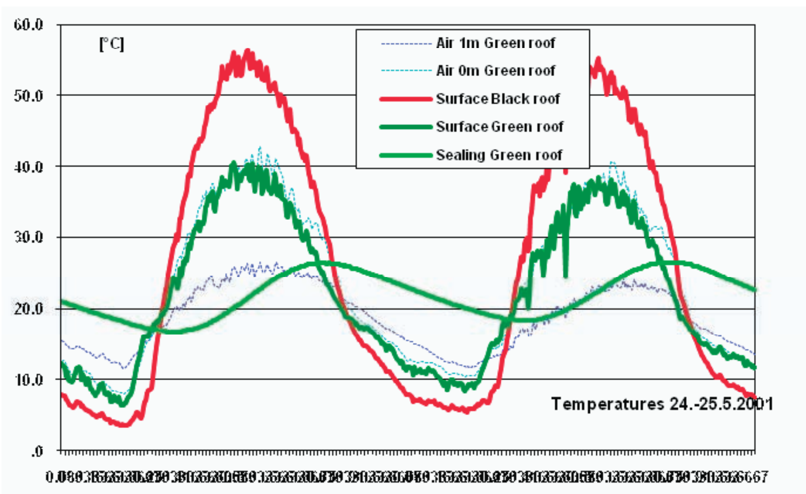

Figure 17. Reduced surface temperatures of a greened roof compared to a conventional asphalt roof (non-contact infrared measurements)

Green façades

Green façades passively climatize a building through shading and improve the microclimate due to evapotranspiration. Plants provide shade during summer and, when defoliated in winter, in front of a glass façade or translucent insulation system the radiation gain in winter lessen heating needs.

A project where 450 climbing plants in 150 experimental troughs and the natural ground were established is the project “Institute of Physics” in Berlin-Adlershof. Plants are irrigated by a rainwater harvesting system. Water supply is organized in such a way that the water content is maintained at a constant level by a micro automation system. Evapotranspiration demonstrates immediate feedback to water consumption. Since the troughs lack a facility to be weighed, evaporation is determined by measuring the water supplied to the trough throughout the day. Figure 19 shows the mean

Figure 18. Wisteria sinensis growing in troughs in different floors at one of the courtyards Institute of Physics, Berlin Adlershof 5/2008

daily evapotranspiration of this façade greening system, measured as water consumption. The real ETP is extremely high, likely because the plants have an optimized water supply and the surface area of the trough is small compared to the leaf area of the plants. Mean evapotranspiration between July and September 2005 for the south face of the building was between 5.4 and 11.3 millimeters per day, depending on which floor the planters were located (figure 19). This rate of evapotranspiration represents a mean cooling value of 157 kWh per day. Water consumption for the mature Wisteria sinensis increased up to 420 litres per day for 56 of the planter boxes. This represents a cooling value of 280 kWh per day for one of the courtyards. The courtyard has a size of 717 m², the greened façade a surface of 862 m².

In selecting the climbing plants, emphasis was placed on choosing types that can grow in the extreme conditions of planter boxes. In addition to plants, a special system of irrigation and different substrates were also applied and

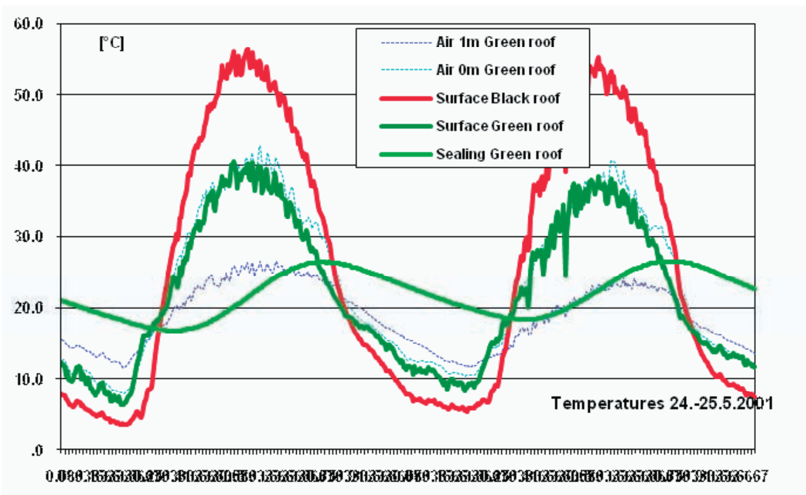

Figure 19. Mean evapotranspiration of a façade greening system in mm/day and correspondent cooling rates in kWh/m²d

studied. A factor in this selection was adequate capillary rise of water through the irrigation and substrate systems. Another aspect studied was providing a layer of insulation to some of the planter boxes, to compensate for large shifts in temperature and especially to help protect against low winter temperatures. This comparison revealed that insulation can lead to significant differences in plant growth.

The combination of providing shade in the summer and permitting solar energy gain in the winter supported a further design for a technological development: the implementation of simple translucent insulation system in arrangement with a vertical climbing plant structure. The overheating process of conventional translucent systems can be avoided, and evapotranspiration improves the local microclimate. This system combines energy saving strategies and provides the natural water cycle, therefore it includes two strategies on mitigating global warming.

Rainwater harvesting for evaporative exhaust air cooling

A technical approach on closing the water cycle are evaporative cooling systems. Energy consumption for cooling and ventilation increases worldwide (EECCAC 2003). Conventional air conditioners are based on compression systems and use electricity. In this process cold is not produced, energy is shifted from one side to another. Due to the use of electricity in this process, more heat is released outside of a building than cold is produced inside. Therefore the Urban Heat Island Effect is increased instead of improved in these conventional technique.

A different approach to cooling, based on rainwater, converts sensible heat into latent heat by evaporation. This energy is released when water vapor again condenses in the atmosphere. The water cycle is the main transport system for shortwave radiation absorbed on earth surface. Missing evaporation in urban areas could be substituted by artificial evaporative systems for air conditioning. These systems use water to cool air by the process of evaporation. First, rainwater is evaporated to reduce the temperature of the air leaving the building (figure 20). This process has the capacity to cool exhaust air from e.g. 26°C to 16°C. In a second step, fresh air entering the building is cooled as it passes across a heat exchanger with cooled air on its way out. This process is sufficient to maintain indoor temperatures of 21-22 °C with outside temperatures of up to 30 °C.

Figure 22 demonstrates the results on performance of the systems studied. To evaluate the reduction in energy consumption, the evaporative cooling system was switched on and off. The resultant energy consumption of the conventional cooling system, in this case cold supplied by absorption chillers, indicate a decrease of 70%. The performance of 70% for the hottest day of the year at 38°C suggests that the process is much more successful than expected. We can predict a reduction in energy consumption for cooling between 80 to 90% as an annual mean, compared to conventional systems. Additionally the evaporation of (rain)water reduces the urban heat island effect, whereas conventional air conditioning systems exacerbate the problem by consuming electric energy and releasing heat outside, influencing neighbouring buildings.

The advantage in using rainwater instead of tap water, which would also work, is that rainwater has no salt/ no lime, therefore a low electrical conductivity. When using potable water, two cubic meters are needed to evaporate one cubic meter and concurrently produce one cubic meter of sewage water. Using rainwater can conserve 50% in water volume and completely conserves wastewater.

Due to evaporative heat conversion of 680 kWh per cubic meter, even desalinisation by membrane reverse osmosis of seawater as water source makes sense. The energy consumption of membrane seawater desalinisation

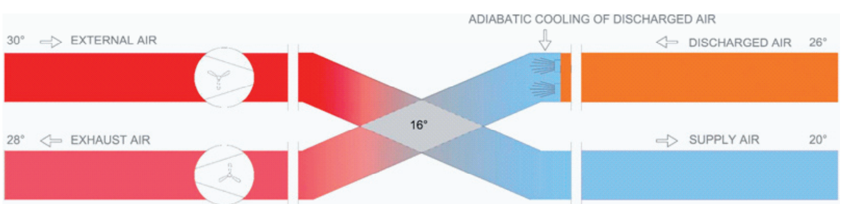

Figure 20. Scheme of evaporative exhaust air cooling, heat exchanger used in winter for heat recovery and in summer for exchange of cold

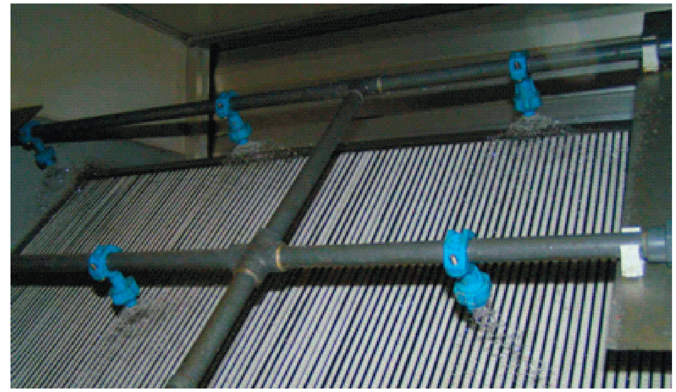

Figure 21. Example for an evaporative exhaust air cooling system

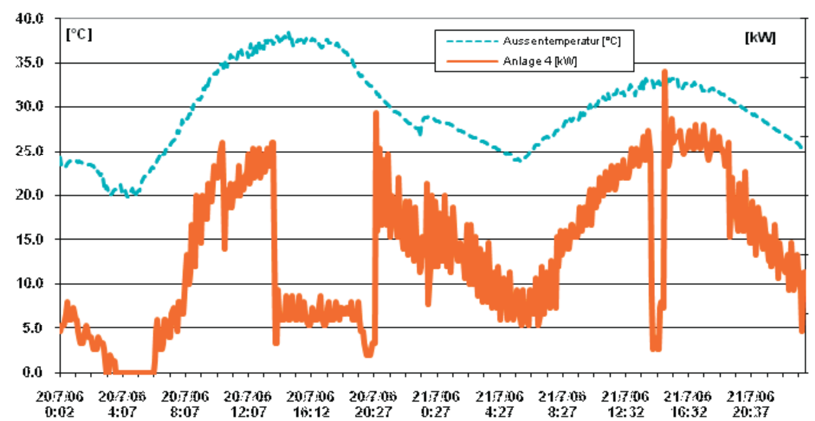

Figure 22. Evaluation of the reduction in energy consumption of an air conditioning system when switching the evaporative cooling system on and off at outside air temperatures of up to 38°C

decreased to a value of 7 kWh per cubic meter in the past years. In this case, evaporation implies energy savings of 100:1! Conventional compression cooling systems consume 200 to 350 kWh compared to the benefit of evaporation of one cubic meter of water. Heat release of conventional cooling systems in the streets outside the buildings are 680 kWh plus additional 200 to 350 kWh of electric energy consumption which is converted into heat as well. Evaporative cooling simply consumes heat and closes the small water cycle, which results in further precipitation out of the evaporated water.

Watergy concept for heating and cooling

Watergy is a concept of integrating the water cycle inside of a building or greenhouse. Due to the large energy shift in evaporation and condensation of water the development of a seasonal storage of solar energy was a main goal (see www.watergy.de). The technological principle was proofed with two different prototypes between April 2003 and March 2006, and was funded by a European Union research project (NNE5-2001-683). In 2004, the first prototype was built for the purpose of greenhouse horticulture in Almeria, Spain. A second prototype was built in Berlin as a living- and office building with an attached façade-greenhouse.

The Watergy system combines solar collection with a mechanism for rainwater and greywater treatment. The building in Berlin (Figure 23) is based on the concepts of passive house insulation and solar-derived zero energy standards. A greenhouse located in front of a transparent wall on the southern face of the building acts as a modified double façade. The air inside the greenhouse becomes heated by solar gain and also humidified by the plants, which are irrigated with rainwater. The warm air rises to the ceiling, where it is further heated and further humidified within a secondary collector element (Buchholz et. al. 2009).

In winter a salt solution inside of an open heat exchanger in the building absorbs the previously evaporated water and releases heat. As opposite process of evaporation, absorption of water vapor releases the same amount of energy that is consumed in the evaporation process before. 680 kWh of heat release for one cubic meter of water absorbed represents 10 times

Figure 23. The Watergy prototype in Berlin- Dahlem (Germany), south-facing greenhouse facade

more energy than available in conventional tanks based on hot water. The previous seasonal storage tank of this building had a size of 35 m^3, enough for heating the building through the wintertime. This concept was unfortunately too expensive and the storage tank too large. The new concept uses a saline solution which is dried in the summertime and diluted through water vapor in the winter time. The solution with a salinity amplitude, in this case MgCl between 20% (diluted) and 33% (concentrated) represents an energy density of 267 kWh/m^3 storage volume. This results in a reduction of size for the storage system by a factor of 3.8. A secondary effect is reduced transmission heat loss, as the storage medium is heated not only once to 90° but rather several times during winter with only low amplitudes. The problematic seasonal storage process from summer to winter is provided without losses due to the thermo-chemical principle of the system. As this prototype shows the use of rainwater for cooling and heating gives large potential for innovative further developments in the buildings sector.

Conclusions

Rainwater harvesting measures which focus on evaporation rather than infiltration have tremendous potential to decrease the environmental impacts of urbanization. When considering a close-up of the small water cycle, we may entertain the emergence of a new water paradigm (Kravčík et al. 2007). As part of this new paradigm, harvesting rainwater for evaporation would become a first priority in urban areas: not a single drop of water may leave urban surfaces simply to be funneled into sewer systems. Rather, harvested rainwater can be used for evaporative cooling via vegetation and/ or air conditioning units.

The research summarized above prove that evaporation of water is the cheapest and most effective way to cool a building. One cubic meter of evaporated water consumes 680 kWh of heat. Thus, instead of conventional cooling systems (old cooling approach) which release heat outside the building, consume energy and produce additional heat, the evaporation of water simply consumes heat (new cooling paradigm). In this way, energy is released when water vapour condenses on any given surface, or in the atmosphere. Condensation in form of clouds in the atmosphere represents the primary energy loss by earth into space. This small water cycle on land needs to be supported by measures which focus on evaporation. Pre-treated wastewater disposal on former sewerage fields as practiced in Berlin or at the Olympic Park in Beijing are further options.

If we take the new perspective of urgency in policy change than the missing global agreements about greenhouse gas emissions of the Copenhagen summit COP15 give a new chance to include land use, water cycle and photosynthesis. A discussion forum was established on the web portal www.ourclimate.eu. A book for download on this whole topic is available for free on the web portal www.waterparadigm.org. Shortly before the Copenhagen Summit (COP15) an international group of scientists published a protocol announcing the existing gap in the climate discussion which is also available on the web portal www.ourclimate.eu (Košice Civic Protocol 2009).

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Practice of Ecological Sanitation in Beijing: a demonstration project

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Abstract

The concept of ecological sanitation (ECOSAN) is practiced in a deserted river-side area of 2 ha, which includes urine separation and utilization, biogas production from faeces, animal wastes and biomass, rainwater harvesting, ecological lake, wetland, etc., Within the practiced area, water cycle, nutrient cycle and energy cycle are simultaneously formed. In this way, a zero discharge of pollutants is realized. Such an ECOSAN concept is very close to the conventional farming and life style in China, and so the demonstration project is intended as a model for the future of villages in China. The article describes the details of the demonstration project.

Keywords

Ecological sanitation (ECOSAN), urine separation, biogas, nutrient, rainwater harvesting, ecological lake, wetland

Introduction

For a couple of decades, an urbanized level in China has risen to 45.7%, and a total urban population has reached to 607 millions at the end of 2008 (Niu and Pan, 2009). Even in left-over villages, the life of farmers has been totally changed towards a modern style. For examples, farmers' houses have been using flush-toilets; black water is discharged aimlessly; animal wastes are hardly been used as fertilizers; electricity has been even applied for cooking. This trend towards the so-called modern life style has actually deviated from a conventional ecological life style persisting for thousands of years in China, which is definitely not a sustainable way. In this way, resources and energy will be quickly consumed, which will result in deterioration of ecological environment, shortage of freshwater and nutrient, and energy crisis. In practice, this situation has appeared in many areas of China.

Under the circumstance, exploring and demonstrating a future development pattern for villages and even towns has become important and urgent. Nowadays, the future of cities and villages towards sustainability is being emphasized and planned globally; some countries and/or organizations have developed some alternative technologies to achieve the closed loop recycling of water resources, energy, and nutrient in rural and urban communities. Among them, the concept of ecological sanitation (ECOSAN) with urine separation, rainwater harvesting and biogas production has been gradually practiced in some European countries such as Germany and Sweden. (Berndtsson, 2006; Langergraber and Muellegger, 2005). In fact, the conventional farming and life pattern in China is very close to ECOSAN to a large extent. Clearly, changing the conventional pattern towards ECOSAN should be realizable and relatively simple. To convince people (especially for farmers), however, a practical demonstration project of ECOSAN has to be set up, as there is a conventional saying in China: hearing for a hundred times is inferior to seeing it one time.

Although the concept of ECOSAN has been accepted academically and even practiced partially in some areas in China, urine separation toilet is only a main concern in practice, and not a real ECOSAN project has been accomplished yet. With this article, a demonstration project of ECOSAN is introduced, which is located in the suburban area of Beijing and is being constructed under the supervision of Beijing University of Civil Engineering and Architecture (BUCEA) and with the financial support of the Beijing municipal government.

The constructed ECOSAN project is practiced on a deserted riverside with an area of 2 hectares. Besides the concept of ECOSAN, green buildings with energy saving are also reconstructed together.

General information about the demonstration project

Contents of the Demonstration project

Ecological sanitation and green buildings, including urine separation at toilet sources, biogas production with faeces/animal manure and biomass, rainwater harvesting, constructed wetlands for both treating grey water and purifying recycled lake water from collected rainwater, nutrient recycling to crops, heat preservation of buildings, and wind and solar energy utilization.

Project Period

Start-up of construction: June 2008.

End of construction: October 2009.

Initiation of operation: November 2009.

Project Scale

Total area of the project: 2 ha.

Installed toilets: 5 vacuum units for mixed collection of faeces and urine; 9 urine separation units with gravitational flow.

Vacuum station: equipped with 2 vacuum tanks for greywater and faeces, 2 vacuum pumps and sewage pumps, and automatic control system, each tank's volume is about 350L.

Anaerobic digester: ϕ2300x2500mm, treatment capacity is about 8m^3/d.

Rainwater harvesting: collecting area is about 1565m^2, of which the road is 1165 m^2, the parking lot is 120 m^2, and the house roof is 280 m^2.

Wetlands: 120 m^2 for rainwater treatment and 55 m^2 for grey water (3m^3/d)

Urine collecting tank: ϕ700x1800mm, design storage time is about 20-30d.

Heat preservation: the total area of housing insulation is about 530 m^2, rooms' outer wall, roofing, and floor insulation properties meet or exceed the current design standards of "energy-saving for residential buildings".

Solar thermal collector: the collector area is 20 m^2 for the winter heating, which can yearly save the electricity of 3,500 KWh.

Equivalent population: 30

Total project budget: $320,000

Location of the Project

Dongzhuang village, Xingshou Town, Changping District, Beijing

Planning Organization

Beijing University of Civil Engineering and Architecture.

Supporting Organization

Beijing Municipal Government

Geography of the project area

The project is practiced on the deserted riverside with the total area of 2 ha, which has been now rented and developed as a resort place. In the resort place, there are the housing rooms of 1200 m^2, a constructed lake of 1800 m^2 (5.5 m deep), a constructed sub-lake of 770 m^2 (2.2 m deep) for purifying lake water, a fish farming pound of 800 m^2 (2.0 m deep), a total farming lands of 200 m^2 for cultivating crops and vegetables and a well for drinking water supply (with a naturally mineral water quality), as shown in Fig. 1.

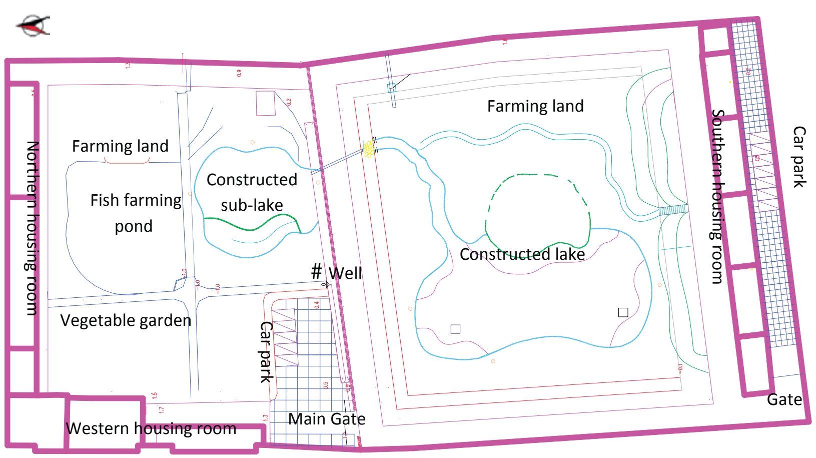

Fig. 1 Geography of the project area

ECOSAN System

Description of the ECOSAN Process

The northern and southern housing rooms are installed with 9 urine separation toilets, and urine is collected in a urine tank and then used for crops and vegetables as a fertilizer; faeces is collected in a faeces tank and then transported to the vacuum station and then pumped into the biogas digester for biogas production. The western housing rooms are installed with 5 vacuum toilets; black water (mixture of urine and faeces) is also transported into the biogas digester via the vacuum station. At the same time, grey water from all the housing rooms is transported into the constructed wetland (vertical flow) for grey water treatment also via the vacuum station; treated grey water is directly discharged into the constructed sub-lake for further purification and then recycled gradually into the constructed lake.

The collecting and treating flow sheets of urine, faeces and grey water are

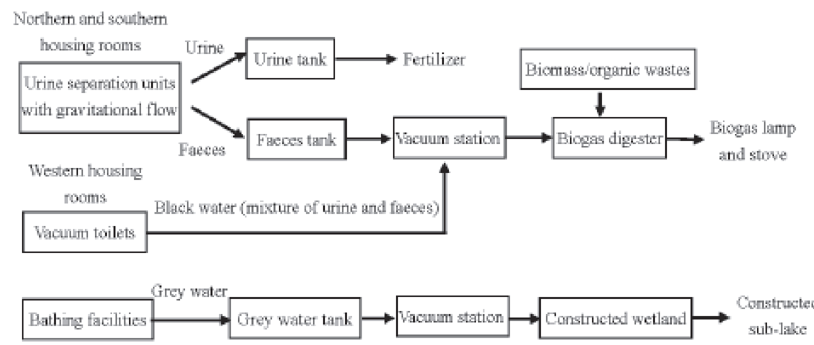

Fig. 2 Collecting and treating flow sheets of urine, faeces and grey water

shown in Fig. 2, and the pipelines' design is shown in Fig. 3.

Tanks Collecting Grey-water, Urine and Faeces

Separated grey-water, urine and faeces from the northern and southern housing rooms flow gravitationally into each collecting tank for storage; urine is then used as the fertilizer after stored for 3 months; faeces is then transported into the biogas digester via the vacuum station; grey-water is then transported on the constructed wetland via the vacuum station.

The collecting tanks of grey-water, urine and faeces are made of brick construction. The tanks' bases are made of concrete (C15) with the thickness of 150 mm; the interior walls (20 mm thick) of the tanks are made of cement/mortar (1:2.5) mixed with 5% of waterproofing powder. Tanks No.1 and No. 4 (ϕ700x1800 mm each) shown in Fig. 3 are used to collect urine; Tanks No.2 and No. 5 (ϕ1000x1800 mm each) are the tanks collecting grey-water; Tanks No.3 and No. 6 (ϕ1000x1800 mm each) are the tanks collecting faeces; Tank No. 7 (ϕ1000x1800 mm) is a monitoring tank.

Vacuum Station

The vacuum station consists of vacuum tanks, transporting equipment and

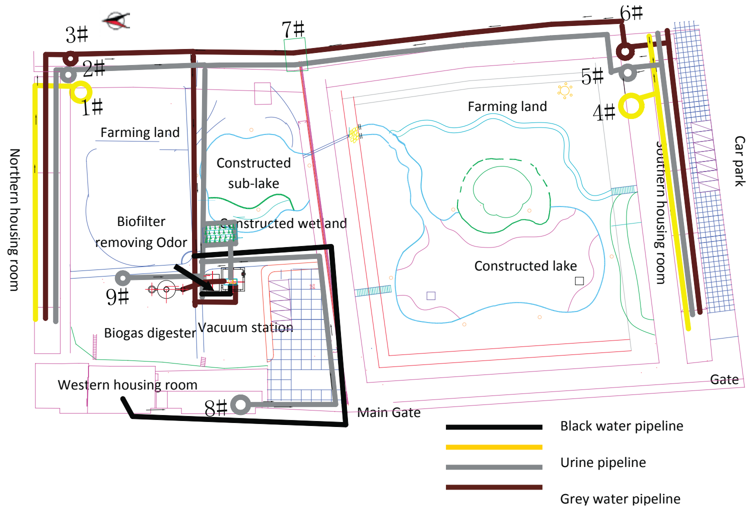

Fig. 3 Pipelines' design for the collecting and treating system

Fig. 4 Northern housing rooms and a collecting tank under construction

Fig. 5 Vacuum station and equipment

controlling devices, which is constructed in the form of semi-underground, with the dimension of 3000×3000×3000 mm. The vacuum tanks were offered by Enviro Systems (Model: WV700).

Biofilter Removing Odor

An off-gas pipeline from the vacuum station is connected with a biofilter (dimension: 2500×2000×1000 mm, shown in Fig. 6)) which is constructed to remove odor from faeces and urine. The biofilter is packed from the top to the bottom, with such carriers as in-situ soil (earth layer: 200 mm thick), bark and leaves (covering layer: 50 mm thick), ceramic pellets (transitional layer: 10-20 mm in diameter and 100 mm in thickness), ceramic pellets (holding off-gas layer: 20-40 mm in diameter and 250 mm in thickness), ceramic pellets (absorbing layer: 10-20 mm in diameter and 150 mm in thickness), and sandy soil (bedding layer: 100 mm thick).

Outdoors Pipelines

Outdoors pipelines are made of polyethylene (PE) material with 75 mm in diameter. The pipelines transporting faeces and grey-water are buried in an identical ditch, with a total length of 500 m, which can be seen in Fig. 7.

Fig. 6 Biofilter removing odor

Fig. 7 Vacuum outdoors' pipelines and a vacuum lifting tank

Biogas Digester

Faeces is transported from the collecting tank into the biogas digester (ϕ2300x2500 mm) via the vacuum station. Biogas (methane: CH_4) produced together with animal wastes and biomass is intended to cook and even illuminate for a family. The biogas digester is equipped with a safe system preventing accidents. The site of the biogas digester is shown in Fig. 8.

Constructed Wetland for Treating Grey-water

The constructed wetland is designed in the type of vertical flow, with a dimension of 9,000x6,400x1,200 mm, which is shown in Fig. 9. The treating capacity of the wetland is at a maximum flow rate of 3 m^3/d, with an accepting COD concentration of 360 mg/L. Grey-water is pumped into a distributing system on the wetland, grey-water flows vertically down to the bottom of the

Fig. 8 Site of the biogas digester

wetland and then over-flows to the sub-lake for further purification. Two pumps (QW25-8-22) for transporting grey-water are equipped.

The surface loading of the wetland is designed at 55 mm/d, which needs a total surface area of 55 m^2. The bed depth of the wetland is designed at 1 m, which results in a hydraulic retention time (HRT) of 5.9 d. The bed of the wetland is packed from the top to the bottom, with such carries as gravels (surface layer: 8-16 mm in diameter and 50 mm in thickness), coarse sands (filtering layer: 0.2-16 mm in diameter and 500 mm in thickness), gravels (transitional layer: 4-8 mm in diameter and 100 mm in thickness), gravels (discharging layer: 8-16 mm in diameter and 200 mm in thickness), and waterproofing cloth with PE membrane (bedding layer: >0.5 mm in thickness).

The distributing pipelines (50 mm in diameter, 50 mm in holes' position and 8 mm in holes' diameter) are made of PE material, which are connected with an influent pipeline (ϕ50 mm). Some valves are installed at the ends of the distributing pipelines and the influent pipelines for emptying. The distributing system is operated in a batch way, working for two times (5 min each time) an hour and stopping for 25 min after each working. The flow rate of the distributing system is designed at $Q=0.0021 m^3/s$ and with a surface loading of $\mu=0.55 m/s$. The discharging pipelines (ϕ110 mm) with even holes at the bottom are made of PE material as well, which is connected into atmosphere with a tube for the purpose of ventilation/aeration.

On the surface of the wetland, some plants such as reeds, cattails and calami are cultivated at a density of 4 pieces/m^2.

The distributing system is designed with an auto-control program, which can be operated in either a manual or an auto mode.

Rainwater Harvesting System

A rainwater harvesting system is planned and constructed to save water and recharge the constructed lakes. Rainwater from the northern and southern areas are harvested and utilized directly and indirectly. The rainwater harvesting system is shown in Fig. 10.

Fig. 9 Constructed wetland and sub-lake

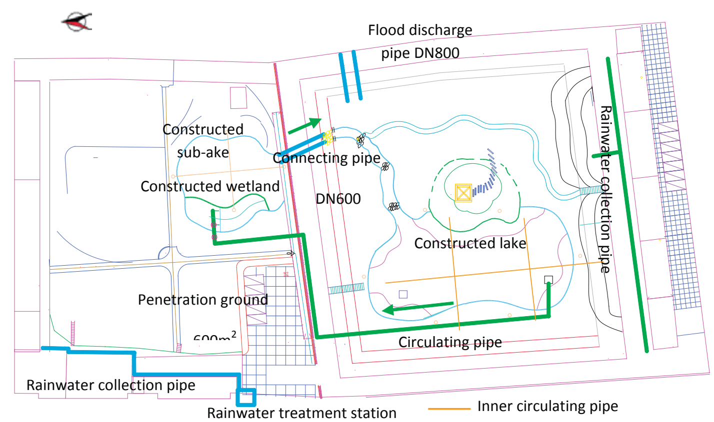

Fig. 10 Planned flow-sheet of the rainwater harvesting system

Direct Utilization of Rainwater

Rainwater from the northern and western housing rooms is designed for direct utilization, which mainly consists of recycled filtration, pressurized filtration and advanced filtration by activated carbon. After treated, collected rainwater can be directly used for drinking purpose. The treating process of rainwater is shown in Fig. 11.

Rainwater on roofs is collected in a storage tank via a hanged screen intercepting dirt. On the storage tank, an internal recycled filter is combined each other. Filtered rainwater is pumped from the storage tank into a pressurized filter for further purification, with chemicals added for coagulation prior to the pressurized filter. After the pressurized filter, purified rainwater is stored in a tank (Tank 1) for advanced purification. Flowing an advanced filtration with activated carbon and disinfection by UV, purified rainwater is stored in another tank (Tank 2), which is ready for drinking. Backwashing water from the filters is discharged into the greywater pipe and then treated by the constructed wetland.

Main units in treating process shown in Fig. 11 are in detail described as bellow: i) storage tank: 8.0 m^3; ii) recycled filter: 1,300 mm in length (two sections of 300 mm plus1,000 mm, connected with a flange in between) and 360 mm in diameter, placed horizontally with silica sand (0.8-1.2 mm) as packing carriers and operated at a cross flow rate of 10 m/h and with a backwashing time of 6 min and an washing intensity of 8 L/s m^2; iii) pressurized filter: double packing carries, 1,108 mm in length (anthracite: 400 mm; silica sand: 600 mm; and supporting layer: 100 mm) and 360 mm in diameter, placed vertically, equipped with a dosing unit of chemicals and operated at a flow rate of 12 m/s and with a backwashing time of 8 min and an washing intensity of 16 L/s m^2; iv) Tank 1: 4.0 m^3; v) advanced filter with activated carbon: 2 stage filters (alternately used for the first stage) with 1,100 mm in height and 360 mm in diameter each (activate carbon: 1,000 mm; supporting layer: 100 mm), placed vertically and operated at a flow rate of 16 m/h and with a backwashing time of 8 min and an washing intensity of 16 L/s m^2; vi) Tank 2: 4.0 m^3.

Indirect Utilization of Rainwater

The purifying system of rainwater for indirect utilization consists of a bioretention areas, a vegetation buffer strips, a constructed wetland and two constructed lakes (an ecological lake and a purifying lake), which collects, treats, stores and utilizes rainwater from the housing rooms' roofs and the ground in the southern area. The purifying system is shown in Fig. 12, which has multiple functions of collection, purification, flood control, landscape and entertainment.

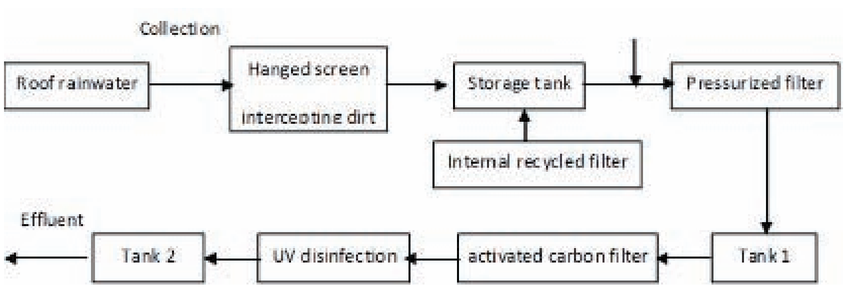

Fig. 11 Treating process of rainwater utilized directly for dirking purpose

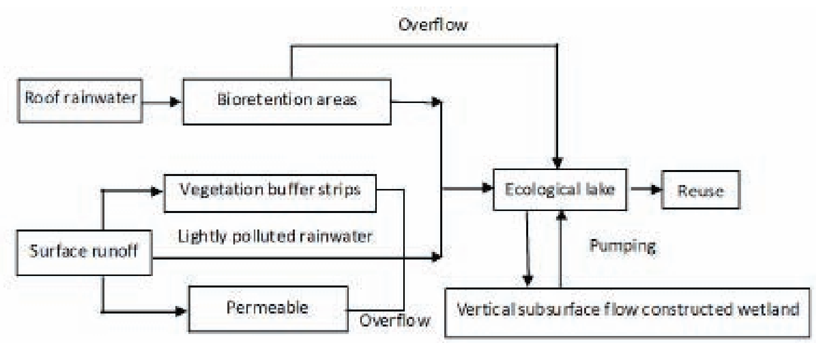

Fig. 12 Purifying system of rainwater utilized indirectly for the constructed lake

Roofs' rainwater from the southern housing rooms is collected in the plants' intercepting device for purification, and both purified and overflowing rainwater is introduced into the constructed lakes. A parking place at the western side is paved with infiltrating bricks, and rainwater nearby either infiltrates into underground or overflows into the ecological lake. Seriously polluted rainwater around the lake flows over the vegetation buffering zone and then enters the ecological lake. Lightly polluted rainwater directly enters the lake.

Some selected plants are cultivated at entrances of rainwater into the lake and at the dead corners for buffering, anti-eroding and plants' purification, with 20% of the total lake surface area.

The constructed wetland (subsurface) is constructed at the northern side of the ecological lake, which is used to recycle and purify the lake water. Usually, the lake water is pumped into the wetland for purification and then returns to the ecological lake via the purifying lake.

Some key parameters about the ecological lake are listed as below: i) plants' intercepting area: 14 m^2; ii) ecological lake: 2,650 m^2 (including 530 m^2 of plants' purifying area), with the banks of grasses, gravels and stones; iii) subsurface flow wetland: 120 m^2.

The rainwater harvesting system of the southern housing rooms and the ecological lake are shown in Fig. 13.

Fig. 13 Rainwater harvesting system and ecological lake

Summary

The project totally demonstrates the concept of ecological sanitation in the deserted area of 2 ha, which includes urine separation and utilization, biogas production from faeces, animal wastes and biomass, rainwater harvesting, ecological lake, wetland, etc. In this way, three closed cycles for water, nutrient cycle and energy can be realized within the practiced area, which results in a zero discharge of pollutants from the area. The demonstration project is intended as a base of research and teaching for the future of villages.

Acknowledgements

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change: institutions and barriers

Paper Abstracts

The Growing Role for Innovation in Urban Water Management

Glen T. Daigger

A model for innovation is presented to achieve the changes in urban water management (1) necessary to meet the needs of the 21st century and (2) possible to achieve the potential contribution to economic and social advancement. This model is based on continuous improvement to existing approaches coupled with breakthroughs allowing approaches with dramatically enhanced performance capabilities to be implemented. These changes are enabled by a growing toolkit of scientific, engineering, and management advances and can be assisted by necessary federal investments to support research and development. Regulatory reform to allow more integrated management across the water sector and on a performance basis rather than in a prescriptive manner will further enable this innovation model. Institutional reform to facilitate more integrated urban water management is desirable, along with reform of professional practice. Leadership for this approach can come from the utility sector and can lead to achieving the full potential of the 21st century vision for urban water management.

Effectively managing the transition towards restorative futures in the sewage industry: a phosphorus case study

Cynthia Mitchell, Dena Fam and Dana Cordell

The water and sewage industry globally is at a transformation point. Whilst infrastructure is ageing, pressures are increasing and expectations are shifting towards quite different kinds of outcomes, including restorative futures that have a net positive impact. There is a growing realization that conventional approaches will struggle to deliver these kinds of outcomes, so new approaches are necessary. The emerging field of transition management offers some guidance for how to strategically manage a transition toward a restorative future. Phosphate scarcity will be a significant pressure and opportunity for new forms of sewage management in the medium term, so phosphorus recovery from sewage makes a particularly interesting case study for applying transition thinking.

Learning Alliances – The SWITCH Approach to Catalyse Change

Carol A. Howe, John Butterworth

SWITCH is a five year, action research programme focused on urban water management. “Learning Alliances (LAs)” have been formed in thirteen global cities to implement innovative demonstrations and undertake planning for strategic integrated urban water management. The focus of each city’s Learning Alliance has been driven by the critical issues faced as well as the cultural and institutional structure of the city. In this paper the process of establishing the SWITCH Learning Alliances and their evolution over a four year period are described. The paper concludes with lessons learned including: flexible research plans and budgets should be in place to allow uptake of learning alliance recommendations, sufficient resources should be allocated to stakeholder analysis and LA facilitation, researchers should play a backstopping role to city LA members, joint visions should be built early in the process, results should be shared in short cycles and investment in monitoring and evaluation is critical.

The Growing Role for Innovation in Urban Water Management

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Abstract

A model for innovation is presented to achieve the changes in urban water management (1) necessary to meet the needs of the 21st century and (2) possible to achieve the potential contribution to economic and social advancement. This model is based on continuous improvement to existing approaches coupled with breakthroughs allowing approaches with dramatically enhanced performance capabilities to be implemented. These changes are enabled by a growing toolkit of scientific, engineering, and management advances and can be assisted by necessary federal investments to support research and development. Regulatory reform to allow more integrated management across the water sector and on a performance basis rather than in a prescriptive manner will further enable this innovation model. Institutional reform to facilitate more integrated urban water management is desirable, along with reform of professional practice. Leadership for this approach can come from the utility sector and can lead to achieving the full potential of the 21st century vision for urban water management.

Keywords

Urban water management, trends, hybrid systems, innovation.

Introduction

A growing number of professionals have concluded that a "tipping point" is being reached where traditional approaches must be dramatically altered to provide truly sustainable urban water management (Monsma, et al., 2009; Daigger, 2009, 2007; Novotny and Brown, 2007). Referred to by some as 21st century urban water management, these professionals contend that a new paradigm is required. Technical, economic, and social innovation are required, but numerous barriers exist to rapid innovation in urban water management. This paper presents a blueprint for innovation in urban water management. But, first the imperative for change is presented, and barriers and enablers to innovation in urban water management are reviewed.

The Imperative For Change In Urban Water Management

One may reasonably ask "Why must we change?". This is an excellent question as change creates disruption and inefficiencies, suggesting that it must also create sufficient benefits to justify the disruption. This is especially the case when it is recognized that modern urban water management systems create enormous value for society in terms of improved public health and safety (Daigger, 2009; British Medical Journal, 2007; Constable and Somerville, 2003). The simple answer to this question is that population growth and an increasing standard of living are pushing human use of our natural resources (including water) beyond sustainable limits (Daigger, 2009; Wallace, 2005). The case can be made that we have no choice. The fundamental requirements for any urban water management system, as listed in Table 1, must still be accomplished. But, they must be accomplished in a dramatically different context from the one within which the existing approaches evolved.

The Changing Context for Urban Water Management

Table 2 compares and contrasts the historical context for the evolution of current urban water management approaches with the future context. The current approach generally involves the importation of water from a remote location; treatment in a centralized drinking water treatment plant; distribution for domestic, commercial, and industrial use; use of the distributed water to remove wastes from their source and transport them to remote locations for treatment and discharge to the environment; and collection and transport of stormwater to remote discharge to control flooding. In fact, historically drinking water and wastewater treatment were not practiced as such technology was not available and was not needed as urban areas were located where sufficient supplies of pristine water sources were available along with discharge locations where treatment was not required. Only as population growth continued was drinking water treatment (first) and then wastewater treatment implemented. This approach was quite logical when water resources were abundant due to the relatively low global population and the relatively small urban population. Natural resources (especially energy) were also abundant (energy was used to transport water), and technology at that time limited water management options. The provision of pristine drinking water and transport of waste away from the population protected public health, and transport of stormwater protected the public from flooding.

This contrasts with the current and especially the future situation with much greater global population, most living in urban areas, and with limited water and other natural resources. The population is also more affluent today which, coupled with population growth, is leading to resource depletion. In fact, the standard of living must increase for the vast majority of the population living in developing countries for birth rates to decline and population growth to moderate, resulting in the mid-range global population projections as summarized in Table 2 (Daigger, 2007; NRC, 2003). An increased standard of living will further exacerbate resource consumption unless approaches and consumption patterns are altered. Fortunately, advanced urban water management technologies are available allowing dramatically more highly performing approaches to be implemented These trends can be understood in the context of the following equation:

$$I(-) = P(\uparrow) \times A(\uparrow) \times T(\downarrow) \quad (1)$$

where I is environmental impact, P is population, A is affluence, and T is technology. The environmental impact of dramatically increased population and affluence must be mitigated by the application of new technologies.

Daigger (2009) outlined the characteristics of a sustainable urban water management system which can meet the imperatives of the future context presented in Table 2, as follows:

- Locally sustainable water supply (recharge exceeds net withdrawal).
- Energy neutral (or positive if possible) with minimal chemical consumption.

• Water Supply • Domestic • Commercial • Industrial
• Protection of Public Health • Flooding • Pathogens • Toxics
• Environmental Protection • Oxygen Demand • Nutrients • Toxics • Micro-pollutants

Table 1. Urban Water Management System Objectives

Item	Historical Context	Future Context
Global Population	< 1 Billion	+/- 10 Billion
Urban Population	< 15 percent	Two-thirds or More
Life Style	Simple	Affluent
Water Resources	Abundant	Severely Limited
Natural Resources	Abundant	Severely Limited
Technology	Basic	Advanced

Table 2. Comparison of Historical and Future Context for Urban Water Management Systems

- Responsible nutrient management, which minimized dispersal into the aquatic environment.

Monsma, et al., 2009 have summarized the principals required to develop sustainable urban water management systems, listed in Table 3. They also list obstacles to achieving this "sustainable path" and potential remedies. Guest (2009 a/b) has outlined procedures for evaluating and selecting the most sustainable option for a particular application. In short, it appears that we know what to do, we just do not know how to get it done!

The Evolving Urban Water Management Toolkit

Since technological innovation will be key to achieving urban water management sustainability, it is fortunate that a rapidly evolving "toolkit" of approaches and supporting technologies to achieve greater sustainability exists (Daigger, 2009, 2007, 2003). Toolkit elements include:

• Transparency • Public outreach & stakeholder involvement • Good governance • Full cost pricing • Allocation of cost of development • Asset management	• Security & emergency preparedness • Conservation & water efficiency • Environmental stewardship • Energy management • Climate change mitigation & adaptation	• Advanced procurement & project delivery methods • Modernized plant operations • Management of environmental impacts • Watershed & regional optimization;	• Network optimization • Regulatory optimization • Workforce management; • Affordability • Research and technological, managerial innovation

Table 3. Principals to Develop Sustainable Urban Water Management Systems (From Monsma, 2009)

- Stormwater Management and Rainwater Harvesting, which provide local water supplies.
- Water Conservation, which reduces the volume of water needed and reduces the associated energy and chemical requirements to convey and treat water and wastewater.
- Water Reclamation and Reuse, which provide local water supplies and can reduce energy requirements in many instances as pumping requirements are reduced to a greater extent than treatment energy requirements are increased.
- Energy Management includes a number of technologies that can directly extract energy from the wastewater stream, including anaerobic treatment, microbial fuel cells, and the direct extraction of heat.
- Nutrient Recovery includes a growing number of technologies which allow nitrogen and especially phosphorus to be recovered from the wastewater stream.
- Dual Distribution and Source Separation create numerous efficiencies by allowing water of appropriate qualities to be distributed for individual purposes and the separation of relatively uncontaminated water, organic matter, and nutrients at the source.

Daigger (2009) and Daigger and Crawford (2007) further demonstrate how these technologies can be deployed in hybrid configurations which incorporate both centralized and decentralized components. The use of local water resources will be maximized in such systems, and water will be managed on a more distributed basis to maximize reclamation and reuse. Organic matter and nutrients will be managed on a more centralized basis to maximize efficiency and effectiveness.

21st Century Urban Water Management

The elements of a sustainable 21st century urban water management system appear clear. First of all, the system will be highly integrated. All elements of the urban water management system, including potable water, wastewater, and stormwater, will be managed in an integrated fashion (Daigger, 2009, 2007; Daigger and Crawford, 2007). This can take many forms, but it is likely that distinctions between the sources of the water will blur and focus will be, instead, on its quality. Distinctions between the built and natural water environments will blur as water increasingly becomes integrated with the urban environment (Monsma, 2009). Water will also become more integrated into economic and social elements of the urban environment. Water will increasingly be viewed as an economic asset and valued socially. The urban water environment will also be integrated into the broader regional and national water environment (Glennon, 2009).

The 21st century urban water management system will be enabled by modern technology. As discussed above, the "toolkit" has expanded significantly since the current urban water management approach evolved, thereby creating new possibilities. The 21st century urban water management system will also incorporate new management and economic approaches. Thus, significant change and innovation will be required to meet the water management challenges of the 21st century.

Enablers And Barriers To Achieving The 21st Century Urban Water Management Vision

Force field analysis is a useful tool for identifying barriers to and enablers of change in any system (Guest (2009 a/b). Figure 1 illustrates such a diagram developed to characterize implementation of the 21st century urban water management vision. Advancing forces are those which enable the desired change, while restraining forces are those which form barriers to it.

Figure 1. Force Field Analysis for Implementation of 21st Century Urban Water Management

Experience suggests that change is implemented most effectively by reducing restraining forces. The advancing forces listed in Figure 1 are generally those discussed above. The restraining forces are largely institutional and social in nature. Thus, it is useful to examine the social science literature on innovation. The role of public policy is also examined.

Diffusion of Innovation

Diffusion of innovation is the term used to describe the classical theory describing the adoption of innovation (Rogers, 1995). Developed initially from study of the adoption of agricultural innovations in the United States, it has been widely applied and subsequently used to describe the development of businesses (Moore, 1999). This research is the origin of the well-known "S-curve" of adoption, illustrated in Figure 2.

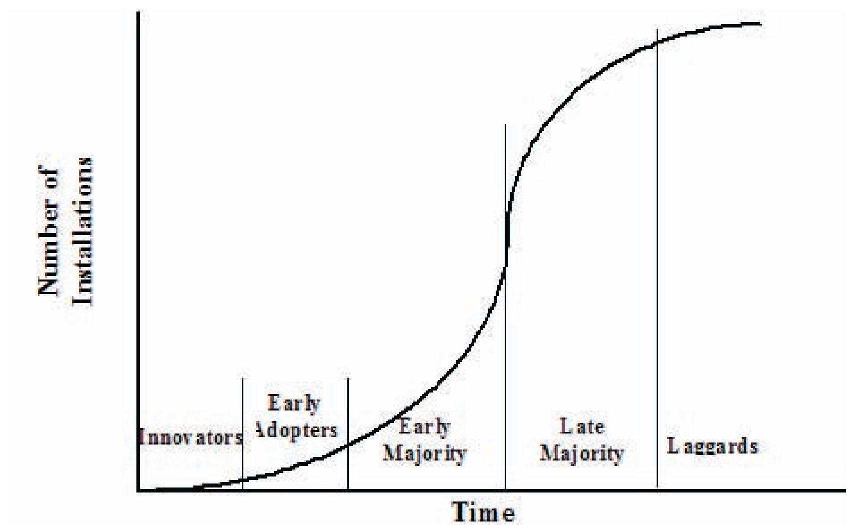

Figure 2. Innovation Diffusion Model (Rogers, 1995)

As shown in Figure 2, the rate of adoption of innovations is initially slow, increases with time until many of the potential users have adopted, at which point the rate decreases. This overall pattern occurs because different types of users adopt at different times in the adoption cycle, and for different reasons. The initial adopters, the innovators, do so simply because they have an appetite for new things. This is an important group for the developers of innovations as they help to fund research and development (R&D) during the critical transition from fundamental concept to commercial implementation. They fund the pilot studies and initial installations that can be critical to position the innovation for broad adoption. However, this is just the first step. The next group, the early adopters, is crucial as they are the "opinion leaders" who adopt new innovations to achieve advantage. These are often the users who others within the group closely watch, so their "endorsement" can be crucial in the adoption cycle. This leads to what has been phrased "the chasm", as it is the transition from the early adopters to the early majority which determines whether an innovation will be successfully adopted (Moore, 1999). If significant added advantage is demonstrated by the early adopters, and the early majority becomes convinced that the risks associated with adopting new technology can be mitigated, the early majority begins to use the innovation because they become confident that it will provide a competitive advantage for them. Once the early majority begins to adopt, they are followed by late majority, who adopt to avoid being placed at a disadvantage, and eventually the laggards who adopt out of necessity.

Benedek (2009) provides an interesting discussion of how these concepts fit into the development strategy for a specific business. He also demonstrates that this theory is applicable to water and wastewater treatment systems. This further demonstrates that the adoption of innovations in urban water management is principally a social process and that, for an innovation to be widely adopted (beyond the innovators and early adopters), it must convey significant advantage with associated risks that can be managed and mitigated.

Disruptive Innovations

Further insight into the adoption of innovations is provided by Christianson (1997, 2003) who introduced the concept of sustaining and disruptive innovations. Sustaining innovations are those which enhance existing approaches. In urban water management this may be viewed as the historical centralized approach described above. As illustrated in Figure 3, user desires for increased functionality (performance, reliability, convenience, reduced cost) increase with time. As further illustrated in Figure 3, users are not all the same and have a distribution – a range – of functionality expectations. Thus, a given "approach" or "product" may not fully satisfy the functionality expectations of all potential customers.

Significant incentive exists to innovate when user-driven functionality requirements exceed the capability of existing approaches to meet those requirements, as illustrated in the left-hand side of Figure 4. However, this increased rate of innovation can lead to "overshoot" when the functionality provided by the current approach exceeds that desired by the user, as illustrated in the right-had side of Figure 4. Innovation is inhibited when this occurs because the "marketplace" will not reward the value created by these innovations and, consequently, those investing in their development will not be able to receive sufficient funding for their development, as illustrated by the dotted line showing potential increases in functionality being constrained to advance only at the rate that user desires progress. From a current perspective features such as piped water, indoor plumbing, and sewers might represent system features which would not meet current expectations (represent a "performance gap" if only these features were provided), advanced water treatment, nutrient removal, and deep tunnel storage approaches to stormwater management might represent a range of features which satisfy current customer functionality requirements, and potable reuse, sustainability, and nutrient recovery might represent features which exceed the functionality requirements of many customers.

As illustrated in Figure 5, disruptive innovations are those with different features (functionality) and a different functionality "trajectory" than the accepted approach or technology. When introduced at a time when the current approach or product is beginning to exceed the functionality requirements of some users, this innovation can gain a place in the market which allows it to grow and eventually displace the existing approach.

Numerous examples exist, with some more recent ones including the replacement of chlorination as a disinfection technology by ultraviolet (UV) disinfection and the current expansion of membrane technology in both drinking water and wastewater treatment (Daigger, et al., 2005; DiGiano, et al., 2004). On a broader scale, urban water management is currently experiencing disruptive innovations in project delivery in the form of contract operations, design-build, and alliance contracting.

Figures 3 through 5 illustrate the situation where users may have a range of expectations but for similar results. This may not be the case for the full range of potential users of urban water management services. Consider, for example, differences in expected service levels between developed and developing countries. Users in developed countries may expect a high level of service and convenience, while those in developing countries may be satisfied with basic water supply and sanitation. This same difference in expectations can exist between the rich and poor in developing countries. As illustrated in Figure 6, this can lead to one approach – perhaps a sustaining technology – meeting the needs of the users who are currently served (in developed countries or the rich in developing countries) while innovative approaches, providing reduced functionality, can develop rapidly to meet the needs of the poorly served. The large number of unserved on the planet suggests that this model may be quite applicable.

In summary, the adoption of new approaches and technologies is driven by system user functionality expectations. Unmet needs for performance, reliability, convenience, and price can incentivize significant innovation as

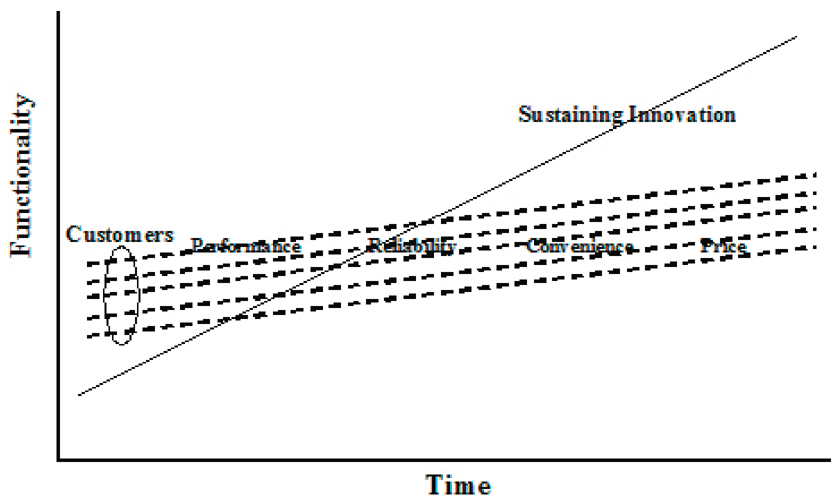

Figure 3. User Desires for Increased Functionality and Innovations Which Increase the Functionality of Existing Systems (Sustaining Innovations) Tend to Evolved at Different Rates

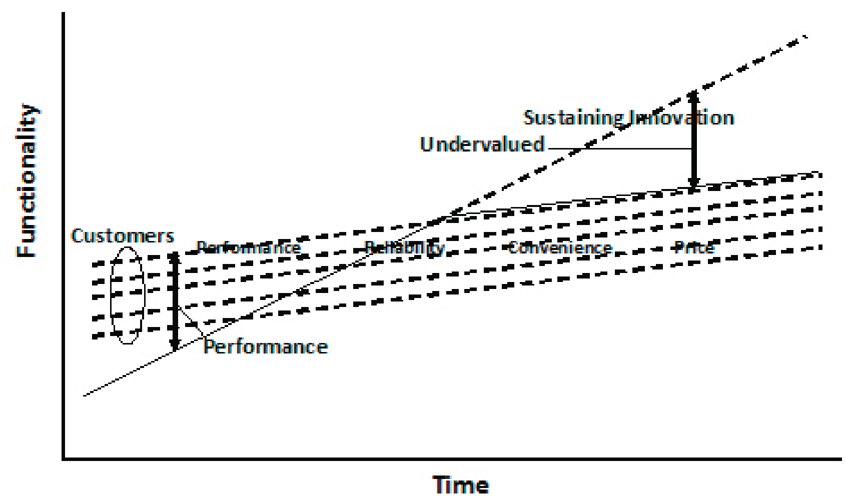

Figure 4. Performance Gap Drives Innovation But Undervalued Features Inhibit It

system users will reward (and fund) such innovations. However, further innovation can be inhibited if user expectations are being met by existing approaches. In contrast, the fact that a range of system user expectations exist allows new approaches and technologies to be introduced and, potentially, to displace existing approaches and technologies over time.

The Role of Policy Choices

The preceding theories (diffusion of innovation and the evolution of sustaining and disruptive innovations) were developed largely in connection with the adoption of new products or services from among multiple options in a competitive environment. In contrast, urban water management services are more often provided by public entities which often operate essentially as monopolies and within a highly regulated environment. Thus, individual customers for these services may not have access to a range of options, as is the case for the products and services where the preceding theory was developed. Furthermore, as illustrated in Figure 1, many of the factors restraining the implementation of 21st century urban water management systems are institutional in nature. These include an apparent lack of acceptance by the public for at least some of the evolving toolkit elements (such as certain types of water reclamation and reuse), along with regulations and embedded professional practices. Thus, public policies can be significant enablers or barriers to implementation of 21st century urban water management. In many ways environmental regulations represent the "user" by establishing practices which urban water management utilities must adopt and levels of performance they must achieve. These regulations are relatively

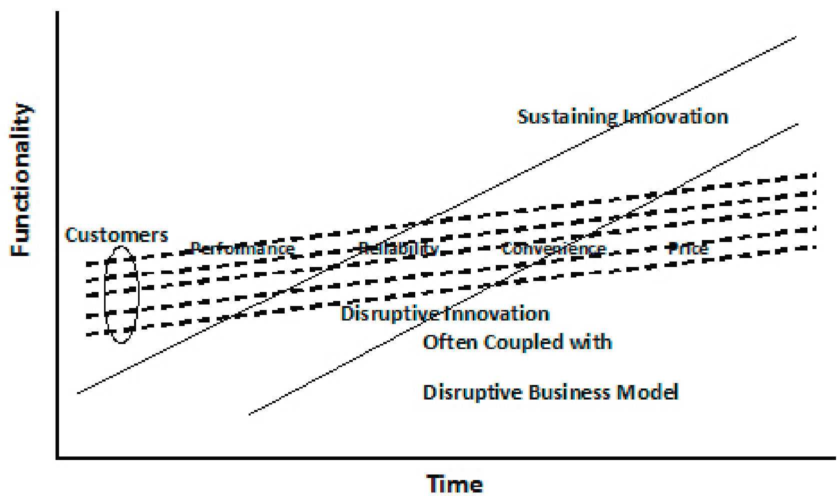

Figure 5. Disruptive Innovations Can Displace Existing Approaches "From Below"

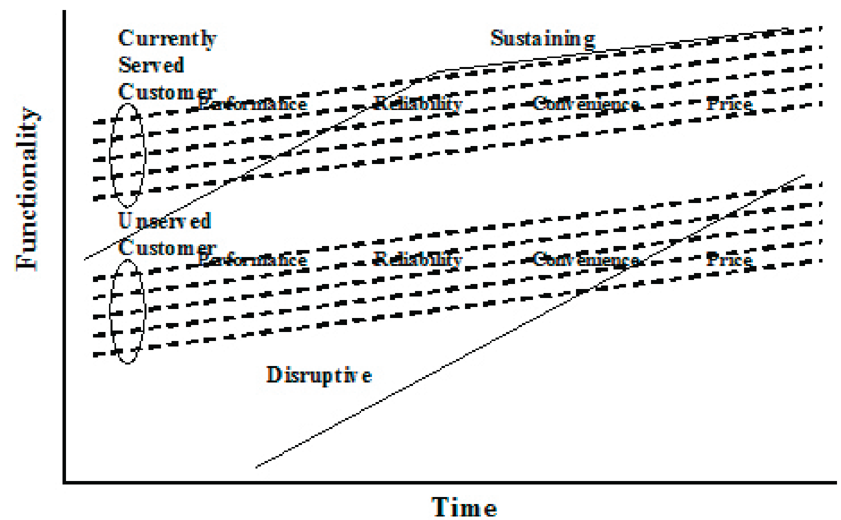

Figure 6. Advancement of Sustaining Innovation May Occur for the Currently Served While Significant Innovation is Occurring to Meet the Needs of the Unserved.

uniform and do not reflect regional or community differences as would be the case for a normal range of user expectation, as illustrated in Figure 3. They can also constrain innovation, as illustrated in Figure 4. However, regulations could also incentivize utilities to achieve higher levels of performance through the implementation of both penalties for noncompliance and incentives for higher performance levels.

Governmental investment in research and development (R&D) is another particularly important public policy decision, which arises due to the tradition of using non-proprietary technologies, products, and services in urban water management systems. The tradition of expecting that knowledge will be held in a non-proprietary fashion is an inhibitor to investments in R&D by the private sector. As a result, in many countries, including the United States (US), federal investments in R&D have been significant in response to the recognized public good created. For example, in the 1970's and 1980's US annual federal wastewater treatment R&D investments were on the order of $100 M/yr, which would be nearly $300 M/yr in current dollars. Others, such as the European Union, Singapore, and South Korea, recognize the opportunity and are currently making substantial investments in water and wastewater R&D (for example, Singapore is investing $S330 M over five years). In comparison, the French system of private operation of water management utilities has allowed significant private investment to be made, resulting in the development of new products and significant innovation. These private investments are further reinforced by those from the European Union.

Figure 7 illustrates the role of federal investments where knowledge is largely held non-proprietary. Consider, for example, the situation in the US, when significant investments are made in fundamental research, focused currently in biotechnology and nanotechnology. The fundamental results in these areas provide significant opportunities to advance water treatment technology, but further investment in fundamental applications research is needed to ready these results for applied R&D leading to new products. The results of this fundamental application R&D can be applied directly to urban water management utilities, resulting in enhanced performance and reduced costs. They also fund the development of necessary human resources since some of these funds are invested in university research, which in turn funds the education of students needed to fill professional positions. These results also transform basic research findings into knowledge that can be used to develop commercial products by private industry. Since these private concerns are for-profit, they pay taxes which pay back the initial federal investment in water-focused fundamental applications research. As a consequence, the federal spending on fundamental applications R&D is not a cost, it is an investment that is repaid through taxes. It is important to recognize that commercial companies cannot make the investment in fundamental applications research because they are not able to directly control the results produced. The federal government is the logical entity to make such investments because they potentially benefit all US citizens. Nordhaus and Shellenberger (2007) discuss this concept in connection with the development of clean energy technology, which is quite analogous to the needs of the water sector.

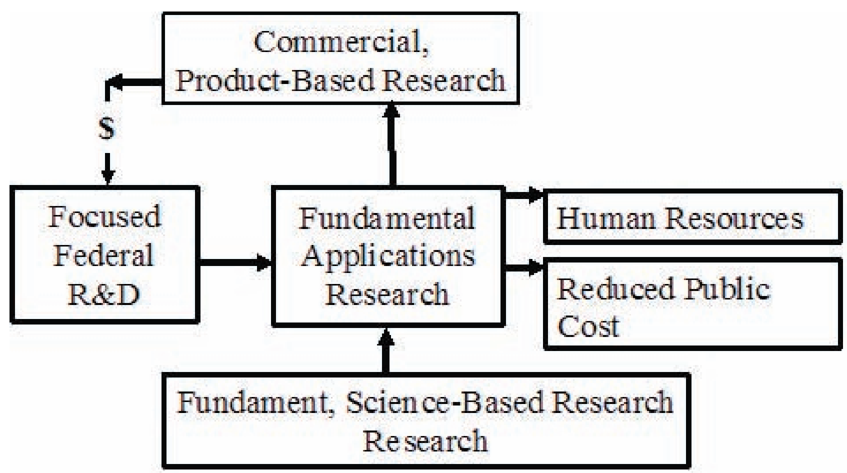

Figure 7. Focused Investments in Federal R&D Creates a "Virtuous Cycle" That Benefits the Public and Enhances the Economy

A Blueprint For Innovation In Urban Water Management

Rapid and directed innovation in urban water management is required to achieve both the potential of the 21st century vision, and the changes necessary to meet the requirements of the 21st century.

A Model for Innovation in Urban Water Management

As illustrated by Figures 2 through 6, the essence of innovation is change. Different groups adopt new behaviors (Figure 2) and the expectations of consumers and capabilities of service providers change over time (Figures 3 through 6). Thus, a fundamental element of the model for innovation in urban water management during the 21st century is change. Two types of change form the basis for this model: (1) continuous and (2) breakthrough. Continuous change will occur as existing approaches improve and as they are used in novel ways to improve service delivery. The techniques of continuous improvement will be employed to achieve this on-going improvement. The second type of change is discontinuous as new techniques and technologies are introduced, leading to dramatic changes in service delivery. These changes can be analyzed and interpreted in the context of the theory of the evolution of sustaining technologies and the introduction of disruptive technologies, as presented by Christenson (2003, 1997).

Theory, reinforced by practical experience, teaches that innovation is driven by the functionality desired by the consumers of urban water management services and, consequently, it must align with the goals and desires of the local community. To accomplish this, urban water management must be integrated with the local community, as described above. These goals and desires will evolve with time, reinforcing the need for urban water management systems to adapt and change. At the same time, local, regional, and national water management are inter-related, and the management of water within individual urban areas must be coordinated with the broader water management issues (Glennon, 2009). These requirements will also evolve with time.

Revolutions in science and technology are continuing and offer significant opportunities for both continuous improvement and breakthroughs in urban water management. Focused R&D is required to translate these advances into products and services which serve the urban water management sector. These advances occur not only in the physical, chemical, biological, and engineering sciences but also the social and management sciences. Practical research and demonstration in each of these areas must become a regular element of urban water management.

Table 4 illustrates the nature of change inherent in this model and contrasts it with the current situation. The current pace of change is periodic and reactive to changes in regulations. In the future it must be on-going and proactive, adapting to local, regional, and national imperatives. The result will be not only more integrated and higher performing urban water management systems but more livable urban areas.

Enablers for the Model

Some elements of this model for innovation are under the control of individual urban water management utilities (as illustrated in Monsma, 2009), but others are not. Individual utilities can reach out to the communities they serve to become more aligned with their overall goals and objectives. Northaus and Shellenberger (2007) have discussed how environmental progress in the future will be achieved by emphasizing its relationship with economic growth and increased well-being rather than the need to reduce negative impacts on nature (the politics of possibilities rather than the politics of limits). Individual utilities can become more aggressive in the adoption of modern scientific, engineering, and management innovations, and they can work cooperatively with other urban water management utilities to achieve greater integration of

Item	Current	Future
Pace of Change	Periodic	On-Going
Nature of Change	Reactive	Proactive, Adaptive
Performance Metric	Regulatory Compliance	Local, Regional, and National Imperatives

Table 4. Current and Future Nature of Change in Urban Water Management

water management and move toward the vision that "water is water". Ostrom (1990) has demonstrated that institutions can collaborate to manage common resources. However, broader changes can enable the nature and pace of change needed to achieve the 21st century urban water management vision.

Regulatory change is perhaps the greatest change needed to increase the pace with which the 21st century urban water management vision can be attained. Water management regulations have evolved on a sector-by-sector basis and are often conflicting when viewed from the perspective of the more integrated approach to water management needed today and in the future. They are also prescriptive – requiring either certain procedures to be used or narrowly specified results to be achieved – rather than performance-based. As discussed above, this approach has produced enormous benefit in terms of public health and environmental protection, but their highly prescriptive nature also inhibits rapid innovation. The evolution of more integrated water management regulations which are performance-based will allow innovations which support the desired performance to be implemented much more quickly. Performance measures will necessarily incorporate penalties for poor performance, but they can also incorporate rewards for performance that exceeds norms. As noted in Figure 4, such incentives can be a spur to innovation. Regulatory reform must occur not only at the national but also the state and local level as codes and regulations (which are also legal instruments) currently inhibit many available urban water management opportunities.

Funding for R&D in urban water management must also be increased to support the translation of fundamental research results into useful products and services. As discussed above, government is the only entity capable of making these investments when the public utility service delivery model used to manage water in the United State is employed. The federal government is the logical entity to make these investments. As also discussed above, from a public policy perspective these are investments, not costs, as they are paid back to the public through improved service delivery and directly to the public treasury through increased taxes.

While individual utilities (drinking water, stormwater, and wastewater) can collaborate to achieve many elements of the 21st century urban water management vision, the inherent division of responsibility creates barriers and inefficiencies which would be minimized by integration of these functions into a single institution. This is not to say that all urban water management services must be provided by the public sector. Significant opportunities exist, and will continue to exist, for the public sector. However, more integrated overall management would result if a single entity possesses the overall responsibility. Integration of professional practice is also needed, as discussed elsewhere (Daigger, 2009).

A Call for Action

The question arises as to where the leadership will come from to implement the innovation model outlined above and greatly accelerate the rate at which urban water management moves toward the 21st century vision. It is best if this leadership comes from the urban water management profession itself. These professionals are the ones who truly understand the needs and practical constraints and can avoid repeating the mistakes of the past. Fortunately a number of examples exist of utilities adopting this vision and taking steps to realize it. Inevitably, however, the imperatives of the 21st century will result in necessary changes to urban water management. The question is whether the profession will lead to implement the necessary change or have the change imposed upon it. Diamond (2005) has described how sustainable societies remain true to their core principals while continuously adapting their practices to evolving realities. The core principal of the urban water management profession has been public service to protect public health and the environment, as summarized in Table 1. The question before the profession is whether it can remain true to that principal and continuously adapt its practices to evolving realities. If the answer is yes, the profession will avoid collapse and will continue to provide this necessary societal function.

Summary And Conclusions

In summary, urban water management must change to meet the imperatives of the 21st century. Population growth and an increased standard of living are pushing human use of natural resources (including water) beyond sustainable limits. The reasons for and nature of the necessary change is expressed in the equation I = P x A x T. The adverse impacts of population growth and increased affluence must be compensated for by the application of advanced technology. 21st urban water management must be achieved using locally sustainable water supplies, being energy neutral and with minimal chemical consumption, while achieving responsible nutrient management. Utilities must adopt a series of principals to achieve sustainability, as detailed by Monsma (2009). Fortunately an evolving urban water management toolkit exists, consisting of stormwater management and rainwater harvesting, water conservation, water reclamation and reuse, energy management, nutrient recovery, and dual distribution and source separation. Hybrid systems incorporating both centralized and decentralized components effectively use these tools. The 21st century urban water management system will be more highly integrated across individual water sectors, across both the built and natural environment, within the economic and social context of the local community, and across broader regional and national settings. Water will be viewed as a highly valued economic and social asset.

The principal barriers to achieving the 21st century urban water management vision are institutional. Consequently, social science theory concerning the diffusion and implementation of innovations is useful to understand how these barriers can be reduced. This theory teaches that the diffusion of innovation follows a definite process as different types of users adopt the innovation, for different reasons. The benefits of the potential innovation must exceed perceived risks for adoption to occur. Innovation progresses in response to user demands for increased functionality (performance, reliability, convenience, price), which can either stimulate or restrain innovation depending on the relationship of user demands and product capabilities. Sustaining innovations are those that support the existing approaches. User functionality demands also vary over a range, thereby allowing new products and services to enter the marketplace, often by offering sufficient functionality to less demanding users. This is typically how new (disruptive) innovations enter the marketplace. Proper policy choices can significantly enhance the rate of innovation.

A model for innovation in urban water management reinforces continuous incremental change punctuated periodically with breakthroughs. Urban water systems must align closely with the goals and desires of the local community while also being consistent with regional and national priorities and realities. On-going change must take advantage of developments in the physical, chemical, biological, social, and management sciences and engineering. In short, change must become continuous, proactive, adaptive, and driven by broad local, regional, and national imperatives.

This model for innovation in urban water management will be enabled by willing utilities that align with the broader goals and objectives of the communities they serve, adopt modern scientific, engineering, and management practices, and collaborate effectively with other relevant utility partners. These efforts will be further enabled by regulations which are integrated across the water sector and are performance-based rather than prescriptive. Regulatory reform must occur at the local, state, and national levels. Sufficient funding for R&D must be provided by the federal government. Institutional reform that integrates urban water management and the supporting professional practice will also enable accelerated innovation. Leadership from the water utility profession will allow this model to be implemented more rapidly. In the absence of such leadership, the imperative for change in urban water management will result in leadership from other sectors.

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Effectively managing the transition towards restorative futures in the sewage industry: a phosphorus case study

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Abstract

The water and sewage industry globally is at a transformation point. Whilst infrastructure is ageing, pressures are increasing and expectations are shifting towards quite different kinds of outcomes, including restorative futures that have a net positive impact. There is a growing realization that conventional approaches will struggle to deliver these kinds of outcomes, so new approaches are necessary. The emerging field of transition management offers some guidance for how to strategically manage a transition toward a restorative future. Phosphate scarcity will be a significant pressure and opportunity for new forms of sewage management in the medium term, so phosphorus recovery from sewage makes a particularly interesting case study for applying transition thinking.

Keywords

Restorative futures; phosphorus recovery and reuse; transition management; strategic niche management; urine diversion; sewage management; water industry

Introduction

The water and sewage industry is at a transformation point. Climate change impacts, changing hydrological conditions, population growth, resource scarcity, aging infrastructure, economic constraints in financing large scale systems, and changing expectations for water quality (e.g. European Union water directives) all challenge existing planning parameters for developing and extending conventional centralized water and sewage systems.

While the resource intense nature of centralized water-based sanitation systems will struggle to adapt to these future uncertainties, there is a growing recognition within the water sector that an environmentally, economically and socially sustainable sanitation system requires sewage to be viewed as a set of resources to be recovered, recycled and reused (water, energy, nutrients) rather than a waste product to be treated to successively higher standards before release to the environment. Whilst such concepts have been core to the ecosanitation part of the sector for many years, what is different now is that the concepts are gaining traction in the mainstream, large-scale end of the industry. For example, this year's International Water Association Leading Edge Technology conference, held as part of Singapore International Water Week that attracted up to 10,000 delegates from across the globe, opened with a workshop explicitly focused on carbon and nutrient recovery (see www.siww.com.sg). The impact of these realizations on the form, scale and operation of the sewage sector could be enormous (see Figure 1).To date, resource recovery from sewage has largely focused on water due to increasing concerns of water scarcity, exacerbated by climate change impacts, urbanization and population growth. The national water industry

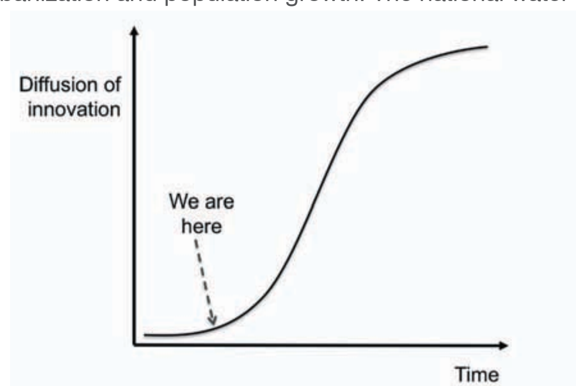

Figure 1. Graphic representation of the scale of change in the sewage sector in coming decades (After Rodgers, E.M. 2003, Diffusion of Innovations, 5th edn, Free Press, New York)

association in Australia recognizes this and the implications for infrastructure in its vision for a sustainable urban water future: 'Given the need to maximize the efficient use of recycled water, it is highly likely that the days of extending sewage collection systems over ever- increasing distances to be connected to coastal sewage treatment plants are coming to an end.' (WSAA 2009, p7). Elsewhere, nutrient recovery has emerged in areas (such as The Netherlands, Germany, Sweden) where changes in sewage management practices are being driven by concerns about contributions to nutrient imbalances, eutrophication, discharge of pharmaceuticals and a loss of biodiversity in receiving water bodies.

By shifting the paradigm from 'removal' to 'recovery and reuse' there is the potential to move beyond 'sustainability' toward developing 'restorative' systems (McGee et al., 2008) of water and sewage management. Restorative systems aim to have positive economic, social and ecological impacts, and are necessary for remediating historical effects of conventional sewage systems and in making up for areas that will not reach the baseline goal of sustainability (Mitchell, 2008).

Innovative thinking across various dimensions is required to move toward restorative systems and is occurring globally with emergence of four significant themes:

1. New costing perspectives

There is an increasing interest in costing approaches that expand beyond a narrow focus on least financial cost to a single stakeholder, and encompass broader costs and benefits and broader stakeholders. One such approach is integrated resource planning (Swisher 1997, Vickers 2001), which seeks the lowest cost to society across the life of the infrastructure whilst providing socially and environmentally preferable outcomes (Mitchell et al., 2007). Since water and sewage management are generally provided by public funds, least cost investment in water and sewage infrastructure and its operation frees up funds for investing in other public infrastructure, like schools and hospitals. Another emerging approach is 'value based' evaluation to design and implement systems that have the most value. This shift in perspective in valuation processes is occurring globally (e.g., The Vancouver Valuation Accord). Another is the increasing interest in bringing externalities inside the decision-making process, through sustainability accounting (see Yarra Valley Water, 2009, p12), assigning value to externalities or deliberative engagement (see below). All of these economic evaluation approaches have the potential to radically change what decisions are made by water authorities in developing water and sewage management systems.

2. Participatory, deliberative decision making in developing water systems

As the adoption of distributed systems and nutrient recovery presents a paradigm shift in wastewater management, community engagement is essential for the introduction of alternative socio-technical systems. By adopting 'representative and deliberative' processes of engagement in decision making, the aim is not only to select participants who are representative of the society of concern but also provide outcomes from the process that will impact the decisions of authorities. Not only does this approach provide the potential for delivering 'well-informed, fair and equitable decisions' (Fung & Wright 2003)(p.x) in the water sector but also of providing much needed public support for new approaches to water and sewage management and the associated institutional arrangements needed to support their introduction. These approaches are closely linked to those that expand notions of costing.

3. Shifting from a resource focus to service focus

While conventional business thinking takes an output focus and is concerned with supplying a commodity, a shift in the sustainable business arena is occurring toward being outcome focus and supplying a service rather than supplying a resource (Dunphy, Griffiths & Benn, 2003). This conceptual shift in thinking is providing significant gains in economic, environmental and social outcomes while improving financial performance (See Mitchell et al., 2007 for further examples).

4. Systemic thinking & synergies between energy, water reuse and nutrient recovery

Systemic thinking is increasingly being acknowledged as critical for sustainable management of our natural resources on a local, regional or global scale (e.g. ESSP, online; Urban Water, 2006; SLIM, 2006). However the institutional and physical structures created to manage natural resources over the last decades do not reflect a translation of systems thinking into practice. A good example of this is the nature of most centralized water and sanitation systems through to the global food production and consumption system. While both the sanitation and agricultural systems have the potential to take advantage of synergies between material flows, such as reuse of wastewater fractions in food production, rarely does either system integrate and make use of the potential resources available. Instead in an energy and resource intense way, the sanitation and agricultural sectors are continually sourcing new resources of water and nutrients. (Cordell, 2008)

A restorative future for the sanitation and water sector would encompass all these shifts, and provide a starting point for backcasting (Dreborg 1996, Mitchell and White 2003) to the present to identify alternative paths for infrastructure planning and investment, in developed and developing countries alike.

There is little doubt that the embedded nature of the sanitation system, with intertwined components of physical assets, organizations, institutions and social habits of practice, create significant barriers to system innovation (Fam et al. 2009) and integrating material flows across the sanitation and agricultural sector. But the critical nature of resource depletion (nutrients) and scarcity (water, energy, nutrients) means there is greater acknowledgement by the water sector (e.g., the Victorian Water Industry Association's annual sustainability seminar this year had the title: 'Responding to a water, carbon and nutrient constrained future') of the need for sustainable resource recovery from sewage. Today the question is therefore not *whether* technological change should occur but *how* to strategically manage a transition toward sustainable means of resource recovery. The water sector has the opportunity and is in the position to facilitate such a shift toward technological change and sustainable reuse of constituents in sewage.

Managing A Transition Toward Restorative Futures

In considering the potential for system change, the weight of the past creates significant barriers to transformation of the water sector and transitioning toward a restorative future. System innovation or transition is generally defined as fundamental transformations in the way societal functions (such as transportation, communication, housing, waste management) are fulfilled (Elzen and Wieczorek, 2005). The emphasis is on the co-evolution of technical and societal change as opposed to incremental change which is characterized primarily by changes in technology. Many of the barriers to radical change and system innovation in sewage management relate to the embedded nature of the centralized sanitation system which has co-evolved over the last century to become a highly interdependent, complex system of institutions, organizations, material infrastructures, technologies and social habits of practice (Hughes 1987) that make it challenging to introduce radical alternatives to the mainstream even if those alternatives may provide more sustainable outcomes.

As with many other large-scale infrastructural systems, such as energy supply and transportation systems, the sanitation system is weighed down by enormous sunk infrastructural costs, embedded institutional and regulatory structures and a life span of physical assets that last between 80-100 years. Shifting the trajectory of sanitation systems toward sustainability is therefore complicated, the investments and decisions made in the past create a tendency to incrementally add to and extend the existing system rather than invest in innovations with radically different sustainability potentials. Although understanding of sustainability is constantly evolving, wastewater design and management processes are aligned to 20th century engineering traditions (Guest et al. 2009) and characterized by incremental change along existing paths and trajectories rather than radical innovation.

While many authors have discussed the difficulties of changing socio-technical systems (Dosi, 1982; Metcalfe, 1997; Rip & Kemp, 1998; Rotmans, Kemp & Asselt, 2001) there is increasing interest from policy makers, NGO's and industrial firms in system innovation and the sustainability benefits the transition may offer. This growing interest in system innovation is reflected in a shift in research of technology and sustainable development, from the level of single technologies to socio-technological regimes (Kemp, Schot & Hoogma 1998; Rip & Kemp, 1998; Smith, 2003). In the 1980's, effort was focused on solving environmental problems with cleaner product and process innovations and were developed in conjunction with end-of-pipe solutions (Geels, 2006; Smith, 2003). Although this incremental step to technological change has, in cases, led to significant improvements in environmental efficiency, substantial leaps in efficiency required to reach the demanding goals of restorative systems and long term sustainability in the water sector may only be possible through system innovation or the large scale transformation of how societal functions such as sewage management are fulfilled (Elzen & Wieczorek, 2005).

Introducing system innovation and cost effective resource recovery requires understanding socio-technical change, how it has occurred in the past and how we may potentially manage a transition toward sustainability in the future. Historically, socio-technical systems have involved multiple actors, factors and levels in system change. For example, the transformation of the sanitation system in many industrialized countries from the use of cesspools to sewer systems was a co-evolutionary process. The transition was not caused by a single factor or the introduction of a technological breakthrough but rather interplay of factors that influenced each other at varying levels. The co-evolution of technology and society in the development of centralised sanitation was a relationship between multiple factors (technical, regulatory, societal and behavioural), actors (users/consumers, government & private enterprise) and levels (macro, meso and micro) (Geels, 2005).

Transition theorists argue that technological transitions and radical shifts in established socio-technical regimes such as wastewater management occur with interactions and alignment between processes at different levels – a multi-level perspective (Geels, 2002; Geels & Schot, 2007; Rip & Kemp, 1998). For example, socio-technical landscape factors such as water scarcity coupled with urban growth have the potential to destabilize established socio-technical regimes (configurations of technologies, institutional structures, rules and norms) providing opportunity for new socio-technical configurations to occur at the level of the technological niche (radical technologies and practices).

At the same time the path dependent characteristics of established socio-technical regimes may limit the emergence of radically different technologies and user practices (Geels, 2002; Rip & Kemp, 1998; Walker, 2000).

Broad landscape drivers such as water scarcity and nutrient and energy constraints have triggered a number of water authorities and research institutes (e.g. the Melbourne water authorities (such as Yarra Valley Water), German Technical Corporation (GTZ), UNESCO-IHE, Dutch Foundation of Applied Water Research (STOWA)) to seriously consider adopting resource recovery systems such as urine diversion, a radical innovation in sewage management.

Although urine diversion is seen as radical today, it has been practiced since ancient times in cultures spanning from Greece to Asia. The modern water-based version of the urine diversion (UD) system was invented and emerged during the early 1990s, where waste streams are separated at the source at the household level with a urine diversion toilet. Due to the nutrient rich nature of urine which consists of phosphorus, nitrogen and potassium, it is collected at the household level, stored, sanitised and reused on-site as a substitute for chemical fertilisers or centrally collected by the municipality in conjunction with a local farmer before being transported for storage, sanitization and reuse in agricultural applications (see Johansson, M., H. Jonsson, et al., 2000) for further details of Swedish experiences).

To practically implement resource recovery systems at any significant scale and deliberately manage a transition toward a sustainable or restorative future in the water sector, will undoubtedly involve a co-evolution of technological and mutually reinforcing institutional and socio-cultural transformation. For example, for the introduction and development of small scale systems of nutrient recovery such as urine diversion systems (UD):

- new regulations need to be developed (e.g. akin to the World Health Organisation guidelines for wastewater reuse (WHO, 2006),
- risks and responses considered (e.g. in the development of decentralised or distributed systems),
- institutional arrangements managed (e.g. service teams constructed),

- innovative decision-making processes implemented (e.g. deliberative, participatory processes),
- interpretations of personal responsibility articulated (e.g. behavioural change, socio-cultural habits and practices),
- pricing and payment structures constructed (e.g. feed-in tariffs, tax incentives) and
- markets stimulated (e.g. for nutrients and new technologies).

In practical terms experimentation means piloting, demonstrating, monitoring, evaluating and providing opportunity for learning across these multiple dimensions and within different application domains.

Technological niche experiments act as domains temporarily protected from harsh selection environments through mechanisms such as tax exemptions, investment grants and other forms of 'protection'. The niche environment is therefore fundamental in transitioning toward a more sustainable state of resource recovery and can be used as a strategic location for learning, building new social networks, improving the innovation and broader diffusion of the concept.

Adopting Strategic Niche Management To Implement Radical Innovation In Resource Recovery And Reuse

The introduction of sustainable technologies is challenging in the face of existing systems characterized by lock-in and resistance to change (Unruh 2000), such as those represented by the global water and sanitation sector. SNM therefore emerged as an area of research through the observation that many sustainable innovations fail to 'take off' in spite of their significant environmental potential. The framework of Strategic Niche Management (SNM) is a rapidly growing area of research revolving around experimental-based learning of the technological, social and environmental possibilities and constraints of innovation (Caniels & Romijin, 2008). 'Niche' is defined here as a protective space or 'incubation' area where actors can experiment with an innovation and learn about the potential barriers and benefits of system change (Raven, 2005; Rip & Kemp, 1998).

The SNM framework has been applied to various case studies in the area of sustainable innovation such as biogas plants and biomass firing (Raven 2005), electric (Truffer, Metzner & Hoogma 2002) and sustainable transport (Hoogma et al. 2002) and organic food (Smith 2006) to name a few. The analysis of case studies tends to be of experiments, demonstration projects and pilot plants with scholars exploring the challenges, opportunities and the lessons learned. As Smith this suggests this is a very different approach to researching transitions toward sustainability, the conventional approach being to study unsustainability and recommend reforms for mitigating these problems. The more novel approach of SNM explores '…innovative experiments in alternative, sustainable technological niches, drawing lessons from the challenges they face in the context of a dominant unsustainable technological regime.' (Smith 2003, p. 128).

Until now SNM has been a tool for analyzing past experiences: constructive applications of SNM are rare and limited. Raven (Raven, 2005) notes that SNM has primarily been used for improving the design of experiments, evaluating policies in the past, using SNM as a scenario development tool and to design future policies on niche management. In practical terms, the SNM framework offers insight into how radical niche based technologies such as resource recovery and reuse systems might be designed and introduced to contribute to shifting practices away from resource intense infrastructures such as the dominant regime of centralized sanitation. Although we don't presume to present a comprehensive account of transition theory or the intricacies involved in operationalizing alternative technological experiments using the SNM framework, in practice decentralized and distributive systems will undoubtedly play a key role in transitioning toward a restorative futures of resource recovery as they provide a viable means for experimentation and *learning by doing* at a relatively low risk and low cost (Mitchell 2008).

Phosphorus Security: A Case For Transition

A New Global Challenge: From Phosphorus Pollution to Phosphorus Scarcity

Whilst it is widely acknowledged that addressing future availability of energy and water resources will be critical for meeting future demands of a growing global population, the need to address the issue of limited phosphorus availability is at least as serious, and not yet widely recognized. Awareness and management of environmental challenges related to phosphorus have typically been associated with water pollution and eutrophication. Today we are on the brink of a new global understanding: global phosphorus scarcity and the serious threat it poses to future food production (Cordell, Drangert & White, 2009).

Phosphorus (P), together with Nitrogen (N) and Potassium (K), is a critical element for plant and animal growth, and therefore food production. There is no substitute for phosphorus in food production and it cannot be manufactured, hence its significance to humanity (Cordell et al, 2009a).

Historically, crop production relied on natural levels of soil phosphorus with the addition of organic matter like manure and in parts of Asia, human excreta ('night soil') (Mårald, 1998). To keep up with rapid population growth and food demand in the 20th century, concentrated mineral sources of phosphorus were discovered in guano and phosphate rock and applied extensively (Brink 1977; Smil 2000). Chemical fertilizers (containing N,P,K) contributed to feeding billions by boosting crop yields between 1950-2000 (IFPRI, 2002). Additions of phosphorus fertilizer are essential for maintaining high crop yields and replenishing soil with what is taken away by harvested crops, especially in agricultural systems with naturally phosphorus deficient soils. Modern agriculture today is dependent on fertilizers derived from phosphate rock: around 170 million tonnes of phosphate rock are mined and traded each year (containing around 23 million tonnes elemental P), 90% of which is used for the production of phosphate fertilizers (and to a lesser extent animal feed and food additives).

Yet phosphate rock, like oil, is a non-renewable resource and approximately 50-100 years remain of current known reserves. Further, a peak in global production – peak phosphorus – is estimated to occur by 2035 (Cordell, Drangert & White, 2009). After the peak, supply will decrease year upon year, constrained by economic and energy costs, despite rising demand. While the exact timing of the peak may be disputed, there is general consensus among industry and scientists that the quality of remaining reserves is declining and that cheap fertilizers will become a thing of the past in the long term (IFA, 2006; Smil, 2002; Stewart, Hammond & Kauwenbergh, 2005). Increasing energy and other resources are required to mine, process and extract the same nutrient value from phosphate rock.

While all farmers need access to phosphorus fertilizers, just five countries control around 90% of the world's remaining reserves, including China, the US and Morocco (Jasinski, 2009). The period 2007-2008 saw an unprecedented 800% spike in the price of phosphate rock (Minemakers Limited 2008; World Bank 2009) that was unforeseen by most of the world's farmers and policy-makers. China has the largest reported reserves, yet in 2008 it imposed a 135% export tariff on phosphate, effectively banning any exports in order to secure domestic supply for food production (Fertilizer Week 2008). The US is running out of its domestic high-grade reserves and increasingly importing rock from Morocco to process into high analysis fertilizer for sale on the world market. This is geopolitically sensitive as Morocco currently occupies Western Sahara and controls its vast phosphate rock reserves. Trading with Moroccan authorities for Western Sahara's phosphate rock is condemned by the UN, and importing phosphate rock via Morocco has been boycotted by several Scandinavian firms (Corell, 2002; WSRW, 2007). Further, in a carbon-constrained future, shipping millions of tonnes of phosphate rock and fertilizers around the globe may no longer be either appropriate or feasible.

The demand for phosphorus is expected to increase over the long-term due to increasing world population, preferences towards more meat- and dairy-based diets (which demand more phosphorus) in emerging economies, and increasing demand for non-food crops such as biofuel crops. Further, current market demand for phosphorus fertilizers only represents those farmers with sufficient purchasing power. An additional 'silent' demand is also present from poor farmers with phosphorus-deficient soils, particularly in Sub-Saharan Africa (Cordell et al. 2009).

Despite this growing demand coupled with increasing phosphorus scarcity, there are no alternatives to phosphate rock on the market today that could replace it on any significant scale. While small scale operations and trials of phosphorus recovery from excreta and other waste streams exist, commercialization and implementation on a global scale could take decades to develop and significant adjustments to institutional arrangements will be required to support these infrastructural changes (Cordell, Drangert & White, 2009).

However the current use of phosphorus is extremely inefficient: approximately 80% of the phosphorus mined in phosphate rock for food production never actually reaches the food on our forks (Cordell, Drangert & White, 2009). Phosphorus is lost at all key stages of the food production and consumption chain: from mining to fertilizer application, crop uptake and harvest, food processing distribution and consumption by humans and animals. Close to 100% of phosphorus consumed in food is excreted (Jonsson et al., 2004). Human excreta (urine and faeces) are renewable and readily available sources of phosphorus. Urine is essentially sterile and contains plant available nutrients (P,N,K) in the correct ratio. Indeed, the global population generates around 3 million tones of elemental phosphorus in urine and faeces each year which typically ends up in waterways if not intentionally recovered (Cordell, Drangert & White, 2009). Given half the world's population lives in urban centres and urbanization is set to increase, cities are becoming phosphorus 'hotspots'. This means there is a substantial opportunity to consider localized phosphorus recovery. Urine alone represents the largest single source of phosphorus emerging from cities. Recirculating urban nutrients such as urine back to agriculture therefore presents an enormous opportunity for the future (see Figure 2). Further, sourcing phosphorus from more local, renewable sources (such as excreta or food waste) rather than depending on access to an increasingly scarce global commodity can increase communities' phosphorus security and potentially reduce wastage and energy consumption in the food system.

The Role of Niche Based Approaches to Resource Recovery in a Sustainable Phosphorus Future

While incremental system change, such as increasing the efficient use of phosphorus in agriculture is likely to be an important measure, optimizing current practices will alone not be sufficient to secure a sustainable phosphorus future. More fundamental changes will be required that seek to incorporate a range of supply- and demand-side measures, as depicted in Figure 3 (Cordell et al., 2009).

For example, business-as-usual global demand for phosphorus can be substantially reduced through measures that seek to change diets to less meat and dairy (which require more fertilizer per unit of food nutrition), reduce losses in the food chain, and increase efficient use in agricultural and livestock sectors. On the supply side, the water sector is likely to play a critical role, together with the food and other sectors in recovering and reusing phosphorus from the entire food production and consumption system: from excreta to food waste to crop residues.

There are several socio-technical sanitation systems today that support the recovery and re-use of nutrients, from small-scale greywater systems for example, source-separating composting toilets, wetlands for recovering nutrients, to more large-scale high-tech recovery from mixed wastewater streams. If a key objective of nutrient recovery is to *reuse* the nutrients in food production (which is indeed argued in this chapter), then health, environmental and economic costs of the entire system from toilet to field become paramount. Reuse is often safer if sanitation service providers and urban planners avoid infrastructure that mixes human excreta with other wastewater streams such as industrial wastewater which often contain heavy metals and other toxic contaminants (for example through the use of decentralized and distributed sanitation systems). Further, if urine is separated from faecal matter in the toilet, the urine can be safely used through simple storage (WHO, 2006). Urine has the potential to provide half the phosphorus required to fertilize cereal crops (Drangert, 1998; WHO, 2006). While reusing human excreta has been practiced in parts of the world for over 5000 years, Drangert (1998) suggests a 'urine-blindness' has prevented modern societies from tapping into this bountiful source of plant nutrients and thus there is still a need to legitimize the use of human excreta among water authorities in many parts of the world.

In addition to reuse of source-separated urine and faeces, examples of other nutrient recovery and reuse systems ranging from commercial operations to R&D phase include struvite recovery from wastewater treatment plants (Ostara, 2009; Rahamana et al., 2009), use of ash from incinerated sludge (Schipper & Korving 2009), or a combination such as struvite precipitation from source-separated urine (Ganrot, Broberg & Byden, 2009; Tilley et al., 2009). Indeed, Schenk et al. (2009) suggest there are over 30 processes for the recovery of phosphorus from wastewater. While such emerging initiatives are certainly on the increase around the world, they are far from the mainstream and are generally not operating within an overarching coordinated framework or strategy at a broader scale linked specifically to sustainable nutrient recovery, sanitation and food production (Cordell forthcoming). Hence there is still a need to investigate the most appropriate ways of recovering phosphorus in a given context (within a region, country, city) as it is likely that no one social-technical solution will meet all needs. Important criteria for consideration might include life-cycle energy costs, other resource inputs, spatial distribution between nutrient recovery system and end users, farmer's views and preferences regarding the product, effectiveness of the product as a fertilizer and so on.

Implementing (or even trialing in some instances) such demand and supply-side measures are severely hindered by a fragmented institutional setting. For example, there are no policies, regimes or institutions explicitly ensuring long-term accessibility and availability of phosphorus resources for global food security (Cordell forthcoming). Global phosphorus resources are by default governed by the market system, which alone is not sufficient to ensure all farmers have access to sufficient phosphorus resources for food production and ensure environmental protection in both the short and long-term (Cordell forthcoming).

There is a 'lack of fit' (Young, 2002) or mismatch between the phosphorus cycle and the institutional arrangements governing phosphorus resources. There is a noticeable fragmentation between the different sectors that phosphorus flows through in the global food production and consumption system. For example, there is a mismatch between the agricultural sector where phosphorus is typically perceived as a fertilizer commodity and the water and sanitation sector where phosphorus is typically perceived as a pollutant in wastewater (Cordell forthcoming; Cordell, Drangert & White, 2009). Phosphorus scarcity is currently not a priority within any sector and has no institutional home. It is only when the phosphorus cycle is perceived as a whole system which includes connections between entities, that its importance becomes obvious (Cordell, 2008). Similarly, and partly as a consequence of this institutional fragmentation between the sanitation and food sector, urine diversion and reuse systems have no institutional home (Cordell, 2006).

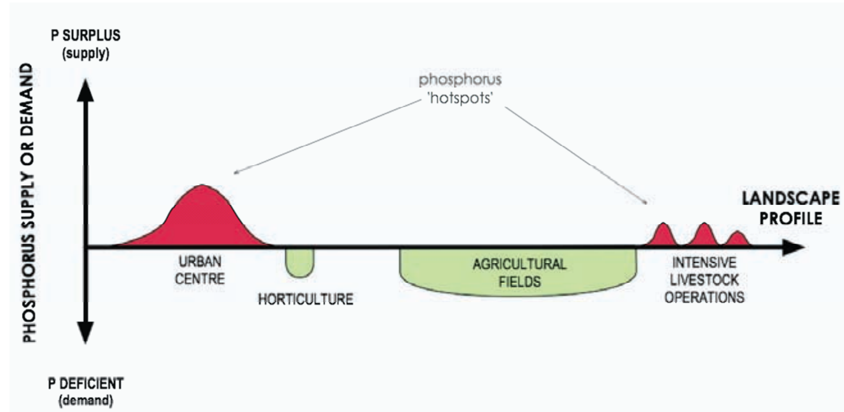

Figure 2: Spatial profile of an urban-rural landscape – indicating that while agricultural and horticultural fields demand continual phosphorus fertilizers, cities are 'phosphorus hotspots' of food waste and human excreta that could be productively utilized to meet some of the fertilizer demand. Source: Cordell, forthcoming.

There have already been significant R&D and piloting of UD systems to recover, recycle and reuse nutrients in urine to land applications. For example twenty years of experiential learning and applied research in Sweden have provided insights into multidimensional challenges and opportunities of transitioning toward small scale nutrient recovery (Johansson et al., 2006).

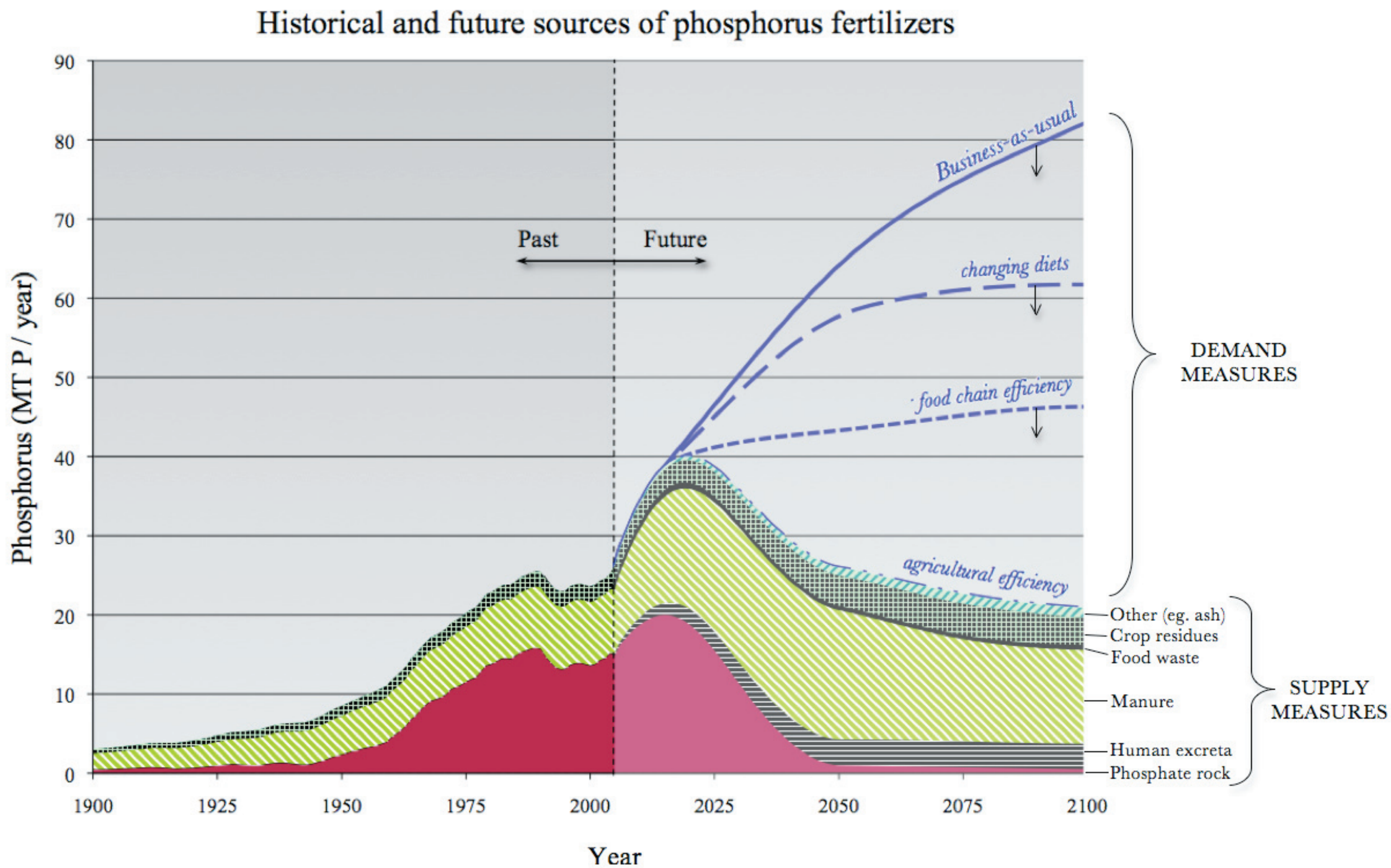

Figure 3: Closing the gap: meeting future global phosphorus demand for food security through a range of ambitious demand and supply-side measures (adapted from Cordell et al, 2009b).

The variable success of UD systems in Sweden highlights the fact that radical innovation cannot be attempted by a simple technological fix but rather requires a radical change in the institutional, technological and social foundations of these systems (Fam et al., 2009; Cordell, 2006), in other words a change in the wider socio-technical setting that structures the behavior and decisions of a broad range of actors involved (Raven, 2007)

In an unprecedented era of global environmental change, it is no longer sufficient or appropriate to take a single-sector approach to complex sustainability challenges. Achieving a sustainable phosphorus situation will require an integrated and collaborative approach to developing new policies, actors and partnerships to support the trialing and implementation of novel socio-technical systems. Proposed sustainability criteria for the goal of phosphorus security addresses social dimensions (such as farmer livelihoods), ecological dimensions (such as soil fertility), economic dimensions (such as cost-effectiveness of recovery systems), environmental dimensions (such as minimizing waste and pollution) (Expanded in (Cordell forthcoming).

Despite the presence of uncertainty and some degree of lack of consensus about the probable future of phosphorus, what is clear is that unless we intentionally change the way we source and use phosphorus, we will end up in a 'hard-landing' situation with increased phosphorus scarcity and phosphorus pollution, further fertilizer price fluctuations and increasing energy consumption. In order to achieve a preferred 'soft-landing' outcome, an integrated and globally coordinated approach to managing phosphorus is required. This is likely to require substantial change in both the physical and institutional infrastructure surrounding the sourcing and supply of phosphorus for food production. Such change cannot be achieved without the involvement of and innovation within the water and sanitation sector.

Conclusion

The water industry is at the start of a period of transformational change. In the coming decades, at least some of our water and sewage infrastructure needs to be restorative, operating in ways that do better no net negative impact. The fundamental characteristics of sewage's key constituents (i.e., water, which is heavy; carbon, which is useful; and nutrients, particularly phosphorus, which is essential) mean that distributed systems, i.e., local scale infrastructure managed centrally, present particular opportunities for transitioning to restorative futures.

While there is no quick fix solution for current dependence on phosphorus fertilisers, there are a number of technologies and policy options that exist at various stages of development – from research to demonstration to implementation, and the water sector has the potential to play an important role in recovering phosphorus from urban wastewater streams.

Meeting these and other pressing challenges in the sector requires significant systemic innovation. Understanding and taking action for systemic innovation requires viewing the issue from multiple perspectives and taking a transdisciplinary approach in creating change. Adopting approaches that are inclusive of stakeholders (broad collaboration), are context dependent (situation/problem based), and support flexible and reflexive approaches to systems change (evolving methodology). Transition management offers some useful insights on how to create such system-wide change.

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Learning Alliances – The SWITCH Approach to Catalyse Change

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Abstract
SWITCH is a five year, action research programme focused on urban water management. "Learning Alliances (LAs)" have been formed in thirteen global cities to implement innovative demonstrations and undertake planning for strategic integrated urban water management. The focus of each city's Learning Alliance has been driven by the critical issues faced as well as the cultural and institutional structure of the city. In this paper the process of establishing the SWITCH Learning Alliances and their evolution over a four year period are described. The paper concludes with lessons learned including: flexible research plans and budgets should be in place to allow uptake of learning alliance recommendations, sufficient resources should be allocated to stakeholder analysis and LA facilitation, researchers should play a backstopping role to city LA members, joint visions should be built early in the process, results should be shared in short cycles and investment in monitoring and evaluation is critical.

Keywords

Learning Alliances, sustainable urban water management, strategic planning, action research

Cities Struggling To Cope

Many cities throughout the world are struggling to manage water effectively, and many more will struggle in the future due to increasing pressures from climate change, population growth and migration, energy shortages and fluctuating economic conditions. Water management, in both developing and developed countries often focuses on today's problems using conventional approaches. Such approaches are often fragmented with components of the various elements of the urban water system being designed and operated in isolation. Short-term solutions to current problems are preferred despite the risk that the implemented measures are not the most cost effective or sustainable in the long-term. The science that underlies decision making also tends to be done in isolation. Interdisciplinary or trans-disciplinary solutions are rarely achieved and systematic solutions that bridge the economic, environmental, social and technical aspects of water management are uncommon.

An increasingly common requirement of agencies funding water management innovation is for researchers to ensure that their work is demand-led and communicated effectively. The underlying rationale is to improve the impact of research on policy and outcomes. Individuals and projects are as a result under pressure to do much more than what was traditionally understood as 'good science'. They are required not only to understand the priorities of potential users, but also to take account of the prevailing institutional context, to undertake research in partnership with implementers and other key stakeholders (e.g. regulatory authorities, civil society agencies, financial institutions, and the private sector) and to communicate results and emerging innovations effectively. However, with little training or experience in these areas, and usually with limited budgets or support, attempts to assess demand and establish and develop alliances with other key stakeholders, are rarely thorough, and even less commonly, well documented. Communication strategies are generally weak, most often focusing on traditional methods to disseminate results towards the end of a project. These limitations, when taken together with the narrow focus of much technical research and the neglect of political context or developmental processes, are increasingly linked to the failure of many water management innovations to have relevant impact (Gyawali *et al.*, 2006).

The concepts underlying complexity science provide researchers and practitioners some of the tools that are needed come to terms with the dynamics and change processes of complex systems. Though initially complexity science focused on physical and biological phenomena, it has gradually started to gain ground in social, economic and political science.

Ramalingam and Jones (2008) distinguish ten key characteristics of complex systems that refer to the system, change, and agents of change. Though it goes beyond the scope of this paper to discuss these key characteristics in detail, the water management systems of large cities display most of these characteristics.

Wicked problems are common in complex systems. Wicked problems can be defined as problems that only can be understood by exploring solutions, and each wicked problem is new and unique. There are no definite solutions and solutions are not right or wrong. Finally, solving wicked problems are one-shot operations as the implementation of a solution will change the problem. Conklin (2006) explains how wicked problems in complex systems often lead to fragmentation. Fragmentation suggests that people consider themselves to separated rather than united and a situation in which knowledge and information is scattered. The fragmentation essentially represents the different views from different stakeholders that all feel that their view is the most correct and their problems are most urgent and need to be addressed on a priority basis.

Switch – Global Action Research To Catalyse Change

It is becoming increasingly clear that traditional science - in which specialists divide complex and wicked problems into small bits and take a linear approach to problem solving - finds it difficult to deal with complexity and to explore solutions for wicked problems. Conklin (2006) argues that the answer to fragmentation – and the start of dealing with complexity and wicked problems – is a creating coherence in terms of understanding the problem and a shared vision.

SWITCH (Sustainable Water Management Improves Tomorrow's Cities Health) is a European Union funded action research program targeted at catalyzing change to a more sustainable and integrated urban water management. The "consortium" comprises the academic and urban planning fields, water utilities and consultants. The network of researchers and practitioners are working directly with stakeholders in 13 global cities (see Figure 1). Testing innovations through demonstrations and related action research and sharing knowledge across a range of different geographical, climatic and socio-cultural settings was expected to contribute to wider adoption and acceleration of more sustainable solutions.

Learning Alliances – A Way to Achieve Comprehensive Solutions

To try and facilitate change towards more sustainable urban water management, 11 of the SWITCH cities have set up "Learning Alliances". Learning Alliances enable scientists and practitioners to come together to work jointly in processes where an increasing and changing understanding of the problems can lead to the emergence of potential solutions (Smits, 2007, Verhagen *et al.,* 2008). Creating coherence and developing joint understanding and a shared vision for a city's water management is what Learning Alliances established by the SWITCH project set out to do.

As well as undertaking original research with a strong technological emphasis, the SWITCH project has encouraged these learning alliances to help set the research agenda, and to put research across different aspects of the urban water cycle into use in cities to help improve integration and scaling-up of impacts (see Table 1). An action research approach where implementing organisations work to test and innovate supported by researchers (Moriarty, 2007) was a key element in the SWITCH project design. The learning alliance methodology that has been adapted for the project is summarised in a series of briefing notes (www.switchurbanwater.eu/learningalliances), and progress made has been documented at various stages in briefing notes and working papers (see for example Butterworth & Morris, 2007; Da Silva, 2007; Butterworth et al., 2008a; Butterworth et al., 2008b; and Sutherland and Darteh, 2008).

The learning alliances are groupings of constituent organisations from a given innovation system that each seeks to effect widespread impact through the adaptation and up-scaling of an innovating approach (Butterworth & Morris, 2007; Smits et al., 2007). The more representative the alliance is, the better it will capture the institutional complexities that constitute the realities of the innovation system. By working on the agreed underlying problems, and contesting and evolving potential solutions together (i.e. working in an action research mode), it was anticipated that mechanisms for addressing institutional constraints and encouraging institutional learning will be generated. The approach in SWITCH was based on the idea that the key challenge to impact is not in devising new technologies but in bringing about appropriate institutional change within the relevant innovation system. The mindset of the SWITCH learning alliances approach is summarized in Table 2.

Learning alliances are about creating new or better innovation systems to build bridges between researchers, implementers and policy makers that often work ineffectually in their corners of the sector. The urban water management 'system' or 'sector' (like many other parts of the water sector) has relatively little inherent ability to adapt or learn, with few organisations willing to take on facilitating roles, and a learning alliance creates mechanisms and a process to facilitate more learning and sharing. The project design (implicitly) envisaged the following four part outline 'theory of change' through which the desired outcomes might be achieved (Butterworth et al., 2008):

1. *Setting:* A research consortium of 33 partners linked to13 major cities where water management is an important issue. City learning alliances provide a structure for city level stakeholder engagement and institutional learning, while a project-level learning alliance provides a structure for more global learning.

2. *Actions:*

- Resources made available to support demand-assessment by researchers.
- Joint visioning and problem solving to address institutional constraints and encourage institutional learning.
- Researchers develop alliances with other actors.
- Attempts to establish demand and develop alliances are monitored and documented.
- A communication strategy developed and deployed early on in the project.

3. *People:* Researchers (national and international) link with city service providers, city planners, regulatory agencies, private companies, environmental groups and NGOs, community groups and user associations, consultants etc.

4. *Outcomes:*

- Researchers understand the priorities of local users and take account of the prevailing institutional and political context in their design.
- Researchers undertake research in partnership with implementers and other key stakeholders,
- Research results are communicated appropriately and on time.
- Learning alliances become networked learning organisations.
- Research is used by local actors to improve water management in cities.
- Results are scaled up and have impact beyond the focus cities.

Learning alliances should ideally be formed from connected stakeholder

Figure 1. SWITCH Cities

platforms at the different levels of administration (e.g. national, city, neighborhood). Their structure and activities ought to build on existing formal and informal networks and be designed to optimize relationships, breaking down barriers to both horizontal (i.e. across platforms), and vertical (i.e. between platforms) learning. Alliance members should share (or come to share) a common desire to address an underlying problem, for example, to improve urban water management. They should also be willing to share or develop common approaches – visions, strategies and tools – on how this can be achieved. Each platform groups together a range of stakeholders who capture diversity and bring together complementary skills and experiences.

Typical activities of a Learning Alliance

Some of the typical city activities undertaken by learning alliances have included:

- Meetings: very many and with different purposes but often bilateral meetings focused on developing trust, understanding and gaining buy-in of various key stakeholders
- Workshops on various topics such as specific technologies or approaches (like sustainable urban drainage) that may be relevant and interesting, visioning and scenario-based joint planning and strategy development
- Training aiming to build awareness and skills of best practice of city practitioners (in subjects like demand management)
- Facilitating communications on the activities of SWITCH and other related actors in the city e.g. using e-mail groups and newsletters (printed or electronic)
- Needs assessment and expressing demand for research or other interventions based on a shared understanding of real underlying local problems
- Design of pilot demonstration projects (in local partnerships) to test new technologies and approaches
- Awareness raising activities e.g. engagement of local mass media, school art competitions, and joining other city initiatives
- Arranging visits to other cities and key sector events such as the World Water Forum
- Process documentation: documenting what happens but also why things happen (or don't)

Classical approach	The approach SWITCH strives towards
Technology-driven	Problem-driven
Top-down/ externally-driven processes	Processes driven by stakeholders/users
Priorities identified by researchers	Priorities identified by users
Single issue/ sectoral activities	Multiple issue activities/ integrated urban water management
Blue-print/ one size fits all solutions	Action research/ learning by doing/ experiments
Result: Incremental change	**Result:** System change (paradigm shift?)

Table 1. SWITCH approach: Doing research to have influence

Allocating Adequate Funding For Stakeholder

Planners	Searchers
Announce good intentions but don't motivate people to carry them out	Find things that work and create right incentives
Raise expectations but take no responsibility for meeting goals	Accept responsibility for actions
Determine what to supply	Find out what is in demand
Apply global blueprints	Adapt to local conditions
Lack knowledge at the top of the bottom	Find out what is the reality of the bottom
Never hear whether the planned (city) got what they needed	Find out if the customer (city) is satisfied
Think that they know the answers	Admits they don't know the answers in advance
See problems in linear mainly technical terms	See problems as a complicated tangle of political, social, historical, institutional and technological factors and finds answers to problems by trial and experimentation
Believes that outsiders know enough to impose solutions	Believes that only insiders have enough knowledge to find solutions, and most solutions must be homegrown

Source: Adapted from Easterley (2006) with original focus on aid approaches

Table 2. SWITCH approach: the learning alliance mindset (searchers)

Engagement

In analyzing the effectiveness of SWITCH city learning alliances, it is obviously important to link outcomes to the levels of investment that have been made. Multi-stakeholder processes are known to be time and resource intensive while expectations are often high and budgets low. The currently budgeted costs for the SWITCH learning alliance activities are about 6.5% of the total budget (€1.6 million) including matching partner contributions. Approximately €690,000 or 42% of this budget was spent in years 1 and 2 of the project. A little under half (again 42%) of that expenditure was at city level (linked to 9 cities) and about 58% was related to the supporting activities (management, methodological development, guideline development, provision of five training courses, research/documentation and city backstopping) of two support partners (IRC and GUEL). The expenditure at city level[1] averaged about €33,000 per city including costs of staff involved in facilitation, workshops, documentation, communication, training participation and other activities. In practice most of this city level expenditure was during year 2 of the project, and some cities took until year 3 to get learning alliances underway and to effectively utilize available budgets.

In the original project budget, the costs of SWITCH learning alliance platforms were not fully included. The assumption was that city level processes did not require funding to cover facilitation and operational costs, or that such funding could be securely locally in cities. This assumption proved to be incorrect. The emphasis in SWITCH is on integration across the water cycle. As this is a new topic in most SWITCH cities there is no clear entity responsible for leading this work. Also, the value of integration needs to be proven before organisations are willing to invest in further development of joint initiatives. After the end of the first year, budgets for the recruitment of city learning alliance facilitators and operating costs were approved. Subsequently the project has invested heavily in supporting learning alliances with funds switched from research and other activities towards supporting the processes. During the first project year, city learning alliances were only marginally operational. The long-term future of Learning Alliances in SWITCH cities is unclear. Coordinators are investigating longer term funding possibilities to continue the Learning Alliances after SWITCH project support ceases.

Moving The Discussion From A Short Term To Long Term View

Although there are defined methods for creating Learning Alliances the evolution of Learning Alliances in each SWITCH city has depended heavily on the character of the city and the critical issues it faces such as flooding, water scarcity, pollution of waterways, and improvements to livelihoods and health/safety of city residents.

A common problem in following a learning alliance approach is that in the early stages of a project or programme the activities are seen as too vague, and it is not sufficiently clear what they will do and why they need funding (this was also the case within SWITCH). This is a familiar characteristic of demand-led processes which seek to include and involve representatives from such diverse stakeholder groups. The agenda cannot be set from the beginning and funds cannot (or should not) be committed to a set of tasks that the alliance did not formulate or at least adapt. However, it is vital that learning alliances identify objectives, quickly start some joint activities, and monitor their progress against set objectives. To focus the Learning Alliances, projects that demonstrated innovative technologies were developed for each city.

Early on it became obvious that a neutral focus was needed to move the cities from current, often politically fraught issues to a more long-term and comprehensive systems approach to water management. Scenarios, strategic planning and sustainability indicators were introduced as ways for different groups within the city to integrate their efforts across time, institutions and urban systems. Visioning, scenario development and strategic planning are now underway in most SWITCH cities. These initiatives have had varying degrees of success. Imagining the future has proved a challenge for most cities and visions have tended to be very broad and ambitious (See Table 3)

Evolution of SWITCH Cities

There is strong evidence that in most cities SWITCH is engaging users of research in non-traditional and more effective ways leading to more potential for impact. SWITCH (just past its mid-point) appears to have made progress on the key issue of getting research into wider use with the intention of securing greater impacts. Each SWITCH city's activities and learning alliance have evolved in its own opportunistic way. The section which follows groups the cities into pathways that focus on objectives such as "Living with Water", "Improving Livelihoods", "Addressing Water Scarcity" and "Improving the Rivers". This is an arbitrary grouping by the authors for purposes of discussion but in reality each city has multiple dimensions and could be grouped in many ways including by climate type, institutional structure and economic situation.

Living with Water

Some SWITCH cities have focused on making water an amenity and part of the urban form.

Lodz, Poland, is the 2nd biggest city in Poland with 800,000 inhabitants. It is also on of the best examples of the difference that a learning alliance can make. In Lodz, the SWITCH focus has been on restoring and making accessible the 18 small streams that have been buried under the city. Most of these urban streams were channelised and converted to combined sewage and stormwater systems in the early 20th century. Lodz's focus was influenced by the learning alliance coordination group and its close association with the UNESCO Centre for Eco-hydrology. Channelisation of streams had created flooding issues and severely affected the aquatic ecosystems. The SWITCH demonstration project involved restoration of a section of one of the city's streams. Work on the stream began with water balance and pollutant studies and construction of small reservoirs and a bio-filtration system. The initial learning alliance was expanded over time with new members and new activities including society representatives from the arts community and media and the private sector including developers. This allowed the demonstration and the underlying ideas to be expanded to new areas (See Figure 2). Developers in particular have recognised the value of the economic and aesthetic value of these systems for their new development areas.

The Lodz Learning Alliance has become a vehicle for up-scaling in other areas of the city by both the city management and private investors. The most evident is the embracing of the Blue-Green network concept which has been accepted by city management as the basis for the sustainable development of the city. The symbolism of the network is connected to the art nouveau character of the city. In 2008, the Learning Alliance expanded its focus from river restoration and storm water management to strategic planning for the urban water cycle. They adopted a vision and created potential future scenarios.

Theses example from the city of Lodz in Poland (Box 1 and 2) illustrate some of the interactions and spin-off activities and impacts that the learning alliance approach can generate.

Belo Horizonte, Brazil, has a long history of community engagement and participatory budgeting at the local level. As flooding is a major issue in the City the Learning Alliance has used innovations in storm water management and local demonstrations as their starting point for action.. Participation in a city-wide Learning Alliance has proved difficult. Water supply and sanitation are not major issues (or at least not urgent issues) making it hard to move to an integrated water management approach. However, in the last year there has been movement towards a wider understanding. Activities such as having the SWITCH annual scientific meeting in Belo Horizonte enabled wider participation from local organisations and exposure to SWITCH ideas and other SWITCH cities. This has helped to raise awareness of the benefits of joint planning.

The Birmingham, United Kingdom, Learning Alliance is very traditional and primarily built out of existing groups who have been involved in water management for a long time. A primary issue in Birmingham is stormwater and this has resulted in green/brown roofs being the SWITCH demonstration focus in this city. Interestingly the brown roof demos were originally designed for bio-diversity benefits. The water aspect and research was an add-on and expansion to an existing project. Although the Learning Alliance in Birmingham has functioned well as a knowledge exchange network it has had difficulty having a real impact with regard to strategic and integrated urban

STRATEGIC PLANNING: CITY VISIONS AND INDICATORS

Vision excerpts	Example indicators
HAMBURG 'Make water visible' is the new motto of the river island of Wilhelmsburg in the year 2030. The various water bodies on Wilhelmsburg are visible and accessible, serving as attractive locations for the purpose of recreation, living and work.	* Water as urban design element * Water quality * Water and nature conservation * Protection from floods * Awareness among citizens
ACCRA **Every household a metered connection with water flowing 24 hours a day, 7 days a week.* ** 10-15% physical losses and zero commercial losses in Ghana Water Co. Ltd operations.* **Accra would see waste as a resource) and make use of it.*	* Level of public health * Access to water & sanitation * Cost recovery * Water quality * Recycling * Waste management * Awareness levels
ALEXANDRIA We envision a proud water city where available water resources are managed in an integrated manner, with the participation of all citizens, and are used effectively for development within a framework of environmental sustainability,	* State of the aquatic environment (coastal zones and water bodies e.g. lake Maryout) *Extent of network renewal / upgrading *Extent of separation of sanitation and (agricultural and rainwater) drainage networks
LODZ The city's resources management is based on an efficient and integrated system ensuring access to information for all. Investors and authorities respect ecological properties of land and waters. Infrastructure serves the functions and requirements of an environmentally secure city, is reliable, meets the needs of all the city's population and assures good status of aquatic ecosystems.	In Lodz indicators are still being selected.
TEL AVIV Integrated future water management in Tel-Aviv city, to ensure safe drinking water and safe water, for other applications in the city Establishment of UWM based on sustainability indicators	In Tel Aviv discussions are on-going with the municipality to add a set of water-related indicators to the exisitng set of sustainability indicators in use by the municipality for monitoring the cities progress towards its vision.
BIRMINGHAM Birmingham provides localised treatment of astewater coming from all new developments to treat wastewater at source using more natural methods to purify and re-use water for urban landscaping and agriculture (parks, allotments, etc).	The extent to which: * local storage of rain water for non-potable uses is implemented. * the option for dual potable/non-potable water supplies. * prices are higher in summer (for water used over 100 litres per person) to encourage householders to harvest/store rainwater for use in the garden. * all "hard" external surfaces are either porous or used to capture rainfall for re-use or to soak-aways, etc.
CALI BELO HORIZONTE	These cities are starting the process
BEIJING ZARAGOZA	These cities focus on upscaling of innovations rather than strategic planning

An iterative process of global info to cities – local relevance feed back

GENERAL SWITCH VISION: SUSTAINABILITY OBJECTIVES & INDICATORS

Potential indicators	SWITCH Sustainability Objectives
# of awareness raising activities # public meetings on water where citizens and NGOs involved	Citizens aware of water and sustainability and involved in decision making
# docs that follow SWITCH strategic approach to planning	Integration of water system is realised
# of decisions where sustainability was used in decision making	Sustainability indicators used for planning
Investments in research on UWM	Science is basis for decisions
% of citizens that spent more than X% of their income on water	Access to water is equitable
Non-renewable energy consumed GHG emissions	Energy use and greenhouse gas emissions are minimised
	Water supply
Total water demand Availability of renewable fresh water	Sufficient supplies of good quality water
Investment in WDM as % of total budget	Priority to demand management
	Sanitation
% of population with sanitation	All citizens have access to proper sanitation
Investment in pollution prevention measures as % of total budget	Priority to pollution prevention
Understanding of carrying capacity % of nutrients recycled	Do not exceed carrying capacity of natural systems
	Natural systems & Stormwater
Investment in eco-hydrology	Encourage use of natural systems
Decrease in damage costs due to floods Decrease in health impacts/loss of life due to floods	Flooding at acceptable levels and adaptable to climate
% of waters meeting EU Framework and Groundwater directives	Protect and enhance receiving water quality
% of people valuing water bodies for amenity value	Source control of stormwater
% of total demand satisfied by local sources	Rainwater/stormwater harvested locally
Water runoff mimics pre-development flows	Establish a natural water balance

END PRODUCT

- An agreed city-specific vision and set of indicators in most demonstration cities; inspired by the general SWITCH Sustainability Vision for UWM and the SWITCH indicators.
- A general SWITCH vision and set of indicators, formulated based on the real situation in the demonstration cities and therefore fit for application in most European and global cities.

Table 3: City visions, objectives and indicators

water management planning. This could be due to the plethora of existing plans and activities underway and the strong structure of existing institutions making them especially resistant to change.

Chongqing, China has focused its SWITCH demonstration work on aesthetic use of greywater for ornamental ponds. The Chinese ability to innovate is heavily influenced by the Central Government's five year plans. The Government is currently implementing the 11th 5-year plan from 2006-2010. (http://www.gov.cn/english/special). A strong central focus with goals and targets (i.e. 70% of wastewater treated, 100 million provided safe water, etc.) can create a positive environment for innovation. In China, the 5 Year Plan has caused a heavy push for increased local rainwater collection and effluent recycling schemes. Successful demonstrations can be rapidly up-scaled to have high impact. However, from a Learning Alliance perspective it is unlikely that city-wide, strategic, integrated urban water management planning can be accomplished under SWITCH. In SWITCH's Chinese cities (Beijing and Chongqing) learning alliances have functioned more as knowledge-exchange networks.

Hamburg, Germany, decided that instead of focusing on the entire city they would limit their activities to Wilhemsburg Island. This river island is the 2nd largest in Europe. The city has a vision called "Leap across the Elbe" to develop this area in a water sensitive way. To progress, the Learning Alliance has focused on "strategic directions" for integrated urban water management for the island. Focusing on strategic directions instead of a full-blown plan has allowed brainstorming and more open discussion of potential solutions and prevented territorial disputes that can sometimes arise in a strategic planning exercise. Unfortunately delays in the schedule of the International Building Exhibition have meant that the physical demonstration on the island could not go ahead.

Improving Livelihoods

Demonstrations in Lima, Accra and Beijing have taken forward the idea of peri-urban and urban agriculture as a means to alleviate poverty, use wastewater productively and improve the liveability of the city. Each project has a strong focus on including socially marginalised communities. Although the focus is similar in each city the climatic and institutional situation is extremely different.

It virtually never rains in Lima, Peru, a fact that limits the water supply options available to the city. The Learning Alliance in Lima was built from a local platform in collaboration with one of the impoverished communities. It's focus was on community improvement of a local site for multiple uses (football field, playground, landscape plant production, etc.). SWITCH helped with providing access to recycled water to green the site and to allow production of landscape plants for sale by the local community back to the City government. The formation of the Lima Learning Alliance has raised awareness of the need for and advantages of recycling and has provided a vehicle for water recycling to be included as a basic principle and action in the National Water Law.

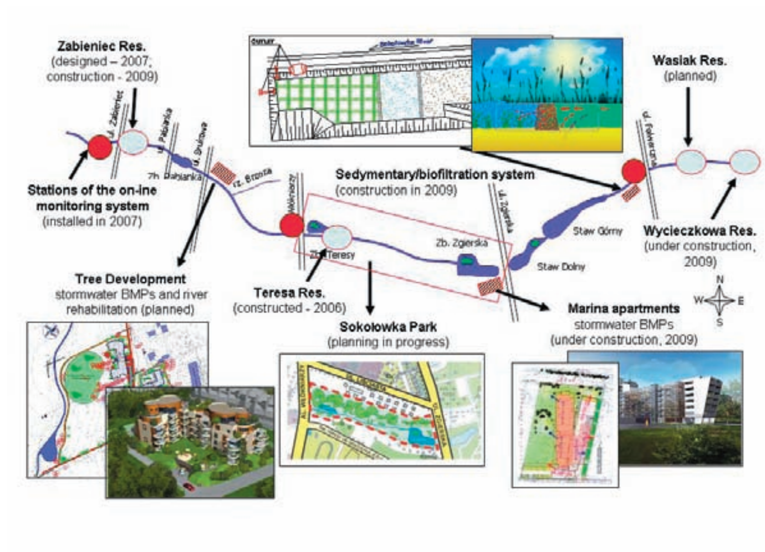

Figure 2. SWITCH demo activities in Lodz

Box 1. Andrzej Czapla is an engineer in middle management at the Łódź wastewater treatment plant

Many organisations are involved in water and wastewater management in Łódź and it is institutionally complex, says Andrzej Czapla. This is where he sees the SWITCH supported learning alliance having an important role: he says it was the first attempt to improve communication between the different organisations and to provide a cross-institutional platform to share information and discuss water and sanitation issues. Andrzej mentioned that through the learning alliance he first met some people that he only knew by name before. He went on to say that SWITCH is giving an overall picture of how everything is working together in the city and is addressing the issues in an integrated way. This is needed by the individual organisations that themselves only work on a small part of the system. He says that the learning alliance has enabled the participants to 'send signals' about key issues to the city authorities, and to 'open the eyes' of people to areas that are beyond the scope of their own jobs.

Andrzej says that he or his colleague have attended all of the 5 or 6 learning alliance meetings held to date. These meetings take a large amount of his time and for him that is scarce: sometimes the whole day. But it is worth it, he says. He was happy to be involved in the development of the SWITCH programme and is looking forward to the results it will generate. In fact, he would now like to see a higher intensity of meetings and events including smaller workgroups to take up specific issues. It has also been useful to learn from other cities and countries on how similar problems have been tackled like creating retention to deal with flood flows, and he cites the example of Birmingham from SWITCH as well as similar learning opportunities he has had from Krakow through the Polish Association of Water and Sewerage Operators, visits to Germany and contacts with the International Water Association. He has particularly encouraged the SWITCH learning alliance to address stormwater management issues since 50% of the city has combined stormwater sewers, and the plant struggles to cope with peak flows of highly diluted sewage. He mentionned this as an example of an issue to be picked up, recognizing that SWITCH and the learning alliance are only at the beginning of their journey.

Source: Butterworth et al. (2008d)

Box 2. Integrating water and environmental issues with overall city re-development initiatives

The revitalization of the city of Łódź has provided an excellent entry point for linking IUWM and SWITCH to wider processes of city development. Through involvement of the learning alliance facilitator, water and environment were brought into the agenda 'integrated city revitalisation' through a stronger focus on revitalizing Łódź its 18 rivers and improving the quality of the water system in the city. In 2006, the European Regional Centre for Ecohydrology presented itself (as the local coordinators of the project and learning alliance) and the SWITCH project at the Łódź 2023 conference, part of a series on city regeneration (www.vision-Łódź-2023.info). With over 100 participants, this conference brought together a diverse audience including city decision makers, developers, planners, architects, banks, private developers, heads of universities, journalists and 'creatives'. This shows how SWITCH can be effective by linking to existing events and initiatives or networks in the city.

In April 2008, the links between water and city redevelopment were further strengthened as a full session at the latest conference was dedicated to urban water and SWITCH. During this session the deputy mayor expressed the importance of recognizing water and green resources as key in the city's redevelopment. This showed how building relations with him over the course of the project is paying off. Several newspaper articles made mention of the conference and referred specifically to the importance of water for Łódź development. Media interest has continued since then and one of the results has been that the Tree Development Group (a development group) approached ERCE for information on how they can improve the river fronting one of their development areas.

Source: Butterworth et al. (2008d)

In Accra, Ghana, the demonstration has expanded to a systems approach to solution solving. Toilet blocks in one of the city's slum areas are being designed to collect urine which will be transported to peri-urban farmers as a lower-cost fertilizer. It is hoped that economics of the system will allow it to be self-supporting and replicable. On the wider city-scale the Learning Alliance in Accra has been very active at undertaking strategic planning across the water cycle. There is wide stakeholder participation in the process.

Beijing, China, has a water scarcity problem which leads to allocation issues between agriculture and urban users. There are many peri-urban farmers on the fringe of the city and their continued viability is important to the overall sustainability of the city. In Beijing, SWITCH is working with the Huairou Fruit & Vegetable Cooperative to capture and reuse rainwater for uses including crop production but also recreation (farm holiday ventures, fishing, etc).

Addressing Water Scarcity

Tel Aviv, Alexandra and Zaragoza have focused their activities on water scarcity. Tel Aviv, Israel's demonstration has looked at improving the quality of effluent for irrigation using soil aquifer treatment and nano-filtration. Alexandria, Egypt, is looking at water loss and demand management in informal settlements and Zaragoza, Spain is investigating water loss in the pipe network and water conservation education.

Strategic planning in Tel Aviv for urban planning has been going on extensively for the last few years including a process of visioning and sustainability indicators. However, when the SWITCH Learning Alliance engaged with city planners it was discovered that no sustainability indicators had been developed for water. Rather than create a separate plan it was decided to join the two activities by adding a water component to the urban plan.

In Alexandria, strategic planning has been undertaken in a more traditional way. The intent is to use Alexandria as an example for Egypt of how integrated water resource management plans can be applied at city levels through integrated urban water management plans. Extensive stakeholder engagement and technical studies are being done to support the planning process.

Zaragoza, has an established "Water Commission" that provides the communication network on water issues. Because of this existing structure, the cities strong focus on demand management and the logistics of hosting EXPO 08 which focussed on "Sustainable Water Management" and other major water events it has not been realistic to progress a Learning Alliance in this city.

Improving the Rivers

In Colombia both Cali and Bogota face major problems with pollution of their waterways. The pollution affects drinking water quality as well as the health, safety and livability of the city. The focus of both cities is on improving the quality of their waterways. The Learning Alliance in Cali is addressing more sustainable ways of developing expansion areas of the City. In Bogota the focus is on conflict resolution between small (and poor) tannery industries that pollute the Bogota River and the Environment Agency and Government.

Assessing Effectiveness Of The Learning Alliances

Mid-way into the project, a series of progress assessments were undertaken in eight of the SWITCH focus cities (Butterworth et al., 2008). These assessments aimed to draw lessons and make recommendations that would contribute to learning and to help inform the implementation of the remainder of the project. They also inform the lessons learned section of this paper. In this assessment, skilled professionals with strong analytical and documentation skills were asked to work on a joint assessment with key city staff involved in SWITCH implementation (the city coordinator and learning alliance facilitator). In some cases, these were persons with a research interest in institutional change processes in water management. In other cases, the reviewers were learning alliance facilitators and SWITCH researchers from another city. Such a joint assessment of the SWITCH supported change process required a capability to both work with a city team but also to sometimes stand outside that city process and to ask critical questions. Outsiders can best do the latter, and hopefully also bring in some fresh thinking to take a new look at exciting ideas that may at times become rather static and hidden within conventional research project plans and reporting.

The scope of the facilitated progress analysis included all SWITCH supported research, demonstration, training, learning alliance and other activities within the cities. Each assessment was based upon semi-structured interviews with three target groups: 1) research providers ('scientists'), 2) facilitators and research managers (including the learning alliance facilitator and city coordinator) and 3) research users: key organisations expected to utilize the research findings to improve urban water management within each city. The reviews were rapid, being undertaken during a visit of one week and with a target of about 12 in-depth interviews in each city. Interviews were guided by a generic checklist of questions but were adapted in all cases. In total, about 95 persons were interviewed during the assessment with about half being research users and one quarter each classed as researchers and facilitators/research managers

Although it was originally planned as a regular activity, prior to this study all SWITCH cities had struggled to complete any reflective and analytical process documentation that could contribute to project learning and planning. The individual draft city papers are available at http://www.switchurbanwater.eu/page/2853. A summary of the results of this assessment can be found in Table 4.

Lessons learned

The lessons that follow summarise some of the key experiences of SWITCH in trying to implement action research within a stakeholder engagement approach:

Develop a representative project management structure: it is important to involve legitimate representation of cities and learning alliances (as research users) within your project management structure including involvement in budget allocation and decision-making.

Ensure clear research priority setting processes: there should be a transparent mechanism for the process of priority identification by learning alliances, approval of learning alliance recommendations, research team formation, action planning and budgeting with communication back to the learning alliance at all steps.

Leave some flexibility in resource allocation: It is important not to allocate all your resources on day 1 of the project, and not to allocate all resources to research that is not linked to clearly expressed learning alliance needs. A mix is usually best where some funds are allocated to research identified by the learning alliances (throughout the course of the project), and some to more researcher-led topics (may from the outset or later, and may be to less action-orientated research). Learning alliances should also have some (even very limited) amount of flexible funding that is untied and can be used to address local needs as they emerge including additional research topics, additional documentation or communication activities etc.

Understand stakeholders: Stakeholder analysis needs to be undertaken thoroughly with sufficient resources allocated to the task. This activity should be supported by a specialist with experience of institutional issues, and despite the temptation, you should not continue with (very pressing and exciting) project activities until stakeholder analysis is completed.

Use the capacity of facilitators: It is necessary to avoid overloading facilitators who play a key role in so many interactions, but it also important to avoid setting up a structure where facilitators don't have enough to do and are waiting for the next team of expatriate researchers to arrive, limiting the role to working as logistics managers or translators. Encourage facilitators to become research managers and action researchers themselves.

Build mixed action research teams: action research should be undertaken by teams selected and composed of learning alliance members: research by implementers supported by researchers. Traditional 'researchers' then take a backstopping role playing key roles in planning, methodological development, training and supporting documentation. 'Researchers' often need a lot of support in adapting to this new but potentially challenging and rewarding role.

Build joint visions: Visioning (and in some SWITCH cases leading to

City	Focus of learning alliance process/ scale	Strengths	Weaknesses	Opportunities	Threats
Accra	Broad, learning focused group engaging middle level professionals across sector organisations and civil society with sub-groups on strategic planning, urban agriculture, and sanitation	• Strong facilitator also engaged in PhD research on the SWITCH process in the city • A broad range of SWITCH supported research on strategic planning, urban agriculture, sanitation and social inclusion • SWITCH has achieved good visibility within some key institutions • Have received significant backstopping support from IRC and NRI	• Difficulties in realising demonstration activities to date due to need to find 65% matching funds • Strongest demonstration activity in urban agriculture (linked to sanitation and social inclusion), but this is hardly linked to learning alliance • Lack of seed money for initiatives identified by the learning alliance (no funds for local activities) • Difficult to engage municipality effectively	• New SWITCH office in Accra sharing space with related initiatives and similar learning alliance/ action research processes	• Loss of continuity and staff through gaps in learning alliance funding
Alexandria	An integrated urban water management planning process for the city of Alexandria	• Planning focus provides clear pathway for potential lasting impact • Link to demonstration activities in slums with a strong social inclusion component • Extremely high level engagement in learning alliance and political support	• Unbudgeted senior facilitation support in Alexandria and tasks between workshops towards plan that are likely to be crucial to success • Lack of a framework for an integrated planning process • Engagement of facilitators in city and low intensity of process between workshops (distance to Cairo)	• To develop a framework for strategic IUWM planning that has potential to be utilised in Alexandria and other Egyptian cities	• Long delays likely to lead to loss of momentum, and reduction in support for SWITCH learning alliance
Belo Horizonte	Local scale (schools, parks etc) demonstration projects on stormwater management, and city level platform focused on institutional issues	• Builds on ongoing processes/ paradigm shifts with both technical/ environmental (urban drainage) and institutional (more democratic decision making) elements • Municipality is actively engaged as a partner facilitating real-scale demonstrations, and University is providing quality monitoring and research (strong partnership)	• Learning alliance at city level has been more difficult to progress, with less involvement of key organisations outside the municipality • Documentation, analysis and communication • Research is multi- rather than interdisciplinary (covering many aspects but requires more integration)	• To increase intensity of sharing of progress and results e.g. monthly SWITCH seminars (especially between disciplines/ aspects) • To build learning alliance platforms at sub-catchment scale • Potential for SWITCH to link into other existing platforms at city level (to institutionalise learning alliance) • To strengthen governance research with an action research (learning alliance) element	• Limited support from the international consortium on learning alliance process issues • Delays related to internal (municipal) administration procedures • Language barrier and relative isolation

Table 4. Summary of some key characteristics of SWITCH learning alliance processes in focus cities

City	Focus of learning alliance process/ scale	Strengths	Weaknesses	Opportunities	Threats
				• Potential to influence other cities in Brasil through city networking activities	
Birmingham	Scaling up technological innovations and their application within regeneration schemes	• Builds upon existing linkages between organisations • Strong host (ARUP) and facilitation • Momentum is being gradually built up, and facilitation capacities have been increased	• Limited facilitation capacities during first 2 years	• To increase the intensity of the learning alliance process • A potential Young SWITCH and educational opportunities for the project	• Too high expectations. Many of the real benefits are likely to come after the project ends
Cali	Learning alliance subgroups around 3 specific problems requiring integrated approaches (water quality of Cauca river and impacts on supply, drainage and wastewater in southern Cali and southern expansion of the city)	• Experience of Cinara (host) in facilitating learning alliance type processes • External researchers have embraced need for institutional as well as technically focused interventions (and to link these elements) • Momentum has built up and organizations are developing new projects in an environment of trust	• Gap in research on governance in the city which is likely to be key to integrated solutions • Limited involvement to date of trade unions, civil society and communities • Has just benefited from one year of SWITCH funding for learning alliance activities	• New projects are being developed with a lot of learning/demonstration potential • To carefully engage media and increase communication activities as results become available • To strengthen institutional / governance research areas building on existing capacities in Cinara and the SWITCH consortium	• Risk that learning alliance remains a platform for exchange on technical and organisational solutions without attempts to improve decision making and governance processes • Under-resourcing of estimated learning alliance costs in the city • Strong facilitating support from IRC (on project liaison/ language, documentation and learning alliance process issues) will not be possible in 2009/10 under existing budgets
Hamburg	A strategic plan for the river island of Wilhelmsburg	• Linkages to International Building and Horticulture Exhibitions in 2013 which provide opportunities to showcase results	• Capacity of facilitation team (including low utilisation of budget)	• To increase frequency of learning alliance events and activities • Outreach through educational activities with schools	• Water is low on the list of priority issues
Lodz	River restoration across the city to create new urban water environments	• Well advanced demonstrations on river re-engineering (using ecohydrology principles) and sewage sludge utilisation for energy production • Good balance between science and stakeholder engagement • Strong communication activities	• Lack of unallocated funds to respond to new initiatives/ requirements • Insufficient (human) resources for reflective process documentation • Gaps in research on economics/ financing, institutional issues and social inclusion	• Now is the right time to intensify learning alliance activities • Huge interest for city to engaged in cross-city learning • Opportunity to continue strategic planning process which captured interest of learning alliance	• Risks of losing key staff that probably could be effectively replaced • Difficulties in securing funding for facilitating and learning types activities. Value of integration is not recognised
Tel Aviv	Water club at city level focused on exposing stakeholders to advanced technological developments	• String applied focus of research effort linking to demonstrations • Links established to key organisations	• Learning alliance process is of low intensity • Insufficient capacities to complete routine tasks (stakeholder analysis, reporting, monitoring, website etc.)	• To influence city strategic planning through inclusion of water related targets/ indicators	• Significant additional local capacity and external support likely to be required to realise potential of learning alliance in the city

scenario-based joint and strategic planning) exercises provides a useful mechanism to help develop the objectives of learning alliances and to move stakeholders from current issues to longer term plans.

Allow each city to follow its own path: Each city will focus first on issues it is familiar with and that are perceived to need immediate action. Strategic planning, visioning and scenario planning can help but it is important to be flexible in adapting the process to various starting points and building gradually into a more holistic framework. .

Sharing results in short cycles: Learning alliances will often require non-traditional scientific outputs (e.g. not only journal papers) and will require more frequent and regular sharing and discussion of results. Rapid and short cycles of action research and feedback are more desirable and more likely to lead to uptake than just sharing results at the end of a project. Providing appropriate and timely outputs for learning alliance members does introduce challenges for peer review and quality control, but can be compatible with also producing those precious scientific papers that researchers are often rewarded for by their institutions.

Invest in monitoring and evaluation (M&E) including process documentation: Better M&E and process documentation that builds on tested methods for monitoring and demonstrating impact of multi-stakeholder processes are probably two of the most promising approaches towards more constructive dialogue and engagement with learning alliances. They also provide the potential to demonstrate success where it happens. Although always a good investment, M&E can be costly and is often restricted to looking at the achievement of outputs rather than outcomes. Innovative uses of M&E and process documentation need to be promoted as important activities for all researchers, and more value attached to the different types of products and learning that they will generate. To notice why as well as what changes occur, a process documentation plan is recommended (Schouten, 2007). Process documentation needs specific skills (may require additional people) and consider taking time-out from other activities to focus on reporting (e.g. allocating every sixth month solely to reporting).

Estimate the costs of stakeholder processes realistically: Unfortunately, multi-stakeholder research processes are expensive. The costs of promoting change are high and frequently underestimated. While many partners will readily contribute inputs in kind and their own time, the initial facilitation, training and capacity building inputs needed are considerable. It is difficult to secure additional funding later for such ‘software elements’ and since they are critical and needed at the start of a project especially, they should be fully funded from your main budget. Too often, learning alliances may be included in a project as a means to secure funding for an attractive idea and way of working, without an adequate understanding and commitment (in management, funding etc) to really changing the balance stakeholder engagement in the research process.

On a cautionary note, urban water management was earlier identified as a complex and even wicked issue where conventional research approaches are unlikely to have transformation impacts or result in a paradigm shift. Learning alliances, to be true to their intentions, need to engage a wide range of stakeholders in order to provide a safe space for contestation of truly new solutions and innovation that are not merely technical but also address related institutional change and integration issues. Stakeholder analysis within SWITCH cities was generally not comprehensive enough, and in some cases the more difficult to reach non-traditional research partners e.g. civil society representatives, citizens, politicians, unions have not been included. Within representative learning alliances it is expected to find a broad range of actors with different objectives and ideas on solutions that would at times lead to some conflict. Unless the mix of stakeholders is representative there is always a danger of reinforcing the existing cross-organisation relations within cities rather than forging the potentially conflictive but truly innovative and new ways of collaboration that could lead to new directions.

That said, the SWITCH approach of Learning Alliances coupled with research, demonstrations, and training is proving to be a catalyst for change in a number of SWITCH cities.

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eco-cities: an update

Paper Abstracts

Ecocities: Evaluation and Synthesis

Vladimir Novotny, Eric V. Novotny

This report presents concepts and synthesis of ecocity developments, using Hammarby Sjöstad in Sweden, Dongtan, Tianjin and Qingdao in China, Masdar in the United Arab Emirates and Treasure Island and Sonoma Mountain Village in California as case studies. An ecocity is a city or a part thereof that balances social, economic and environmental factors (triple bottom line) to achieve sustainable development and results in a minimal or no adverse ecological or carbon footprint. With exception of Dongtan, these ecocities are in various stages of development and realization. Dongtan's development has stalled because of political reasons. Tianjin is a joint project of China and Singapore. Two developments, Masdar and Sonoma Mountain Village have applied for One Planet Living (OPL) community certification.

The majority of the investigated ecocities were medium density communities. The concept of cluster development and ecoblocks were introduced and discussed. Dongtan, Qingdao, Masdar and Sonoma Valley designs are proving that ecocities can fulfill the OPL criterion of zero green house gas emissions from infrastructure heating, cooling, electricity consumption and traffic. All cities use the latest technology for in-house water savings such as low flush toilets, showers, etc. Ecocities use surface drainage for collecting urban runoff and clean water inputs and implement extensively best management practices for urban runoff such as pervious pavements for infiltration, capture and storage in underground basins, and reuse for various purposes such as irrigation, fire protection, and plan to tap into their groundwater resources for reclaimed water.

The analysis has revealed some problems with the lack of macroscale measures, models, and indices for some key components of the triple bottom assessment. Several research hypotheses and ecocity concepts were suggested for further research and studying.

Ecocites: Evaluation And Synthesis

Vladimir Novotny
Eric V. Novotny

I. SUSTAINABLE URBAN DEVELOPMENT – OVERVIEW

I.1 General Concepts

The original and most frequently quoted definition of "sustainable development" comes from the Brundtland et al. (1987) report of the World Commission on Environment and Development

"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

The terms "sustainability", "sustainable development" and adherence to their principles is the historical shift from "a maximum economic use model" that perceived resources to be merely raw materials for production and sinks for the disposal of waste, to an optimal model that recognizes the environment as a finite resource needed to be conserved through governmental regulation in order to create a "long – term relationship between the economy and nature" (Dilworth, 2008). However, Mihelcic et al., (2003) pointed out sustainability is not merely a preference for economic development with some environmental protection (an anthropogenic development view) or preserving nature with "green" low impact low imperviousness development (a biocentric view). It is a megascience defined as a design of human and industrial systems to ensure the development and use of natural resources do not lead to diminished quality of life due to either losses in future economic opportunities, or adverse impact on society, human health, and the environment. The time point of reference must be added to these concepts.

It is now generally agreed the present urban water/stormwater/wastewater systems are not sustainable and there is a need to change the paradigm for how to efficiently build and operate cities. Many cities, especially in the developing world, cannot provide an adequate amount of water; also water provided during a few hours in a day is contaminated by cross-connections with sewers due to low pressures and damaged pipelines. Urban pollution is still very high in many cities. China, for example, due to its tremendous economic and environmental unrestricted growth, had in 2006 six out of thirty most polluted cities in the world (Blacksmith Institute, 2007), yet, it needs to build in the next twenty five to thirty years new cities for a population of about 300 million people. Even in developed countries, the urban environmental infrastructure is crumbling and will require massive investments for repairs but no matter how many billions will be spent to rebuild in the old way, cities will not be sustainable and the environmental goals will not be met. Furthermore, urban water supplies are threatened by nutrients resulting from excessive fertilizer applications in intensive agriculture and on suburban lawns (Novotny, 2007). Excessive nutrients in many parts of the world stimulate dense algal blooms of cyanobacteria (blue green algae) exhibited by a pea soup water quality that renders reservoirs and lakes unsuitable for water supply, recreation, and maintenance of balanced aquatic biota (Novotny, 2009). Cyanobacteria prefer warmer conditions; hence, frequency of occurrence of noxious cyanobacteria blooms may increase with global warming.

The current unsustainable situation will be further exacerbated by

- population increases (urban population is expected to increase by 50 % in the next 20-30 years; many new cities will be built in Asia and other parts of the world);
- increasing living standard (more demand on food and, consequently, water resources);
- global warming (increasing sea levels, changes in drought and water availability patterns) (ICPP, 2007)
- emerging new pollutants (endocrine disruptors, pharmaceutical residuals; more frequent massive cyanobacteria bloom outbreaks);
- increasing water scarcity, currently about 0.7 billion people experience true water scarcity, they live on less than 25 litres per person per day which is expected to grow to more than 3 billion of people by 2025 if nothing is done (Zhang, 2007);

- conversion of urban waters into effluent dominated water will require management of the total urban water hydrological cycle and decentralization of urban sewerage;
- increased flooding due to global warming effects, increased imperviousness and other land use changes in the watershed; and
- energy shortages due to less oil,; production of biofuel from corn and other crops increases food prices.

The concepts of the new paradigm of sustainable water centric ecocities have been emerging for the last fifteen years in environmental research and landscape design laboratories in several countries in Europe (Sweden, Germany, United Kingdom), Asia (Singapore, China, Japan and Korea), Australia, USA (Chicago, Portland, Seattle, Philadelphia, San Francisco area) and Canada (British Columbia, Great Lakes area). This paradigm is based on the premise that urban waters are the lifeline of cities and focus of the movement towards more sustainable cities. The evolution of the new paradigm of urbanization is ranging from the microscale "green" buildings, subdivisions or "ecoblocks" to macroscale ecocities and ecologically reengineered urban watersheds, incorporating also transportation, food production and consumption and neighborhood urban living. This expanded concept might lead to "ecoregions", i.e., sustainable regional development that would include urban living spaces and sustainable (organic) suburban agriculture and nature areas. All concepts developed by landscape architects incorporate surface water bodies as a focus and water management. At the same time, environmental engineers and urban planners are developing water/stormwater/wastewater management concepts based on a change from the linear once through water management (minimum reuse) to a closed hydrological cycle system that maximizes reclamation, reuse and recycling. Reduction of green house gas (GHG) emissions has become a major social goal in the last five years. The third component of the ecocities/cities of the future is application of green technologies. Table 1.1 (Valerie Nelson, personal communication) lists major differences between the current unsustainable paradigm and the new paradigm as it is emerging in concepts and reality in Europe, Asia, Australia and North America.

Traditional	Cities of the Future
• **Drainage-** Rapid conveyance of stormwater from premises by underground concrete pipes or culverts, curb and gutter street drainage	• **Storage oriented** – Keep, store, reuse and infiltrate rainwater on site or locally, extensive use of rain gardens, drainage mostly on surface
• **Wastewater:** Conveyance to distant downstream large treatment plants far from the points of reuse	• **Local reuse:** Treat, reclaim and keep a significant portion of wastewater locally for local reuse in large buildings, irrigation and providing ecological low flow to streams
• **Urban habitat Infrastructure:** No reuse, energy inefficient, excessive use of water	• **Green buildings (LEED certified):** water saving plumbing fixtures, energy efficient, larger buildings with green roofs
• **Water/stormwater/wastewater infrastructure:** Hard structural, independently managed	• **Local cluster decentralized management:** soft approaches, best management practices as a part of landscape, mimic nature
• **Transportation, roads:** Overloaded with vehicular traffic and polluting	• Emphasis on **less polluting fuel**, urban renewal to bring living closer to cities, good public transportation, bike paths, best management practices to reduce water pollution by traffic
• **Energy for heating and cooling, carbon emissions:** Energy (electricity, gas, oil) brought from large distances, no on-site energy recovery, high carbon emissions	• **Energy recovery and reduction of use**: Part of the heat in wastewater will be recovered and used locally without carbon emissions, biogas production from organics in waste, fuel saving by people traveling shorter distances, use of geothermal, solar and wind energy that reduces carbon emissions
• **Overuse of potable water**: Drinking water is used for all uses (household, irrigation, street washing, fire protection), large losses in the distribution system	• **Use of treated drinking water** from distant sources should be limited to potable uses only, reused water or water from local sources for other uses, reduced losses in distribution
• **Economies of scale** in treatment cost and delivery is driving the systems- the bigger the better	• **Triple bottom line pricing and life cycle assessment** of the total economic, social and environmental impact
• **Community expectation of water quality** distorted by hard infrastructure and past abuses such as buried urban streams, fenced off streams converted to flood conveyance and/or effluent dominated	• **Daylighting and/or renaturalization** of the water bodies with ecotones (parks) connecting them with the built areas enhances the value of the surrounding neighborhoods and brings enjoyment
• **Low watershed resilience to extreme events**, underground stormwater conveyance can handle only smaller storms, infiltration is low or nil, fast conveyance results in large peak flows	• **Surface drainage with flood plain ecotones,** in addition to storage and infiltration, increases dramatically resilience of the watersheds to handle extreme flows and provide water during times of shortages

Adapted from Valerie Nelson – unpublished document

Table 1.1 Comparison of Traditional and Cities of the Future (Fifth Paradigm)

Water centric developments recognize the ecological value of surface water resources first. In this approach the ecological integrity of the water resources and riparian and flood zones is preserved or restored, using integrated resource management which also considers the impact on GHG emissions. Integrated resources management of water centric cities will consider; (1) Water conservation (green development); (2) Distributed stormwater management using best management practices of rainwater harvesting, infiltration and storage of excess flows, and surface drainage; (3) Distributed wastewater treatment generating water for reuse in buildings, landscape irrigation and ecological flow of existing or restored water bodies; (4) Using landscape and landscape components (e.g., ponds, wetlands, grass filters, etc.) for attenuation of diffuse pollution and post treatment of effluents recovered for reuse; (5) Heat and energy recovery, (6) Nutrient recovery, (7) Biogas production, and (8) Degree of use of alternate renewable energy sources.

Sustainable development based on the triple bottom assessment and evaluation will balance in an intergenerational context social equity that recognizes the needs of all members of the society (e.g., public health, reduction of GHG emissions, recreation and leisure time), economic development ensuring economic growth and employment, better life for the society today and in the future, and protect and enhance the quality of the environment. This also implies if the current and near past generations have damaged the environment or distorted social equity for the sake of development, a new triple bottom relationship must be achieved to restore the balance for future generations.
The time has come to critically evaluate what has been developed during the last twenty five years in the field of urban drainage and diffuse pollution abatement according to green city concepts and create a new approach to drainage and building/retrofitting the cities to mimic nature and the pre-development hydrology. Other trends can also be considered such as reducing or eliminating GHG emissions from buildings, vehicles and improved public transportation by reducing urban/highway pollution. Table 1.2 presents the components and features of the new 21st century urban water/stormwater/wastewater sustainable systems.

- Water conservation
- Distributed stormwater management
    - o Rainwater harvesting and raingardens
    - o Mostly surface drainage
- Distributed water treatment
- Water reclamation and reuse in buildings, irrigation and for ecologic stream flow
- Heat and energy recovery from wastewater and potentially from stormwater
- Organic management for energy recovery
- Source separation
- Nutrient recovery

Table 1.2 Components of the 21st century urban water/stormwater/wastewater management (adapted from Daigger, 2008)

I.2 Microscale Measures and Macroscale Watershed Goals

LEED Criteria

The US Green Building Council has proposed and is developing standards for "green" buildings and neighborhoods (USGBC 2005; 2007) that are becoming a standard for building and development. For example, each federal, state and city owned building in Chicago (Illinois) is expected to comply as close as possible with the LEED (Leadership in Energy and Environmental Design) standards by installing a green roof and implement water conservation. Green roofs reduce runoff and provide substantial savings on energy use, which again reduces green house emissions. New green tall buildings are showcased in New York and elsewhere.

"Green" subdivisions and satellite cities are now emerging throughout the world and in the design studios of landscape architects. The concept and designs for up to one half million inhabitant "ecocities" are now being implemented in the United Kingdom, United Arab Emirates, Sweden, Singapore, China, Australia, and elsewhere. The LEED standards address:

- "Green" certification formulated for homes, neighborhood development and commercial interiors
- Smart location & linkage which include, among others, required indices of proximity to water and wastewater infrastructure, flood plain avoidance, endangered species protection, wetland and water body conservation, and agricultural land conservation;
- Neighborhood pattern and design such as compact development, diversity and affordability of housing, walkable streets, transit facilities, access to public spaces, or local food production;
- Green construction & technology; and
- Innovation & design process.

Low Impact Development (LID)

LID concepts are used in and restricted to subdivision size developments that practice mostly on site stormwater containment, storage, infiltration and conveyance. The LID approach selects "integrated management practices" which are distributed small scale controls closely replicating predevelopment hydrology. The goal is to achieve the highest efficiency or effectiveness at approximating predevelopment conditions (Oregon State University et al., 2006). LID goals are aimed primarily at controls of urban runoff, water conservation and other aspects of "green" development contained in LEED or ISO criteria that are not a priori considered. However, there is no such thing as "no impact" development. LID developments often are situated in rural settings with very high open/built space ratios which could imply long distance travel and urban sprawl.

Best Management Practices

LID practices can be considered as a subgroup of a more general category of Best Management Practices (BMPs) known under this term in North America or under Sustainable Urban Drainage Systems (SUDS) in the United Kingdom. Many manuals have been developed and published on the BMPs and SUDS, their design and implementation. It should be noted that the BMPs category is broad, BMPs deal with diffuse pollution caused by precipitation and other causes and are not focused only on drainage (Novotny, 2003; Oregon State University et al, 2006).

Macroscale (watershed wide) goals

Architects, builders, developers, local governments and consultants are pushing for implementing "sustainable" and "green" infrastructure, land and resources development. The LEED index, with its metric, is a step forwards towards better developments and more sustainable urbanization. These microscale LEED standards are aimed at individual buildings and small subdivisions and commercial developments, ISO standards and LID criteria also are applicable only to small neighborhoods and commercial establishments. However; the impact of the LEED certified and similar developments and infrastructure on sustainability of water resources, their water quality, increasing resilience against extreme events such as floods or catastrophic storms, as well as protection and enhancement of natural terrestrial resources is fuzzy at best and some could be found irrelevant, at worst, when macroscale, for example, watershed scale hydrological and ecological goals and impacts are considered. The development of the cities of the future, the ecocities, requires a comprehensive and hierarchical macroscale approach to the microscale and often fragmented piecemeal transformation (Hill, 2007) of the current unsustainable urbanization to the new eco friendly and sustainable urban areas and finally entire cities. There is a strong rational for integrating urban water management concepts into the ecocities concepts and vice versa. The convergence of efforts to improve the quality of life in urban communities and the campaign to improve our water quality offer potential synergies that could overcome the often confrontational encounters that can occur between environmental regulation and economic development.

The macroscale goals of the fifth paradigm for water centric communities are:

- Developing an urban watershed and its landscape that is sustainable and resilient over the long run and mimics but not necessarily reproduces the hydrologic processes and ecological structures present in the predevelopment natural system;
- Protection of the natural systems and restoration of the natural drainage (daylighting);
- Mimicking predevelopment ecology and hydrology, relying on reduction of imperviousness, increased infiltration, surface storage and use of plants that retain water (e.g., coniferous trees);
- Developing or restoring interconnected green ecotones (green areas bordering the streams that connect nature with the built human habitat), especially those connected to water bodies, that provide habitat to flora and fauna, while providing storage and infiltration of excess flows and buffering pollutant loads from the surrounding inhabited, commercialized, and traffic urban areas. (Hill, 2007; Ahern, 2007);
- Adaptation to the trends of global warming and stresses caused by increasing population. It is not enough to be carbon neutral, i.e., keep the emission at the present level; the new development must reduce carbon emissions and increase resources to accommodate anticipated urban population increases.
- Retrofitting and reconnecting old underground systems interlinked with the daylighted or existing surface streams.

The macroscale goals should be evaluated by a watershed or city wide summation of the Triple Bottom Line-Life Cycle Assessment of the clusters and intracluster components (infrastructure, BMP, water, green developments and retrofitting, stream restoration and daylighting and water reclamation).

One Planet Living (OPL) principles

The World Wild Life Fund (WWF, 2008) has developed and is promoting the principles that include social and technological metrics under the name of One Planet Living. Some ecocity developments are now aiming to obtain OPL certification. These criteria for ecocities are far more broad and stringent than LEED or Low Impact Criteria. OPL criteria are as follows:

- zero carbon emissions with 100% of the energy coming from renewable resources;
- zero solid waste with the diversion of 99% of the solid waste from landfills;
- sustainable transportation with zero carbon emission coming from transportation inside of the city;
- local and sustainable materials used throughout construction;
- sustainable foods with retail outlets providing organic and or fair trade products;
- sustainable water with a 50% reduction in water use from the national average;
- natural habitat and wildlife protection and preservation;
- preservation of local culture and heritage with architecture to integrate local values;
- equity and fair trade with wages and working conditions following the international labor standards; and
- health and happiness with facilities and events for every demographic group.

I.3 Ecocity/ecovillage concepts

Clusters and Ecoblocks

An Integrated Resource Management Cluster can be defined as a semiautonomous water management/drainage unit that receives water, implements water conservation inside the structural components of the cluster and throughout the cluster; reclaims sewage for reuse, such as flushing, irrigation and providing ecological flow to restored existing or daylighted streams, recovers heat energy from wastewater; and recovers biogas from organic solids. The energy reclaimed from wastewater and possibly from stored stormwater is supplemented by wind, solar, and geothermal energy. The IRMC are fitted to the natural urban environment and are water centric, i.e., existing or daylighted water bodies such as streams, wetlands, lakes, etc. are incorporated into the design. One of the components of the design is to provide ecologic flow to these water bodies that was lost (retrofitting

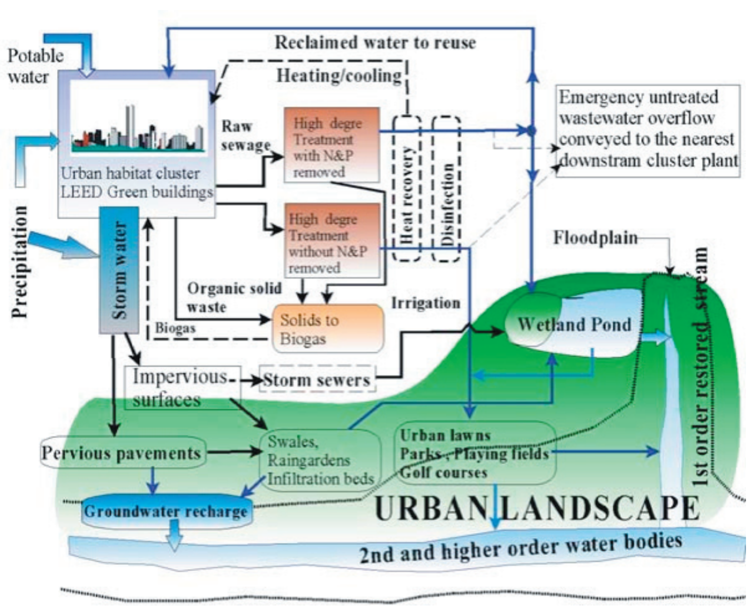

Figure 1.1 Concept of the Integrated Resource management Cluster (IRMC) of sustainable water/stormwater and wastewater management with water reclamation and reuse (Novotny, 2009)

older urban areas) or would be lost by urbanization. Clusters may range from a large high-rise building, larger shopping center, or a subdivision, special modular ecoblocks, to a portion of a city (Furumai, 2007; Lucey and Barraclough, 2007). Figure 1.1 shows the cluster concepts (Novotny, 2009). Implementing IRMCs is necessary if closed water loop systems, water reclamation and reuse, are desired. IRMCs are a sustainable alternative to an open unsustainable linear regional system. While water and energy reclamation in regional end of the pipe facilities is sometimes practiced, the cost of pumping water and bringing the energy (heat electricity) back to the points of reuse in the cities is very high.

Ecoblock is a specific architectural component of an ecocity. Ecoblock can be assembled as modules to form an ecocity (see Section 2.3 describing Qingdao ecoblock developed by Harrison Fraker's team from the University of California-Berkeley College of Environmental Design.).

Ecocities

Ecocity is a city or a part thereof that balances social, economic and environmental factors (triple bottom line) to achieve sustainable development. The first definition was coined by Richard Register (1987) as "a sustainable city, or eco-city is a city designed with consideration of environmental impact, inhabited by people dedicated to minimisation of required inputs of energy, water and food, and waste output of heat, air pollution - CO_2, methane, and water pollution". Ecocities or ecovillages are now emerging on subdivision or urban levels in reality and on large city levels (up to one half million people) in planning and some already in construction. In developed countries, the movement towards ecocities is based on the realization that the limits of the current paradigm have been reached, population will be increasing, technology (e.g., high level treatment is available), new architectural diffuse pollution controls are functioning and desirable by the public, intensity and frequency of catastrophic storms will be increasing, and population desires these developments (Novotny and Brown, 2007).

The next Chapter will present case studies of seven ecocities already designed and in various stages of development. This chapter will then be followed by a synthesis and research needs.

CASE STUDIES

1 Hammarby Sjöstad (Sweden)

Hammarby Sjöstad means “a city surrounding Hammarby Lake”. The city was conceived in the early 1990s and was planned originally as part of Stockholm’s bid for the 2004 Summer Olympic Games (which were awarded elsewhere). About 200 ha (480 acres) of old industrial and port brownfields were converted into a modern, sustainable neighborhood. The development has a strong emphasis on water, ecology and environmental sustainability (Figure 2.1). Once the city is fully built, in 2015, there will be 11,000 residential units for more than 25,000 people. A total of 35,00 people is estimated to live and work in the area.

Hammarby Sjöstad is being developed as Stockholm’s largest urban development project. Located on Lake Hammarby Sjö, the waterside environment shaped the project’s infrastructure, planning and design of the buildings into a modern mixed-use urban space. The scheme has attracted international acclaim for the quality of habitat it created and convinced many that carbon neutral development does not require lifestyle changes. The development is successfully linked with Stockholm’s inner city, including adoption of the contemporary inner city street dimensions, block lengths, building heights, and density. Its mix of uses provides a quality neighborhood.

The use of glass as a core material maximizes sunlight and views of the water and green spaces. The scheme successfully connects the historic landscape with aquatic areas which act as storm water drainage, encourages biodiversity, creation of new habitats, informal amenity areas and formal areas of public open space (Figure 2.2). Sustainability is also enhanced through the use of green roofs, solar panels, and eco-friendly construction products. The city has a fully integrated underground sanitary (separated) waste collection system conveying wastewater to the local district treatment and heat recovery plant.

The development has its own ecosystem, known as the Hammarby Model which also includes a wastewater plant. The ‘Glashusett’, Hammarby Sjöstad’s

Figure 2.2 Hammarby Sjöstad with a central canal (source public file of the city)

environmental information center disseminates knowledge to residents and visitors via study trips, exhibitions and demonstrations of new environmental technologies. Public information reports by the center (Anon, 2007; 2009) provides most of the information.

Overview

History

In the early 1880s the area was a popular park providing enjoyment of nature for the inhabitants of Stockholm. However, in the late 1800s a large bay, a part of the original area, was filled for a planned port. The natural elements of the area were also partially destroyed during the construction of a highway transecting the area. The port was never built and the original and reclaimed

Figure 2.3 Residential area with the surface stormwater channel

(filled) area was made available for storage depots and industries. However, until 1998 most of the buildings were temporary shanty town structures (Vestbro, 2005).

The industrial operation left the soil contaminated and the site became a brownfield. Hence, the first step in preparing the land for the Hammarby Sjöstad ecocity development was monitoring and decontamination or removal of highly contaminated soil.

The project planners worked with various companies (Table 2.1) to change the brownfield area into a livable sustainable habitat to make sure all aspects of clean energy were considered and included. Great emphasis was placed on the importance of collaboration and synergistic thinking between these agencies, each having responsibility for different segments of the system.

Location	Stockholm, Swedden
Area of development	200 ha (480 acres)
Population served	25,000 – 35,000 when fully developed in 2015
Population density	133 inhabitants/ha (56/acre)
Project team	
Key partners	Exploaterings kontoret Stockholm Stad and app.20 different proprietors
Lead planners	Stadsbyggnads kontoret
Architect	Stadsbyggnadskontoret in cooperation with architects from the app. 20 other architectural and consulting companies
Water and wastewater	Stockholm Energi, Stockholm Water and SKAFAB (the city's Waste Recycling Company)
Contact web site	www.hammarbysjostad.se
Project cost	20 billon Swedish Krones (appr. US$ 2.4 billion)
Type of drainage	
Sanitary	Subsurface (sewers) connected to a centralized on-site experimental treatment plant
Storm runoff and snowmelt	Local surface channels and green roofs. Stormwater from streets with more than 8000 vehicle/day traffic is treated by local BMPs (infiltration, storage, sedimentation)
Renewable energy	Solar cells, solar panels
	Heat extraction from treated wastewater (also converted to cooling)
	Buildings green architecture
	Heat extraction from incineration of combustible solids
	Biogass production by digestion from organic solid residuals
Water conservation	Outside source, inhouse water saving fixtures (low flushing toilets, dishwasher machines, showers; potential gray water reuse)
Wastewater system and management	Linear and centralized (no water reclamation from the central treatment plant). Heat is recovered by heat pumps.
Transportation	Light rail and (free) ferry to Stockholm
	Car pools
Recreation, leasure, sports	Extensive network of foot and bicycle paths, cross country skiiing, down hill ski slope
	Sports arena and a cultural center
Green areas and nature	Extensive, interconnected, natural and man made; see below

Table 2.1 Characterstics and parameters of Hammarby Sjöstad

Hammarby Sjöstad is a full-scale, living proof that usage of clean energy and energy saving solutions do not have to increase project costs.

Environmental Goals

The overall environmental goal of the development is to preserve the existing natural areas as much as possible and create new parks and green areas within the city.

- The city will have at least 15 m^2 of green courtyard and 25 to 30 m^2 open court yard and park space available to each inhabitant of the city. Park area should be available within 300 meter of every apartment building.
- At least 15% of each courtyard should be sunlit for 4 – 5 hours on sunny days during vernal and fall equinoxes.
- Development of the green public areas shall be compensated by creating biotopes benefiting the biological diversity in the immediate area.
- Natural area shall be protected from development.

Transportation

Hammarby Sjöstad offers the following low energy transportation alternatives to minimize the energy demanding use of private cars: (1) Light rail connection with Stockholm center; (2) Ferry to Stockholm; and (3) Carpools. It is expected 80% of residents and workers' trips in the city will be by public transportation, bicycles or on foot. The city limited private car users to 0.7 parking lots per household.

Approximately one third of the town's residents are members of the car pool. Most people use the car pool to shop at the supermarket over the weekend, whereby two or three people share a car. The light rail provides commuting possibilities to residents who work in the Stockholm center which is about 15 to 20 minutes away by all means of transport. The water ferry is free between the city and the nearest subway stop Slussen, a transfer stop. There are also several bus lines in the city.

Energy

Figure 2.4 Capture of renewable energy by roof solar panels provides heating of water

The city uses renewable sources of energy with no carbon footprint such as solar cells, fuel cells and solar panels. The building architecture enables maximal capture of the solar energy by southern exposure of buildings with large glass windows and solar panels on the roof (Figure 2.4). Solar energy from solar cells and panels is converted to electricity.

In the central Henriksdal sewage plant, the city's wastewater is treated and the heat recovered by heat pumps is used for heating and cooling houses. Sludge is converted into biogas by sludge digestion.

Combustible solid waste is transferred to an incinerating plant where it is converted to heat and electricity.

Water and Wastewater Management

Water conservation is implemented by installing water use conserving fixtures in the buildings but no reuse of treated wastewater is practiced. Grey water reuse was proposed. The goal is to reduce the per capita water use to 100 litres/capita/day, which is about one half of the current average water use in Sweden. Note that the average water use in the US is much larger, about 400 litres/capita/day (100 gpcd).

The area has an experimental on-site centralized wastewater treatment and resource recovery treatment plant (no water is reclaimed currently from the plant for reuse), officially opened in 2003. The plant, receiving only sanitary sewage flows, reduces the nitrogen level in the effluent to below a standard of 6 mg/l and recovers 95% of phosphorus for reuse on agricultural lands. The phosphorus concentration in the effluent is expected to be below 0.15 mg/l.

Barriers to decentralization: Most of the city concepts were conceived before the onset of discussions of the benefits of decentralization. Also building codes in Sweden are under rigid governmental controls. Concepts essentially followed the established codes.

Landscape architecture

The street dimensions, block lengths, building heights, density and usage mix were designed to take advantage of water views, parks and sunlight. Restricted building depths, set backs, balconies and terraces, large glass areas, and green roofs are the main features.

Landscape architecture planning is crucial in the implementation of surface storm drainage. Stormwater from the developed area is infiltrated, routed on the surface in channels into three surface canals transecting the city.

A green avenue links the city district's public green spaces creating a green corridor running through the southern part of the city. The parks are also linked to the nature conservancy and forests. Most pre-development natural areas have been preserved and new nature areas around the shoreline (former brownfield areas) were recreated.

Solid waste recycling

Figure 2.5 Source level separation and disposal of solid wastes into the vacuum conveyance system

Solid water management is conducted on three levels: (1) domestic, building source base, (2) block-based, (3) area-based.

At the source solid waste is separated into combustibles, food waste and paper (newspapers, catalogues, etc.) wastes are deposited into three color marked chutes or bins (Figure 2.5).

The block level depository room receives other solid waste such as glass, plastic and metal packaging, bulky items (e.g., furniture), electrical and electronic wastes (light bulbs, small batteries, fluorescent light) as well as textiles are deposited in special recycling depository rooms.

The area base deposition facilities receive potentially toxic wastes such as paint, solvents, batteries that must not be deposited with the other block level waste nor poured into household drains. These wastes are separated and handled at the hazardous waste collection location.

Combustible wastes are recycled as heat and converted into electricity in an incinerator located in South Stockholm. Food waste is composted into soil along with the sludge residuals after sludge digestion and methane extraction. The biosolids are currently used in the surrounding forest and the application will be expanded also to farmland.

Newspapers and similar items are delivered to paper recycling enterprises. Metals are recycled; some other discarded bulky items (e.g., furniture) are incinerated. Noncombustible and non reusable solid waste is disposed onto landfills. Hazardous waste is either incinerated or recycled.

The city uses a sophisticated automated waste disposal system that conveys the source based waste into underground tanks separated for each fraction from which the waste is emptied by vacuum into large collection vehicles and delivered for processing.

Health and Social Well Being

The city thrives to be a healthy place to stimulate the body and soul by providing ample opportunities for exercise, sports and culture. It has numerous foot and bicycle paths, a slalom ski slope, sports hall and a nature reserve. Cultural outlets include a social and cultural center and a library. It offers tuition for students and adults to engage in art classes.

Integrated Planning

The goal of the integrated planning was to create a residential environment based on sustainable resource use, wherein energy consumption and waste production would be minimized, and resource and energy savings maximized. This is accomplished by:

- Heat extracted from the treated wastewater by heat pumps used for heating and cooling;
- Heat energy extracted from water solids by incineration
- Biogas from digestion of organic sludge and solids

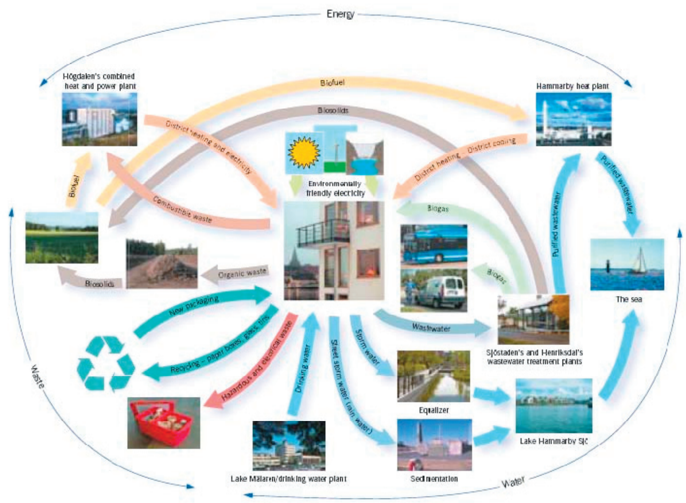

Figure 2.6 The Hammarby ecological cycle model (Anon., 2007)

- Biosolids for soil conditioning from digested sludge and other organic solids
- Waste recycle
- Surface stormwater management and treatment

The ecocycle Hammarby Model, is presented on Figure 2.6. The various energy and materials emission and recovery streams shown in the figure are:

Energy	Water and Sewage	Solid Waste
• Combustible waste is converted into heating and electricity • Biodegradable waste is converted into biofuel and subsequently into heat and electricity • Solar cells convert solar energy into electricity • Solar panels use solar energy to heat water • Good heat insulation, southern exposure, solar panel and building materials reduce the energy demand	• Water consumption is reduced through the eco-friendly installations, low flush toilets and air mixed taps • A pilot wastewater treatment plant was built to treat separated sanitary wastewater and to research treatment technologies • Digestion extracts biogas from the sewage sludge • The digested solids are used for fertilization • Rainwater is drained via surface paths to the lake • Local BMP treatment of polluted street runoff	• An automated waste disposal system with three deposit chutes, a block based system of recycling rooms, and an area based environmental station sorts and disposes the waste • Organic waste is converted/digested into biosolids and used as fertilizer • Combustible waste is converted into electricity and heating • All recyclable materials are sent for recycling • Hazardous waste is incinerated or recycled

Summary

The Swedish traditional urban and suburban housing model is different from what is prevalent in the US. Swedish suburbs mainly contain large blocks of apartment houses and not detached single family units typical for US suburban developments. Also the central city developments prefer high density habitat that provide better conditions for local services and lively streets. This policy of higher density resulted in more households per 10,000 inhabitants than anywhere in the world (Vesbro, 2005). At the time of planning Hammarby Sjöstad virtually all major political parties in Sweden supported the traditional high density development concepts. This resulted in the planners' opting for a compromise between the suburban and urban concepts. The average population density in Hammarby Sjöstad is 133 inhabitants/ha which is in between the typical suburban density in Sweden of 34 inhabitants/ha and that in the central city ranging between 163

– 273 inhabitants/ha. It was pointed out in Chapter 1 and 2 that higher density developments are more environmentally friendly and have a smaller carbon footprint than typical suburban developments. A "compacted" city with good transportation and other services such as recreation, shopping, etc, reduces the demand for private car ownership.

The ecocity is still based on the linear model and water reclamation and reuse is not included.

The Hammarby Sjöstad goal, model and reality document energy and water use can be halved in comparison to the standard Swedish urban settings even when considering the fact that typical Hammarby apartments are larger and more illuminated (provided by oversized windows) than a typical flat in the Stockholm area (Vestbro, 2005). The development also has a number of other worthy environmental and sustainability features previously mentioned in this analysis and literature.

The city development promotes a sustainable lifestyle and serves as a laboratory for sustainable development. In this sense, Hammarby Sjöstad is the first city built on ecological principles that broke the barrier toward sustainable urban development. It uses modernistic and advanced twentieth century principles and concepts. It is a true lower impact development without the drawbacks typical for some other "low impact" developments resulting in low density developments in rural suburban areas. Hammarby does not incorporate some key twenty-first century principles such as closed loop water/storm-water/wastewater management or wind power. However, because Sweden is rich with water resource and has low population density, the closed water loop criterion of sustainability may not be as critical as ecocity development in water deficient areas and wind power can be relatively easily installed. The environmental, social and economic benefits are balanced.

II.2 Dongtan (China)

Introduction

Dongtan, planned near Shanghai (China), is apparently one of the first comprehensive conceptual ecocity developments and has changed the direction ecocities have been going. Phase I – a demonstration settlement for 5,000-10,000 inhabitants was to be ready for opening at the time of the

Shanghai International World Expo in 2010. The Exposition follows traditional World Fairs held at the beginning of each decade throughout the world. Because of the theme of the exposition, “Better City – Better Life”, the Dongtan development was implicitly assumed to be one of the main attractions for visitors and was to signify Shanghai, a megacity with 19 million inhabitants (2009), as a 21st century major economic and cultural center (Langellier and Pedroleti, 2006).

Dongtan, means “east beach” in Chinese. It was planned to be at the eastern tip of Chongming Island at the mouth of the Yangtze River (Figure 2.7) in the middle of a designated nature reserve with outstanding biodiversity. Chongming is the third-largest island in China (at 1,200km^2 or 120,000ha) and its principal land use has been agriculture, rice farming (Figure 2.8). Chongming Island contains vast environmental sensitive wetlands that are home to migratory birds flying all the way from Siberia to Australia. The natural resource value is very high (SIIC, 2003). The location of the proposed Dongtan on the island is about 40 kilometres from downtown Shanghai and in 2008 was accessible only by ferry. A bridge and tunnel opened in 2009 shortens the commute from Shanghai from 3 hours to about 45 minutes.

The contract for the project was awarded to the Shanghai Industrial Investment Corporation (SIIC), a state owned developer, in 1999. SIIC appointed Arup, a British-based urban planning consultancy, to design Dongtan. The contract was signed in London on November 1999 at 10 Downing Street (British PM Office) in the presence of the Prime Minister, Tony Blair, and visiting Chinese President, Hu Jintao. The construction was supposed to begin in 2008 and the demonstration Phase I development for about 10,000 inhabitants finished by the time of the World Exhibition. The final population in about 2050 was planned to be 500,000. The commitment to the British – Chinese cooperation for the development of ecocities in China was reconfirmed by the current Prime Minister, Gordon Brown.

However, the realization of the Dongtan vision has stalled, mainly because of political reasons and the inability of SIIC and Arup to receive the necessary permits after former Shanghai Communist Party Chief, Chen Liangyu, a primary mover for the project on the Chinese side was deposed in 2006. The

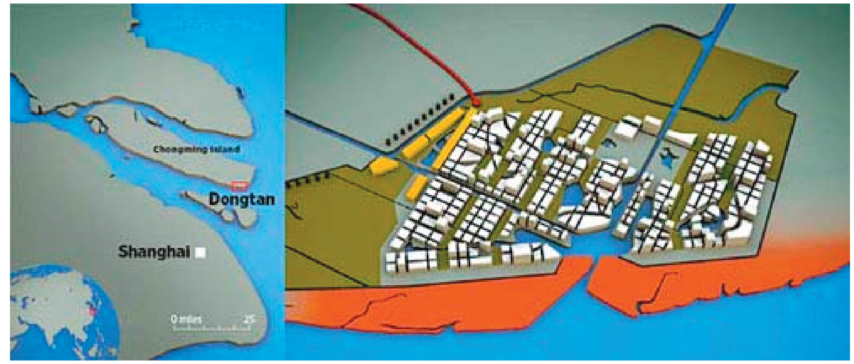

Figure 2.7 Dongtan Phase I (South Village) Location (Source Arup)

outlook is uncertain and the start-up of construction has been indefinitely postponed (Moore, 2008; Anon, 2009a). Nevertheless, because of the pioneering nature of the Dongtan concepts and the eventuality that it might be built later, either at the original location or somewhere else in China, it has been included in this report. It is now clear that the claim to be “the first ecocity” is now unrealistic.

Description of the Dongtan ecocity concepts

How Big and How Many People

Arup’s approach to the design of Dongtan was completely different from other designs submitted by various architectural firms in the mode of “low impact” spread out subdivisions that would put up to 50,000 inhabitants on the entire island and, to some degree, push sprawl into one of the few remaining green spaces around Shanghai. It is also different from other ecocities such as Masdar (Urban Agent, 2008). In this way, Arup’s approach is pioneering and initiated the new paradigm of ecocity building that was then adapted by other ecocity developments. However, although the city design is exceedingly

Figure 2.8 Chongming Island in 2008

Figure 2.9 A vision of the harbor entrance into Dongtan from the Yangtze River showing a lagoon, canals with water taxis and wind turbines (Art picture by Arup)

water centric, the canals and lagoons within the development have mostly architectural functions of aesthetics, recreation and transportation (Figures 2.9 and 2.10). In other words, Arup architects decided to create another Venice (Italy) with all the characteristics of a Venice type of a city, including parking only outside of the city and potentially pollution in the canals, based on the Chinese thousand year tradition of several historic water cities of their own. Also included is the necessity of considering the flooding potential exasperated by global warming because the alluvial Chongming Island has very low elevation and is geologically unstable, like the 128 wetland alluvial islets forming Venice. The ecological and hydrological functions and benefits of the water bodies have not been fully addressed on a macroscale but implicitly assumed and incorporated into a potpourri of various reuse, recycle, and infiltration measures incorporated in the landscape design. Arup has not used a comprehensive hydrological and ecological model to assess and design the overall macroscale impact of the city (Stanley Yip, Arup-China Director of Planning, personal communication).

Arup realized building low impact spread out American – style subdivisions with low-rise condominiums and single family homes scattered across the island with lawns and parks in between would lead to a dead end and an environmental disaster on the Chongming Island. For one, low impact spread out developments would need automobiles and/or uneconomical public transportation which would lead to more adverse global warming effects and traffic pollution and congestion. Arup decided that Dongtan, instead of having 50,000 people on the entire buildable portion of the 1200 km^2 island, needed a lot more people to be a sustainable ecocity. If population density is low, then public transportation and energy and water reclamation/recovery are not economical (McGray, 2007, Urban Agent, 2008).

Arup analyzed and plotted the population density vs energy consumption. They found when the population density reaches 120 residents per hectare, which was approximately the density of Hammarby Sjöstad in Stockholm or Copenhagen in Denmark, such communities use more biking, walking and public transportation is most economical. Furthermore, heating and cooling energy recovery and savings make more sense. When the population density is increased, for example to 290 people/ha like in Singapore or up to 720 people/ha in Hong Kong, energy savings are negligible. Hence, Arup proposed the density for Dongtan around 150 residents per hectare (McGray, 2007).

Because of the foundation conditions on the island that did not allow high rises, Arup settled on a range of four to eight stories buildings across the city. The combination of such buildings allowed for passive energy savings by sun and ocean breezes as well as for implementation of solar panels, voltaics and small wind turbines (Figures 2.10 and 2.11). The result was the population could be increased to about 500,000 on less than 10% of the island area, hence, leaving ample space for wetlands, nature, and sustainable agriculture.

Characteristics

The water centric nature of the city is inspired more by the Chinese thousand year traditions of their own water cities located in the Yangtze River delta and elsewhere along the Yangtze River (e.g., Wuxi) with canals, ponds, arch bridges and water transportation, than on Venice although the concepts are very similar. Arup's landscape architect, Gutierrez, created flood cells within the city so if Dongtan was hit by a once-in-a-century storm, the seawater would stay in a single cell. At the water's edge, instead of a high levee, a gentle hill that would recede into a wide wetland basin — a park, bird habitat, and natural storm barrier would be created.

Regarding energy, the designers located the energy (electricity and heat) producing plant in the center of the city to efficiently distribute heat to the buildings. As an energy source, the city would use rice husks abundantly produced by the agriculture on the island. In addition, a big wind farm, conversion of waste sludge into biogas, and numerous smaller contributions to the grid — including photovoltaic panels and small wind turbines are planned. Dongtan could get 100% of its energy from renewable sources within 20 years after Phase I is opened.

The city sustainability influence would also expand to suburban agriculture that would be mostly organic and use treated effluent for irrigation. Most of the

Figure 2.10 Architectural vision of the city showing the medium height (4-8 stories) buildings and vertical wind turbines

Figure 2.11 A scene around a canal showing also wind turbines. Note that the artist is anticipating (unintentionally perhaps) nutrient enriched/eutrophic conditions in the canal. The Yangtze River carries heavy nutrient loads that cause hypertrophy in some sections. Art picture by Arup.

food would be produced on the island.

The features of the city were summarized in Table 2.2 as follows (Head and Lawrence, 2008; Arup, 2008; Urban Agent, 2008):

Project	Dongtan New City
Construction Start Date	Indefinitely postponed
Anticipated Completion Phases	Phase I demonstration (10,000 pop.) in 2010(?) Phase II (80,000 pop.) by 2020 Final (500,000 pop.) By 2050
Location	Chongming Island, 40 km from Shanghai
Island Size	1200 km² (120,000 ha)
Dongtan City Size	86 km² (8,600ha)
Connection to Shanghai	By bridge and tunnel completed in 2009
Travel Time to Shanghai	45 minutes
Project Built-up Size	30 km² (3,000ha)
Target total population	500,000
Population density	160 people/ ha
Developer	Shanghai Industrial Investment Corporation (SIIC)
Design and Master Plan	Arup, Shanghai (Stanley Yip Cho-Tat, Director)
Financing	HSBC and Sustainable Development Capital LLP
Cost	$1.3 billion for Phase II 80,000 population
Water/Wastewater Management	Centralized, partially closed cycle (water reclaimed from wastewater will be reused for toilet flushing and irrigation)
Arup web site	http://www.arup.com/eastasia/project.cfm?pageid=7047

Table 2.2 Dongtan Characteristics

Energy:

- Energy demand in Dongtan will be substantially lower than comparable conventional new cities. Dongtan ecocity aims to have:
  - o 60% smaller ecological footprint
  - o 66% reduction in energy demand
  - o 40% energy from bio-energy
  - o 100% renewable energy for in-use buildings & on-site transport
- When it is completed, the energy used within the city will not add to the level of greenhouse gases in the atmosphere. This will be accomplished by
  - o Energy in the form of electricity, heat and fuel will be provided entirely by renewable means.
  - o In buildings, this will be achieved by specifying high thermal performance and using energy efficient equipment and appliances to encourage building users to save energy.
  - o Transportation energy demand will be reduced by eliminating the need for a high proportion of motorized journeys, and judicious choice of energy-efficient vehicles.
- Energy supply will be via a local grid and electricity and heat will be supplied by:
  - o A combined heat and power (CHP) plant located in the center of the city that runs on biomass of rice husks, which are the waste product of local rice mills.
  - o A wind farm.
  - o Biogas extracted from the digestion of municipal solid waste and sewage.
  - o Electricity will also be generated in buildings using photovoltaic cells and micro wind turbines.
- Some of the electricity generated will be used to charge the batteries of electrically-powered vehicles or to produce hydrogen for vehicle fuel cells.
- A key feature of energy management in Dongtan will be the level of information provided to consumers to encourage them to conserve energy by means such as smart metering and financial incentives. A visitors' centre located close to the energy centre will explain how cities can be sustainable in energy terms.

Resource and Water/Waste Management:

- Two water networks will provide water throughout the city: one that supplies drinking water to kitchens and another that supplies reclaimed treated wastewater for toilet flushing, landscape and farm irrigation.
- Approximate water use for the city (80,000 population) was estimated

as 16,5000 m^3/day, or 200 L/c-day of which 43 % will be reclaimed.

- The design aims to collect 100% of all waste within the city and to recover up to 90% of collected waste.
- Waste is considered to be a resource and most of the city's waste will be recycled and organic waste will be used as biomass for energy production.
- Waste to landfill will be reduced 83%. There will be no landfill in the city.

Ecological Management of Wetlands:

- The delicate nature of the Dongtan wetlands and the adjacent sites for migrating birds and wildlife has been one of the driving factors of the city's design.
- The existing wetlands will be enhanced by returning agricultural land to a wetland state to creating a 'buffer-zone' between the city and the mudflats - at its narrowest point, this 'buffer-zone' will be 3.5 kilometers wide.
- Only around 40% of the land area of the Dongtan site will be dedicated to built-up urban areas and the city's design aims to prevent pollutants (light, sound, emissions and water discharges) reaching the adjacent wetland areas.

Sustainability:

- To be truly sustainable, the city must not only be environmentally sustainable, but socially, economically and culturally sustainable, too.
- A combination of traditional and innovative building technologies will reduce energy requirements of buildings by around 66%, saving 350,000 tonnes of CO_2 per year for the start-up area.
- All housing will be within seven minutes walk of public transport and easy access to social infrastructure such as hospitals, schools and work.
- Although some may choose to commute to Shanghai for work, there will be employment for the majority of people who live in Dongtan across all social and economic demographics –by effective policy incentives, companies will be attracted to Dongtan and people will choose to live and work in the city.

Dongtan will produce sufficient electricity and heat for its own use, entirely from renewable sources. Within the city, there will be practically no emissions from vehicles – vehicles will be battery or fuel-cell powered.

Farmland within the Dongtan site will use organic farming methods to grow food for the inhabitants of the city, where nutrients and soil conditioning will be used together with processed city waste.

The development of techniques that increase the organic production of vegetable crops will mean that no more farmland will be required than is available within the boundaries of the site.

Buildings and Architecture:

- Where possible, labor and materials will be sourced locally to reduce transport and embodied energy costs associated with construction.
- A combination of traditional and innovative building technologies will reduce energy requirements of buildings by up to 70%.
- Public transport with reduced air and noise pollution will enable buildings to be naturally ventilated, and in turn reduce the demand on energy.
- Buildings with green roofs will improve insulation and water filtration and provide potential storage for irrigation or waste disposal.
- A compact city design reduces infrastructure costs as well as improving amenity and energy efficiency of public transport systems.
- The original three villages will be retained and form the historic city centre.
- It will contain 20% affordable housing.
- No building higher than eight stories.
- Dongtan will be a water centric city where lakes and canals will be the focus of the city used for enjoyment, recreation and transportation.

Transportation:

- Dongtan will be a city linked by a combination of cycle-paths, pedestrian routes and varied modes of public transport, including buses and water taxis.

- o All housing is to be within a seven-minute walk of public transportation, walking and bicycling will be promoted.
  - o Public transportation by hydrogen fuel-cell buses and solar powered water taxis
  - o Businesses, schools, hospitals and other public facilities should also be easily accessible.
  - o Vehicular parking only outside the city.
- Improved accessibility in Dongtan will reduce travel distances by 1.9 million kilometers, reducing CO_2 emissions by 400,000 tonnes per year.
- Canals, lakes and marinas will permeate the city, providing a variety of recreation and transport opportunities.
- Visitors will park their cars outside the city and use public transport within the city.
- Public transport with reduced air and noise pollution will enable buildings to be naturally ventilated, and in turn reduce the demand on energy.

Current Situation and the Future

Barriers. Arup's original plan envisioned that in 2010 about 5,000 to 10,000 people would live in the demonstration site at the time Shanghai hosts the World Expo. Apparently this will not happen; the project is suspended but not cancelled. A new bridge/tunnel opened in 2009 connects the island site with the Shanghai mainland. Obviously, the major barrier to Dongtan realization is the political situation in Shanghai and now the potential pressure to develop the Chongming Island as a traditional suburban car based community. Another barrier could be the fragile nature of the island wetland ecology and low elevation with a potential of increased tidal and typhoon flooding.

A March 21st, 2009 article in Economists (Anon 2009a) claims shortening the commute to Shanghai by cars to 45 minutes should boost land prices on the Chongming Island and many residents would be commuting by car to Shanghai instead of living and working in green research centers and industries, buying local produce and using renewable energy. This may give SIIC an incentive to develop Dongtan into a more traditional high price seaside community, or sell the Dongtan site.

Arup envisioned Dongtan to be a vibrant city with green "corridors" of public space ensuring a high quality of life for residents. The city was designed to attract employment locally across all social and economic demographics in the hope that people will choose to live and work there.

"Dongtan is designed to be a beautiful and truly sustainable city with a minimal ecological footprint. The goal is to use Dongtan as a template for future urban design. As China is planning to build no less than 400 new cities in the next twenty years, Dongtan's success is of crucial importance." (World Business Council of Sustainable Development quoted in Urban Agent, 2008)

II.3 Qingdao (China) Ecoblock and Ecocity

Ecoblocks

The ecoblock concepts were developed by the team of Dean Harrison Fraker of the University of California College of Environmental Design specifically for urban developments in China. China is planning to build, in the next 25 – 30 years, cities and new urban areas for more than 300 million people, which means they will build a New York city sized urban area every year. Their current rapid pace of urban development consists of so called super blocks (Fraker, 2008). A super block is a typical high rise residential development in China usually 100 - 200 ha (240 – 480 acres) in area with 2,000 to 10,000 residential units housing 6,000 to 30,000 people. China builds now 10 – 15 super blocks a day. A super block is a traditional unsustainable development relying heavily on municipal services for power, potable water, wastewater and stormwater conveyance (sewers), centralized wastewater treatment, and solid waste collection and disposal.

In contrast, an ecoblock is a city block much smaller than the super block. It is self sustained and semi - independent with its water and energy needs. It generates its own energy from renewable sources, harvests rainwater, produces its own water and processes and reclaims its wastewater. It is a module that can be repeated many times to form an ecocity or an ecocity portion. Unlike the IRMC it is not connected nor does it rely on natural or restored water bodies with the exception of constructed wetlands treating wastewater. In water rich urban areas (e.g. Tianjin) landscape architects may

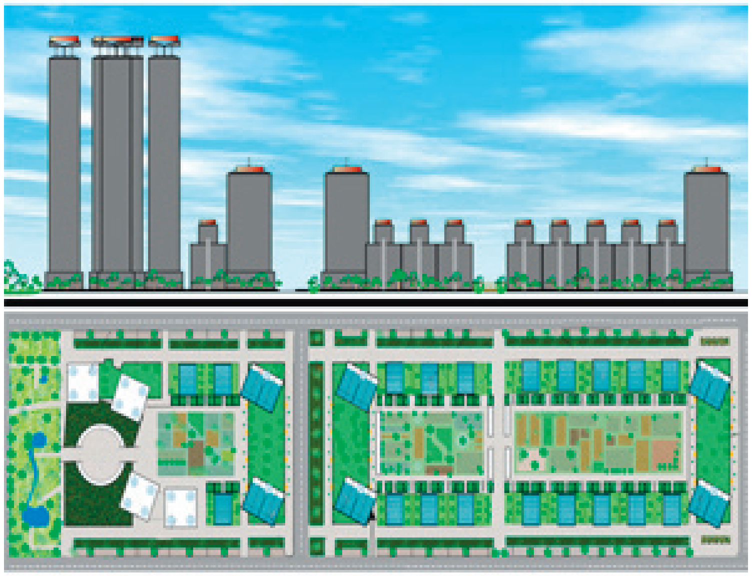

Figure 2.12 Plan and view of the Ecoblock module (Source H. Fraker, UC Berkeley and Arup)

include water bodies for enjoyment and recreation. However, the size of the ecoblock is relatively small and conceivably could be shaped and fitted into the local topography and nature. Fundamentals of the ecoblock and history of its development and application in China are described in Fraker (2006).

A typical standardized ecoblock has 600 units on 3.5 hectares and will house 1500 - 1800 residents. A layout of the ecoblock is shown on Figure 2.12. The Qingdao ecoblock includes several 5 to 7 story townhouses, six 12 story tower blocks, and four 24 story tower blocks arranged around a green courtyard. Parking is minimized in underground and on streets to encourage walking, biking and public transportation. The maximum time to reach public transportation by walking should be less than 15 minutes.

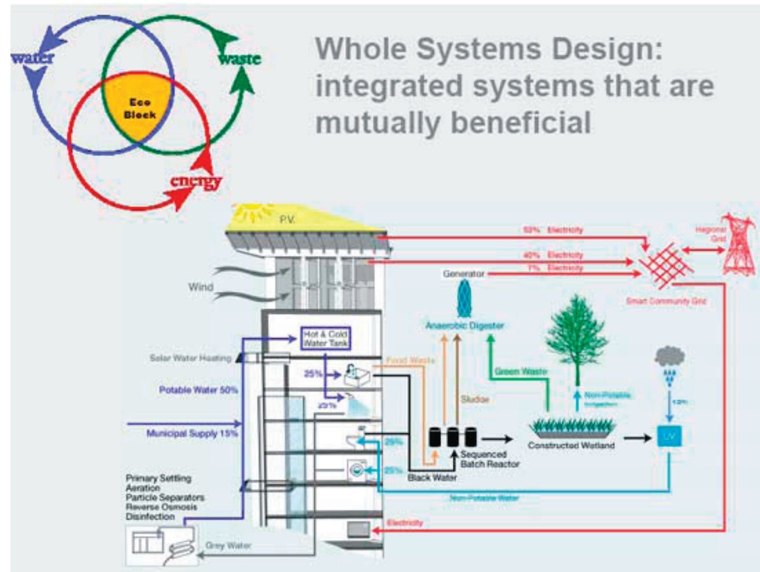

Figure 2.13 Resource recovery system schematic within the ecoblock.

Ecoblock Characteristics Energy and Water Recovery

The resource (water and energy) recovery diagram of the ecocity is shown on Figure 2.13.

Energy. The components and concepts of energy reduction and self sufficiency in the ecoblock are (Fraker, 2008):

1. The best techniques for energy conservation such as
   - Insulation
   - Passive solar energy capture by windows
   - Natural ventilation and daylighting
   - Energy efficient home appliances and lights These technologies can reduce the energy demand of a unit by as much as 40%

2. Renewable energy sources

- Vertical axis wind turbines on the top of tall buildings (30%)
- Building integrated roof and canopy photovoltaics on the lower buildings will generate both electric energy and provide shading (21%)
- Building integrated solar water heaters (3%)
- Bioconversion of sewage sludge, kitchen solid waste, and organic yard waste by two phase anaerobic digestion process into methane running a backup generator (6%).

3. Shared plug-in hybrid cars

Dual closed loop water, stormwater and wastewater recycling and reuse system. Reducing water demand and water reclamation will be achieved by
1. Increased efficiency of water use providing 35% of reduction of a typical water use (160 litres/capita-day) includes

- Xeriscape of the green areas reducing need for irrigation water
- Using reclaimed water for irrigation
- Low flow fixtures in the units (dishwasher, washing machines, faucets)
- Toilet flushing with reclaimed water

2. Recycling water in a dual system, one for gray water and the other for potable water will provide 50 % reduction.

- Gray water from bathroom sinks and showers and washing machines is collected, conveyed for physical treatment by settling, aeration, reverse osmosis and UV disinfection and then returned into the potable water cycle. The sludge is pumped into the biogas digester.
- The gray water cycle is supplemented by make-up potable water from the municipal system representing about 15% of the total water use to replace the loses by evaporation and to control buildup of nonremovable pollutants in the system (e.g., pharmaceutical residues and inorganic solids such as salt). Potable water is pumped into hot and cold water tanks and distributed to the tenants.
- Black wastewater from toilets and kitchen sinks is conveyed to biological treatment by batch reactors and then discharged into wetlands. After wetland treatment it is collected into large communal reservoirs where it is mixed with rainwater and thereafter reused after UV disinfection for landscape irrigation, toilet flushing and in washing machines. On Figure 2.13 the wetland area appears to be about 1/12 of the ecoblock area (3.5 ha) or about 3,000 m^2 which would be less than 2 m^2 per one inhabitant. This may not be sufficient based on the BOD load (see end note to this section below). However, Figure 2.14 shows a larger wetland portion of the ecoblock that could be on the borderline. Furthermore, the wetlands proposed on the ecoblock rendering have standing ponds apparently with partially treated black water which would not be allowed in most countries because of public health problems. Only submerged wetlands would be proper. It also appears evapotranspiration losses from the wetlands were not considered. These issues will be further discussed in Section III-Synthesis.

3. Impervious surfaces will be limited mostly to roofs. Rainwater will be harvested and directed to cisterns from which water will be pumped after UV disinfection for toilet flushing and laundry. Impervious pavement will be used on all streets and paths to enhance groundwater recharge. Groundwater will be also pumped and either added to the cisterns with harvested rainwater or directly used for irrigation.

Assembling an Ecocity

The Qingdao ecocity consists of 16 ecoblocks (Figures 2.14 and 2.15). The city is connected to the public transportation station and the main road. The commercial center is located around the station. The city has central surface and subsurface reservoirs and energy recovery (digestion) units. Used and locally treated black water is conveyed to the reservoirs via the constructed wetlands. Rainwater collected from roofs and pavements is treated by grass biofilters (swale) and conveyed to the reservoirs.

The system includes proven technologies; however, the creators of the ecocity in their video of the Qingdao plan (Green Dragon film, 2008) pointed out this new ecological and sustainable urbanism will provide incentives for new and better technologies for water saving and reuse as well as renewable energy

Figure 2.14 Architectural rendering of the ecoblocks in the Qingdao ecocity

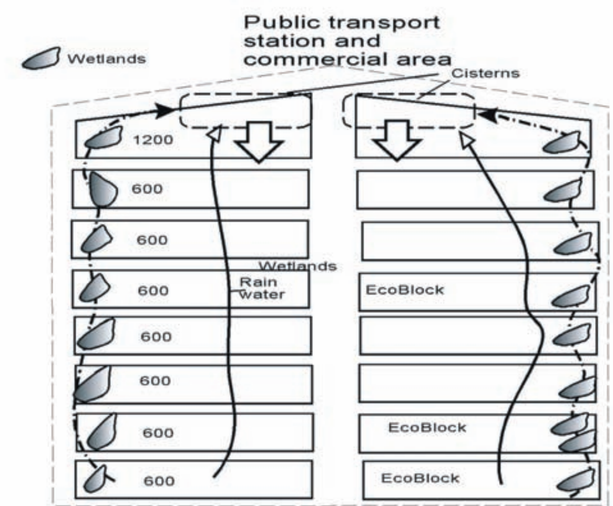

Figure 2.15 Schematic of the Qingdao Ecocity consisting of 16 ecoblocks. The number in each ecoblock represent the number of units. Based on Green Dragon (2008) video.

that will be less costly. It was estimated the capital cost of such developments is about 15% more than the conventional super block development in China.

Barriers. Schlaikjer, (2007) discussed social and economic barriers to the ecoblock and ecocity developments in China acknowledging:

1 Clean technologies are still expensive.
2 It is difficult for foreign and Chinese firms to collaborate which is necessary in order to develop and reinforce responsible business practices.
3 The idea of “gated community“ though having historic precedent in “forbidden city” (Fraker, 2006) does not always appeal to local cultural attitudes and norms.
4 The incentives to build and operate “green” cities are not always evident at the onset.

The chief environmental planner from the Qingdao Urban Planning Office, Zhang Erpeng, in the video (Green dragon, 2008) stated that new more efficient technologies must be developed, management and operation was still discussed, government and/or outside funding is needed, and people have to learn how to live in an ecocity. Also he pointed out that even though the city on average produces excess electricity, the demand is not evenly distributed and the capacity is not sufficient during peak hours and, obviously, on cloudy and/or windless days. The computerized cyberinfrastructure managing the ecoblock, providing information (e.g., about light train schedule and delays), calculating trends and detecting malfunctions with correctives must be developed.

Project Planning and Management

The Qingdao ecocity project is funded one half by the city and the second half by Paul Allen Family Foundation. The development is planned and conducted by Arup (San Francisco) and the Qingdao Urban Planning Office. Leaders are Dean Harrison Fraker (inventor) University of California Berkeley, School of Environmental Design; Dr. Jean Rogers, Arup, San Francisco, and Zhang Erpeng, Director, Qingdao Urban Planning Office. Support for the development was also provided by the Gordon Foundation.

End note – wetland calculation

The Water Environment Federation (2001) wetland manual presents the following design parameters for submerged wetlands treating municipal wastewater: Hydraulic loading HL 0.06 – 0.08 m^3/m-day BOD5 loading BL 80 – 120 kg/ha-day The hydraulic flow in the Qingdao is 50% of the total flow from the population of 1800

Q = 0.5 x 1800 x 160 = 144 m^3/day The BOD5 load is calculated assuming a typical high strength domestic black water concentration of C = 300 mg/L

LB = C x Q = 300 (g/m^3) x 144 m^3/day = 43,200 g/day = 43.2 kg/day
Required area assuming HL=0.06 m^3/m^2 A' = Q/HL = 144/0.06 = 2400 m^2
Required area assuming BL = 80 kg/ha-day A" = LB/BL = 43.2/80 = 0.54 ha
The area of a submerged wetland for Qingdao ecoblock should be around 0.5 ha.

II. 4 Tianjin (China)

Overview

On October 28, 2008 a groundbreaking ceremony attended by Chinese and Singapore government officials and media celebrated the start of construction of one of the first ecocities in China, the Tianjin eco city. The site of the new city development is about 150 kilometers southeast of Beijing and 40 km from the historic Tianjin City (population about 4.5 million) which is the center

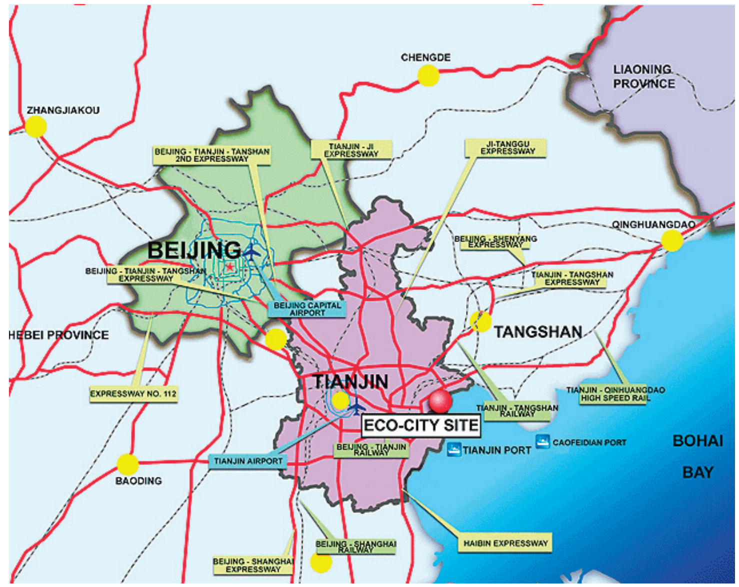

Figure 2.16 Location of the Tianjin Ecocity

of the Tianjin region and largest port city in northeast China (Figure 2.16). The city will be a part of a huge regional development of the Tianjin – Binhai New Area (TBNA) that will include several industrial parks, manufacturing (e.g., Airbus airplane production), several science and commercial centers, port, and recreation tourist zones. Building of the ecocity is based on an international treaty "Framework Agreement between People's Republic of China and Republic of Singapore About Building an Eco City in People's Republic of China" signed by Premier Wen Jiabao of the China State Council and Singaporean Prime Minister Lee Hsien Loong one year earlier. The Sino-Singapore Tianjin eco city will use Singaporean advanced experience and leadership in sustainable urban planning, environmental protection, resource conservation, circular economy, ecological construction, renewable energy utilization, reclaimed water usage, sustainable development. The overall goals of the projects should comply with "three harmonies" namely the harmony between (1) people to people (social), (2) people and economy, and (3) people and environment, which is the same goal as balancing the Triple Bottom Line (TBL) of sustainability. Both governments consider the Tianjin Eco city as a model for other cities in China and the world.

After the signing of the treaty in 2007, the Master Plan of Sino-Singapore Tianjin Eco-city was developed by the design groups from China Academy of Urban Planning and Design, Tianjin Research Institute of Urban Planning & Design and Urban Redevelopment Authority of Singapore. In order to expedite the project, the site selection had to minimize the land acquisition process and legal procedures, saving productive land and water, enabling realizing resource recycling and enhancing independent innovation. Consequently, the project is intentionally placed in a water short area with salty land, scarce vegetation, desert, unfavorable natural conditions and fragile ecology.

The plans for the city and its water management draw heavily on the Singapore experience where such technologies have already been successfully implemented on a large scale. Figure 2.17 shows the architectural rendition of the Tianjin eco city. It can be seen that the city is divided into (eco)blocks. The smallest block unit has an area of 400 x 400 meters (16 ha or 38.4 acres). Harrison Fraker (Clean Energy, 2008) testified that Tianjin would also include the Qingdao ecoblocks which are self-contained smaller ecoblocks with 600 units that have their own water reclamation and energy recovery (see Qingdao ecoblock Section 2.3).

Figure 2.17 shows the layout of the city which will have residential areas; protected historic-cultural districts; urban surface water bodies specified in the plan, including rivers, lakes, reservoirs, dykes and wetlands; urban infrastructure influencing the overall urban development; and transportation facilities such as railway, light railway, and subway.

The city features an "Eco-valley" which is the main north –south green connector in the city. The city site will retain a large ecological wetland, will set aside habitat for birds' migration, preserve the former watercourse of the Ji Canal to guarantee the smooth connection of Ji County Natural Reserve in the

Location	Tianjin region 150 km southeast of Beijing
Area of development	30 km^2 Phase I - 4 km^2
Population served	350,000 Phase I - 30,000
Population density	117/ha inhabitants/ha (49/acre)
Project team	
Key partners	Governments of China and Singapore
Lead planners	
Architect	China Academy of Urban Planning and Design, Tianjin Urban Planning and Design Institute, Singapore Urban Development Authority
Developers	Sino-Singapore Tianjin Eco City Investment and Development Co., Ltd, Arup
Water and wastewater	ARUP, China; Siemens
Contact web site	www.tianjinecocity.gov.sg
Project cost	50 billion yuan (US$ 9.7 billion)
Type of drainage	
Sanitary	Subsurface (sewers) connected to a centralized on-site treatment plant; distributed system considered for future expansions.
Storm runoff and snowmelt	Local surface channels, rainwater capture and recycling .
Renewable energy	Solar cells, solar panels, wind energy capture, 15% energy use from renewable sources
	Buildings green architecture
	Biogass production by digestion from organic solid residuals
Water conservation	Water reuse, inhouse water saving fixtures (low flushing toilets, dishwasher machines, showers; potential gray water reuse)
Wastewater system and management	Closed system but centralized in the first phase. Extensive water reclamation in the treatment plants for landscape irrigation and in-house use. Ecoblocks considered.
Transportation	Light rail to Binhai and Tianjin City, 90% of all trips by public transportation, on foot or bicycles
	No restriction on the use of private cars, the incentive to reduce car use will be excellnt and easily accessible public transporation , walkways and bikepaths linking homes, shops and public facilities.
Recreation, leisure, sports	Extensive network of foot and bicycle paths, cultural center
Green areas and nature	Extensive, interconnected, natural and man made, extensive water based recreation, proximity of large recreation zone.

Table 2.3 Characterstics and parameters of Tianjin Eco City

Figure 2.17 Architectural rendition of the Tianjin ecocity located on Jiyun River. The city is being developed on both sides of the river.

north to Binhai Bay Corridor and to form a regional ecological network with rivers as its arteries. It will be a water centric ecocity emphasizing proximity and aesthetic functions of surface water bodies (Figure 2.18).

Overall Goals

The site was selected based on the requirement that no agricultural or other natural land is used. The site consists of waste land such as salt pan, deserted beach). One third is polluted water including a 270 ha waste pond. The polluted sites are being decontaminated and cleaned up. Another goal is to restore water quality of the Jiyun River that transects the future city (Figure 2.17).

Figure 2.18 Future view of the city central ecological valley with rapid elevated train.

The environmental goals for the city were formulated using twenty six key performance indicators (KPIs) based on the Chinese and Singapore national standards. The most important indicators are (www.tianjinecocity.gov.sg):

- Ambient air quality – at least Grade II China national standards
- Tap water quality – potable
- GHG emissions/unit of GDP - ≤ 150 tonnes of carbon/US 1 million GDP
- Proportion of green buildings – 100%
- Transportation – 90% of all trips in a form of green trips (non-motorized transport, cycling and walking) and public transportation
- Proportion of affordable housing – 20% subsidized
- Usage of renewable energy – 15% of the total energy use
- Water use not to exceed 160 litres/capita-day
- Usage of water – 50% from desalination (high energy use) and

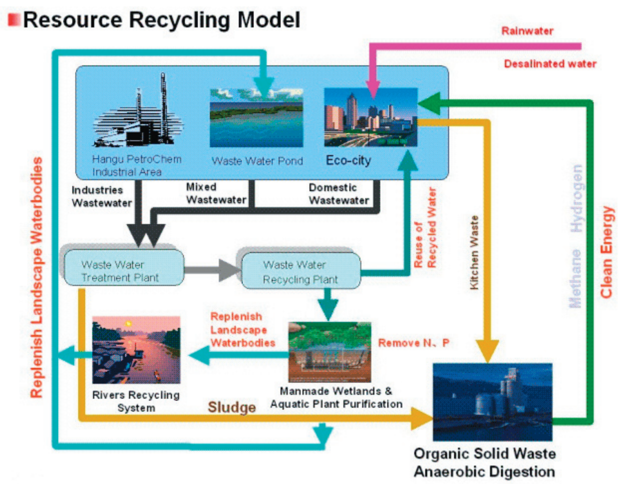

Figure 2.19 Integrated water/stormwater/wastewater resource recovery system in Tianjin ecocity. Source www.tianjinecocity.gov.sg

Figure 2.20 Tianjin ecocity site in November 2008

rainwater and 50% recycled water (see Figure 2.19).

- Employment generated – 50% of the ecocity residents should be employed within the ecocity.

Integrated Resource Recovery System

Water use and reuse. Figure 2.19 is a representation of the water and energy recovery system. The primary sources of water are desalinated water and rainwater. These sources will constitute more than 50% of water used in the city. An extensive system of rainfall collection and sewage reuse will be established relying heavily on the landscape. The city will have a centralized treatment of sewage and wastewater treatment and recycling and will develop and utilize non-conventional water resources such as recycled water and desalted seawater etc. in multiple channels to improve the use proportion of non-conventional water resources. It will implement a reasonable and scientifically based water supply infrastructure that will reduce the need for conventional water resources. It sets up a recycled system of the water body, will intensify the ecological rehabilitation and reconstruction of the surface water systems, collect and use rainfall in rainy season, strengthen the groundwater resource conservation and construct a favorable aquatic eco-environment connected to the Jiyun River.

Energy. The city will rely on a mix of renewable and conventional energy sources that will be linked together. The plan envisions at least 15% energy will be from renewable sources. Traditional energy sources will be “clean coal” and other high quality fuels. The proportion of “clean” energy sources will be 100%. However, some may argue that from the standpoint of GHG emissions is concerned, there is no such thing as “clean coal”. The plan forbids the use of high polluted fuels such as non-clean coal and other low-quality fuels to reduce the influence to the environment. The proportion of clean energies will reach 100%.

All buildings will use green energy conservation technologies and will be built according to the green building standards.

Heat pump technology will reclaim heat and electricity from wastewater and electricity will also be generated extensively by solar panels, wind turbines, geothermal energy and from methane generated by the anaerobic digester. During the initial phases the ecocity will draw waste heat from a nearby major power plant.

Culture, leisure, education. The city will provide ample opportunities for land and water based recreation beaches, water boating, walking, biking. There are several coastal wetland nature areas that provide habitat for water fowl.

A university is planned for the city which will focus on environmental science and technology. The Binhai-Tianjin New Area will have many large research centers and other institutes of higher leaning.

Current Status

During the visit of the first author in November 2008 the site was undergoing preparatory road and earth work. A headquarter building and machine yard was built near the Rainbow Bridge (Figure 5). The project appeared to be in progress and, as stated in the plan, the first phase will be completed by 2011. The city will serve as a research site on which new concepts will be tested.

Summary

Barriers. The system is modeled after the Singapore water reclamation closed system which is not distributed.

The plan performance parameters are surprisingly similar to the ten year older plan for Hammarby Sjöstad. It has about the same water use and renewable energy use. It seems that the creators of the city were on the conservative side and, at least in the first phase, did not commit themselves to goals that might have been too expensive to meet or even could have been questionable with the state of the art knowledge at the end of the twentieth century.

The plan features a partially closed hydrologic cycle system with extensive reuse of reclaimed water for the central treatment plant. It is not clear to what degree the city will incorporate Qingdao's "ecoblocks" which are almost fully carbon neutral. It is possible that in the final outcome the city may be a hybrid between a centralized waste and energy management system and decentralized rainwater harvesting and local renewable energy generation.

The price tag of $9.7 billion for the city may change as new elements may be incorporated in the future. Considering the average family size in China is less than 3, due to the legal one child family restrictions and subtracting about 20% for commercial, transportation, government and education infrastructure, the cost of one flat would be about $60,000 -70,000, which is on a higher side but still reasonable in Chinese economic conditions. Twenty percent of housing units would be subsidized.

The city development is on a wasteland with no resources except coastal wetlands that will be preserved. The site also has meager fresh water resources and make up water is only available from desalination and rainwater. In the Tianjin area, rainfall is low and occurs only during 2-3 months in an average year. The city will be a habitat for many people working in the Binhai-Tianjin New Development area but it will also provide many employment opportunities to its residents within the city.

II.5 Masdar (UAE)

Overview

The Emirate of Abu Dhabi of the United Arab Emirates is building a city, Masdar (Figure 2.21), about 17 kilometers (11 miles) from the city of Abu Dhabi besides the Abu Dhabi International Airport. The city is being funded by the government of Abu Dhabi through the Mubadala Development Company and was designed by the British architectural firm Fosters + Partners. Masdar is designed in two squares, one large and the other a smaller square. With expansion carefully planned, the surrounding land will contain energy farms,

Figure 2.21 Artistic representations of Masdar City (Hahn, 2009; Crampsie, 2008)

research fields, plantations and dense green spaces. The city will be built and was designed to follow the "One Planet Living" (OPL) ten principles (see Section I.1) (WWF, 2008).

Masdar is designed in a tradition of a typical historic Arabic city called "Medina" with a square layout, separated from the surroundings by a wall.

When the city is complete it will be home to around 50,000 people and 1500 businesses in an area of 6.5 km^2 (1,600 acres). 40,000 people are expected to commute to work in the city with a total living and working population of 90,000 people (Bioregional, 2008). Basic characteristics of the development are summarized in Table 2.4 and the locations of many of the utilities around the city are displayed in Figure 2.22.

Green and open spaces will be located throughout the city and along the

Location	Abu Dhabi, UAE
Area of Development	6.5 Km^2
Population Served	50,000 residential 90,000 working and living
Populations Density	135 people/ha (333 people/acre)
Project Team	
Key Partners	Foster + Partners, CH2m Hill, WSP, ETA, Transsolar, QS Cyril Sweett cost consultancy, Systematica
Lead Planners	Foster + Partners, CH2M-Hill
Architect	Foster + Partners
Contact Web Site	http://www.masdaruae.com/
Type of Drainage	
Sanitary	Subsurface connected to a centralized treatment plant
Stormwater	Rainwater harvesting, stormwater reuse
Renewable Energy	Photovoltaic power plant, a solar thermal plant, waste-to-energy plant, wind and photovoltaic energy farms
Water Conservation	80% of water to be recycled for irrigation, toilet flushing and other uses. Irrigation water will also be collected and recycled. Low flow and water monitoring systems will be installed in all condominiums and offices.
Wastewater System and Management	Centralized. 80% water recycled.
Transportation	Car free city. Every resident within 150m of a transportation hub for driverless 6-passenger rapid transportation system. Compact design encourages walking and biking. Light rail systems connects city to Abu Dhabi.
Recreation, Leisure, Sports	Network of foot and bike paths, recreational center with sport fields,
Green Areas and Nature	Green areas surround the city with parks and community squares located throughout.
Project cost	US$ 22 billion

Table 2.4 Characteristics and parameters of the Masdar city development

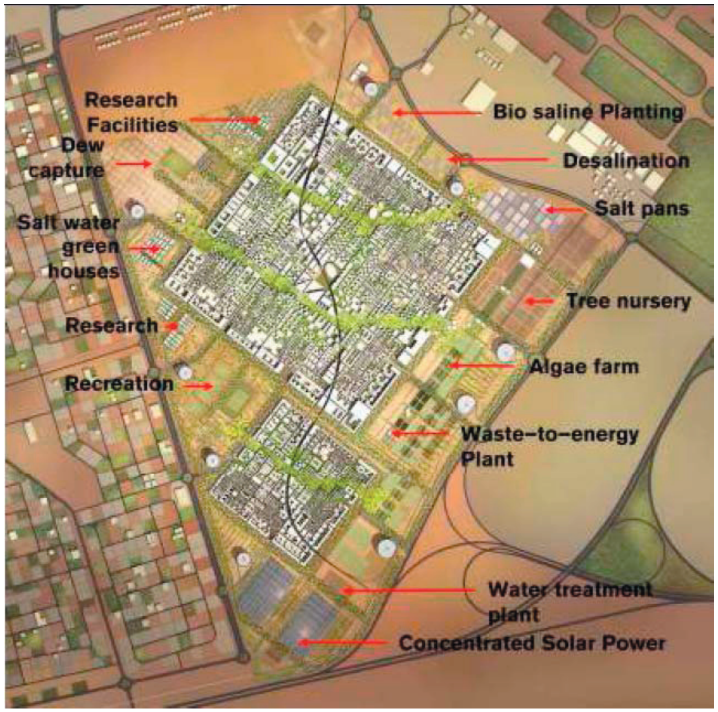

Figure 2.22 Layout of city with space allocation outside of the populated areas.

outside of the populated areas. Recreational fields will be provided in-between the large and small populated centers. A tree nursery, salt-water green houses and a biosaline planting area will also be located around the outside of the city. Salt-water greenhouses will use seawater to cool and humidify the air that ventilates the greenhouse and sunlight to distill fresh water from seawater. This enables year round cultivation of high value crops that would otherwise be difficult or impossible to grow in hot, arid regions. Open spaces

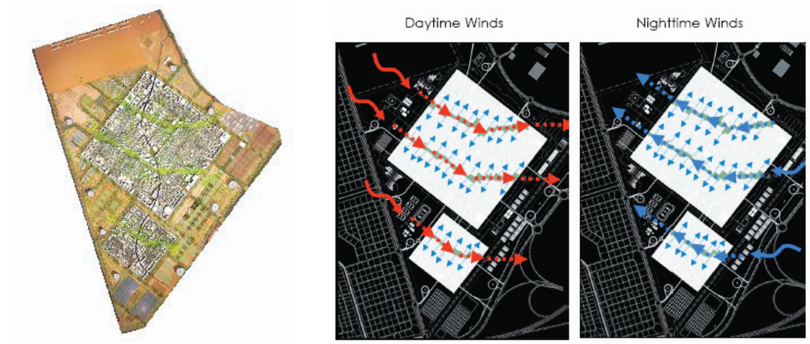

Figure 2.23 Location of green stretches used to facilitate airflow through the city (Hahn, 2009).

will also be located throughout the city including three large pathways (two through the large rectangular populated area and one through the smaller area) to allow for the daytime and nighttime winds to flow through the city. These pathways were orientated to facilitate wind flow through the city to help promote airflow (Figure 2.23).

Energy

Masdar city is being built to be a zero emission city. Many factors will need to be implemented to reach this goal. These factors include energy reduction throughout the city through the implementation of advanced technology reducing the city energy demand, city and street orientation, and the use of renewable energy sources to provide all of the energy needs of the city.

Through the implementation of the most advanced technologies, the power requirements of the city will be reduced to 200 MW power instead of 800 MW for a city of similar size (WSP, 2009). Narrow streets, shaded walkways and orientating the city northeast will minimize the amount of direct sunlight on building sides and windows reducing the need for air conditioning as shown on Figure 2.24 (Palca, 2009). All other electricity and cooling needs will be

Figure 2.24 Artistic representation of a common area in the city (Crampsie, 2008).

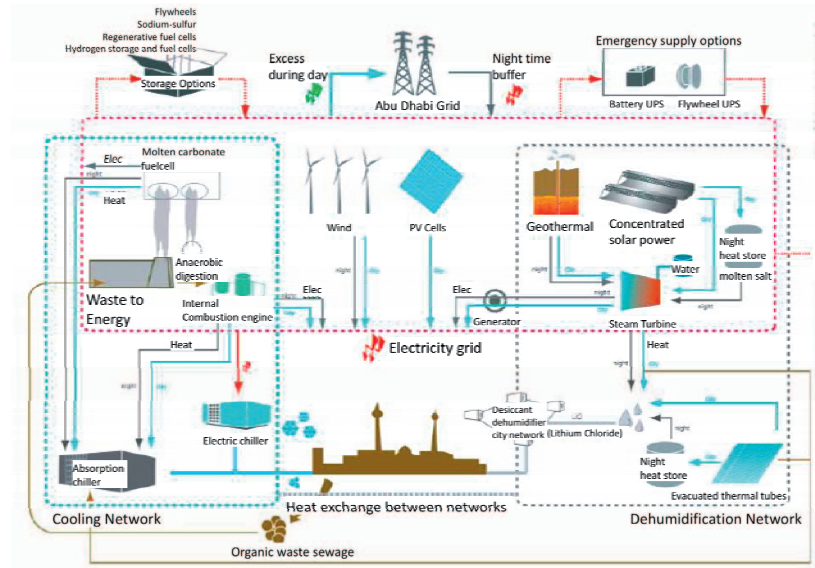

Figure 2.25 Schematic of the electrical, cooling and dehumidification systems to be used in Masdar (Hahn, 2009)

provided by renewable energy generated on site (Bioregional, 2008).

The zero emission goals are not just for the use of the city after implementation, but also during construction. A temporary photovoltaic power plant will be installed on-site before any building commences. Zero carbon heavy machinery will be used during the construction process. As the city nears completion, the photovoltaic panels will be transferred to permanent structures within the city (WSP, 2009). In order to offset any CO2 emissions that are used for the construction of the city, trees will be planted and surplus solar energy will be pumped back into the grid (Palca, 2009).

To provide heating, cooling and other electricity needs of the city, multiple renewable energy technologies will be used (Figure 2.25). There will be a large photovoltaic power plant, a solar thermal plant and the waste-to-energy plant. In addition to these three large power plants there will be both wind and photovoltaic energy farms located in the land surrounding the city (WSP, 2009).

The solar system will include a 10 MW solar farm that will generate 17 million KW-hours per year. 5 MW of the solar panels will be provided by the company Suntech (Corporate Counsel Center, 2009). Suntech uses patent pending Pluto technology for crystalline silicone solar cells, which improves the power output by 12% compared to conventional production methods (Corporate Counsel Center, 2009). In all, the solar plant will be the largest in the Middle East and designed by the Abu Dhabi based Enviromena power systems. Solar power will also be used to power all of the water desalinization needed for the city (Alnaser, 2008). In addition to PV cells, compressed solar power (CSP) plants will be used to produce electric power by converting the sun's energy into high-temperature heat using various mirror configurations. The heat is then channeled through a conventional generator to provide electricity. (Crampsie, 2008)

In addition to solar energy, wind, geothermal and waste heat will also be used. A 20 MW wind farm will be built along the outside of the city (Alnaser, 2008). Also both sewage and waste will be used to provide energy. The waste-to energy strategy involves the implementation of on-site recycling facilities for municipal solid waste and the conversion of organic waste material into gas, which then runs engine generating electricity (WSP, 2009). The city will demonstrate a waste-to-energy facility using EnerTech's SlurryCarb technology. The facility will process biosolids (sewage sludge) produced from the permanent buildings erected during Masdar city's first phase as well as from the accommodation for the several thousand workers building Masdar city between 2008 and 2016. The biosolids will be converted into renewable 'E-fuel', a fossil fuel replacement with a heating value of approximately 7,000BTU/lb and used to generate energy (Crampsie, 2008). The city will still be connected to the power grid of Abu Dhabi allowing for excess energy produced during the day to flow into the grid and energy from the grid to flow into Masdar at night when power requirements exceed supply.

The city itself will be used to house clean technology companies as well as a research and development institutions established in cooperation with the Massachusetts Institute of Technology to research and design clean technologies of the future (WSP, 2009).

Transportation

Masdar City will be a car free city. No cars will be allowed inside the walls of the city. Instead of personal cars a personalized Rapid Transport (PRT) system will be available. This system will be the world's first personalized electric transport system powered by solar energy. It will work on the principal of small electric driver-less cabs carrying up to 6 passengers at a time. Every resident will be within 150m of a transportation station where they can request one of the PRT vehicles (Figure 2.26). Once inside, a passenger can choose from 1500 designated destinations throughout the city to travel (WSP, 2009).

In addition to the PRT system, the city will be compact with short distances

Figure 2.26 Artistic rendition of underground PRT system, PRT cars and infrastructure layers. A) PV roofscape, B) residential, commercial and light rail system C) secondary infrastructure, PRT and raised street network D) primary infrastructure (Hahn, 2009).

to amenities and transportation links encouraging walking or biking to destinations. The shaded walkways and narrow streets will create a pedestrian-friendly environment in the context of Abu Dhabi's extreme climate. It also articulates the tightly planned, compact nature of traditional walled cities (Foster + Partners, 2007).

To accommodate the commuters who will travel in and out of the city every day, there will be a Light Rail Transit (LRT). The LRT is an overland train that runs from Abu Dhabi city centre to the international airport stopping at Raha

Beach, a popular resort development just outside Masdar, and Masdar itself (WSP, 2009). In addition to the light rail, parking structures will be located outside of the city for travelers driving to the city. These parking structures will be near transportation stations for easy access to the city.

Water Use

Water used inside the city will be provided by a desalinization plant run by solar power. The plant will produce two types of high quality water: one fit for drinking and the other fit for personal uses such as showering and washing dishes (Todorova, 2008). The overall efficiency of the desalinization process is expected to be 80% more efficient than other plants (Al-Jaber, 2008). For a typical city of Masdar's size, consumption of desalinization water would be expected to be around 20,000 m^3/day (5.3 MGD). In Masdar the production of fresh water is expected to be around 8,000 m^3/day (2.1 MGD) (Al-Jaber, 2008). The desalinization plant itself will be designed to treat up to 10,000 m^3/day (2.6 (MGD) (Todorova, 2008). In order to obtain these reductions in water use, 80% of the water will be recycled. The water will be used and reused as much as possible. Water desalinization will provide potable water for use in homes. Once it is used it will be treated and then reused for toilet flushing and irrigation (WSP, 2009). In addition to treated wastewater, landscape irrigation will also use grey water (Bioregional, 2008). In some cases the irrigation water will also be reused. Once the water passes through the top 2 to 3 feet of soil, underground collection systems will recover what is left for reuse in irrigation (Palca, 2009).

Individual water consumption is expected to be around 80 litres/day (Todorova, 2008). In order to reach this goal, reduction in water leakage from pipes will be needed. Typically, an estimated 20% of water is lost through pipe leakages. Through the implementation of advanced technologies and systems, Masdar expects to cut the losses down to less than 1%. Of the 80 litres of water used by each resident per day, 50% will be potable desalinized water, the other 50% will be recycled water from sinks, showers, washing machines and dishwashers (Todorova, 2008).

Other tools will be used to reduce the amount of water consumed by each individual. These tools include raising residents' water bills and installing devices throughout the buildings to notify residents and office managers of how much water they are using and the cost of that water consumption. In addition, sensors will be installed on taps and showers that will stop the water flow if a large quantity has been used. This will just be used as a reminder since the water can be turned back on with the simple press of a button (Todorova, 2008).

Masdar city will use a plethora of water management principles in order to treat all parts of the water cycle and use them as a water source. As many as nine water conveyance systems will be employed to be used in 12 different ways and treated at three treatment levels. The variety of water sources to be used includes groundwater, seawater, surface runoff, rainwater harvesting, dew/fog capture, grey and black water reuse and resource recovery from urine streams (CH2MHill, 2008).

Waste Management

The overall goal of waste management within Masdar is to be the first city where waste is converted to energy and reduced to zero (Palca, 2009). More realistically the city plans to divert 99% of the waste from landfills by 2020 (Crampsie, 2008). An intensive recycling program will be implemented along with nutrient recovery to be used in the creation of soils in landscaping as well as waste to power scheme (Palca,2009). Sewage water will be treated at a facility with a capacity of 5,000 m^3/day and the water will be used to irrigate public parks and gardens (Todorova, 2008). Both sludge and organic garbage wastes will be used to create power through the production of gases from anaerobic digestion to be used in an internal combustion engine.

Summary and Current Status

Masdar city hopes to become the first zero carbon, zero waste city in the world. In order to sustain this achievement, the city will control growth instead of sprawl, implement low rise high density developments and use sustainable methods of transportation while following the 10 principles of 'One Planet Living' (OPL), which will be independently verified by the World Wildlife Fund (WWF, 2008). The project began in 2008 and the progress is shown in Figure

Figure 2.27 Progress of the Masdar development at the end of 2008 (Hahn, 2009).

1.8. Not only will the city be used as a model for sustainable development, but also the majority of the people living inside of the city will be working in the renewable energy business. A university designed to research and to teach renewable energy practices will be created and companies in the renewable energy field will have offices inside the city walls. The total cost of the project is expected to be $22 billion USD for the housing of 50,000 people with another 40,000 people commuting to the city for work in 1500 businesses.

The project broke ground in 2008 with the first building phase of Masdar to be completed in 2009 (Figure 2.27). During this phase, all major infrastructures will be built including the Abu Dhabi Future Energy Company (ADFEC) Headquarters; Masdar's own university and a large photovoltaic power plant, which will be the main source of energy to power the city. During the second phase of the project, the larger square of the city is to be completed and during the third phase, the smaller square of the city. The entire city of Masdar will be finished by 2015.

Barriers. Apparently, the cost of US$ 22 billion and funding are no problems in the United Arab Emirates but the cost is most likely prohibitive anywhere outside of the Middle East, except for very affluent upscale communities in the US and Europe. The cost per unit is about $1 million but at this cost the developers were able to overcome the biggest barrier to the development which is lack of water resources. While Tianjin is using conventional energy for desalination, using solar energy in Masdar for desalination is the most important barrier breaking step. With desalinated water they will create an oasis and will make the sustainable urban development in desert coastal areas a possibility for future generations.

II.6 Treasure Island (California, USA)

Overview

Treasure Island is a man-made island constructed to host the 1939 Golden Gate International Exposition. It was built by dredging sediments from the San Francisco bay and was originally scheduled to become an airport after the exposition. Due to increased involvement of the US in WWII, the site was transformed into a center for training and dispatching service personnel. In 1990 Treasure Island supported a population of more than 4,500 people and a daily employee population of almost 2,000. In 1997 the naval base was closed as part of the Base Realignment and Closure III (BRAC) program and redevelopment plans have been developed to transform Treasure Island and the nearby Yerba Buena Island into the most sustainable cities in the United States.

The majority of the information on this redevelopment was obtained from the Treasure Island Development Authority development plan (TIDA, TICD, 2006). A final development plan is expected to be published in April 2009. By 2018 Treasure Island and Yerba Buena Island development will be an entirely

Figure 2.28 Schematic of the final Treasure Island reconstruction project. (Sylvan, 2008)

new built community of 6,000 homes supporting 13,500 residents, a retailed-focused town center including 21,800 m^2 (235,000 sq ft) of retail space, hotels with a total of 420 hotel rooms, adaptive reuse of historic structures, a marina district including ferry transport to San Francisco, a range of essential services and an extensive open space program (Figure 2.30). No official references regarding the cost are available but the total cost has been unofficially estimated to be around $3 billion.

Currently the island is still owned by the US Navy. Negotiations are ongoing regarding the purchase price for the City of San Francisco. In addition to purchasing the land, various contamination sites are present throughout Treasure Island. Soil contamination is related to fuel storage and fueling operations, previous fire training activities, above and below ground storage areas, ammunition storage, and petroleum pipelines. The US Navy is partly responsible for hazardous materials remediation. The city has been working with CH2MHILL and Geomatrix to monitor the Navy's clean up work to date. The cost of the remediation is estimated at around $28 million.

Location	San Francisco, CA
Area of Development	1.8 km^2 (180 hectares - 450 acres)
Population Served	13,500
Populations Density	150 people per hectare of built area
Project Team	
Key Partners	Treasure Island Community Development (TICD), Treasure Island Development Authority (TIDA), City of San Francisco
Lead Planners	SMWM, SOM
Architect	SMWM, SOM with the help of 18 other architecture and consulting firms
Contact Web Site	www.sfgov.org/site/treasureisland_index.asp?id=284
Type of Drainage	
Sanitary	Subsurface connected to a centralized treatment plant
Stormwater	Green roofs, xeriscape, and gravity pipes for excess runoff to a centralized wetland area for treatment
Renewable Energy	photovoltaics, small vertical axis wind turbines, solar hot water heating, bio-gas power generation from WWTP Peak energy use 17.4 MW 5% renewable
Water Conservation	Low flow fixtures (faucets, toilets, showers, dishwashers, washing machines), Recycling 25% of water for flushing toilets, irrigation, boat washing etc. Water use 264 L/cap-day (70 gpcd)
Wastewater System and Management	Centralized. 25% of the water is recycled
Percent solid waste diverted from landfill	95 %
Transportation	100 % of the population within a 15-minute walk to the transit hub, ferry transportation to San Francisco, bus service to San Francisco and Oakland from transit hub. Car share program. Extensive network of bike paths.
Recreation, Leisure, Sports	Network of foot and bike paths, recreational center with sport fields, marina access, neighborhood parks and on island organic farm
Green Areas and Nature	Extensive, covering 56% of the 180 hectares
Affordable Housing, %	30
Probable Cost	$ 3 billion

*Table 2.5 Characteristics and parameters of the Treasure Island development *TICD, 2006)*

Figure 2.29 Artistic representation of the neighborhood parks and residential buildings (TICD, 2006)

Other important issues that need to be addressed during the construction of the Treasure Island development relate to seismic conditions and traffic. Under current land conditions, Treasure Island is expected to perform poorly in a major earth quake event resulting in possible soil liquefaction and lateral spreading. Stabilization of the island needs to take place before construction can be started. Traffic is another issue that needs to be addressed. Currently access to Treasure Island and Yerba Buena Island is only possible via the Bay Bridge. The high volume of traffic on the Bay Bridge and the design of connecting ramps to the two islands mean that vehicular traffic access will remain constrained in the future. By increasing the population on Treasure Island from 4,500 to 13,500, regulators only want to see a 5% increase in traffic on the Bay Bridge.

After the sale of the land, construction of the project is expected to begin. Construction will be phased out over 10 years. Initial estimates were to have construction begin in 2009 and continue until 2018 in four phases, currently it is scheduled to start in 2010 with the first homes available in 2013. Phase one will center on island wide infrastructure improvements including but not limited to: seismic stabilization, utility distribution systems (water sewer and storm sewer), environmental remediation, and deconstruction. This phase is expected to take four years. The following 3 phases are expected to last two years each and include the phased construction of homes, retail space and open spaces starting near the transit center during phase two and expanding to the rest of the islands in phase three and four.

Many groups are involved in the design of this project including the following government agencies: San Francisco Department of the Environment, TICD (Treasure Island Community Development) team, TIDA (Treasure Island Development Authority), and the San Francisco Public Utilities Commission. Private companies involved include Arup, BFK, BVC Architects, CMG Landscape Architects, Concept Marine Associates, CH2MHILL, Concord Group, Engeo, Geomatrix, Homberger Worstell Architects, Korve Engineering, Nelson/Nygaard, Skidmore Owings & Merrill, SMWM, Tredwell & Rollo, Tom Leader Studio, and William McDonough + Partners.

Characteristics

Open Spaces

Extensive open spaces will be provided covering approximately 120 ha (300 acres) for the entire project including 55% of Treasure Island. Because of the population density in the residential areas, a substantial amount of land is free to be used for the entire population of the Treasure Island. There will be a number of neighborhood parks spaced among the residential areas for access and use by the residential occupants (Figure 2.29). Trees will be retained or planted throughout the island to reduce the heat island effect and to sequester carbon to offset emissions. Throughout the island native or non-invasive, climate appropriate and low maintenance plants will be used in consultation with restoration ecologists and landscape architects.

At the center of the island an organic farm will be created. This will allow for the production of local foods, opportunities for training and job creation as well as a place to use composted organic wastes from the residential areas. Other areas throughout the development include public plazas, a sailing center, a 400 slip marina, wetlands for stormwater treatment, connections to the bay trails, sports and recreational areas, and an art park (Figure 2.30).

Figure 2.30 Location of open spaces, parks, urban farm and recreational spaces (Sylvan, 2008)

Energy

A large portion of the energy management is to reduce power demand and energy consumption. Many design criteria will be used in order to reduce the power demand throughout the island including: appropriate building orientation at 35 degrees from due south to optimize solar exposure and create wind protection, natural ventilation, high performance glazing, maximize use of day lighting, integrated lighting and energy controls, specification of energy star certified appliances, centralized heating and cooling, and solar hot water for residential areas (Figure 2.31).

A central utility plant for heating and cooling is planned to reduce energy consumption by 20% below the projected consumption for certain buildings in the central core of the development. This central plant will use a distribution heat pump loop with heat pumps in each building and plate frame heat exchanges to either reject or absorb heat from the bay depending on the season.

Energy production on the island will be gained from the sun, wind, biogas and tide waters (Figure 2.32). In order to harness energy from the sun, roof mounted PV cells will be used. Solar panels will cover 70% of the rooftops

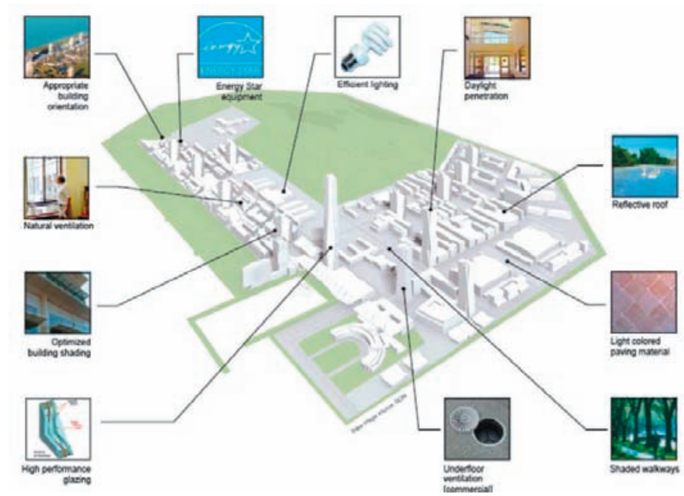

Figure 2.31 Energy saving techniques (TICD, 2006)

Figure 2.32 Energy production for the island. (TICD, 2006)

generating 30 million kilowatt-hours of electricity per year. Solar power will also be used as water-heating systems that can support up to 80% of the hot water needs.

To harness wind power, larger scale wind turbines and small-scale vertical turbines will be placed on top of buildings. Other energy solutions being considered include the installation of tide driven turbines on the floor of the golden gate channel and a biogas generator at the wastewater treatment plant. The biogas generator could provide half the power and heat needed for wastewater treatment.

The on island energy production will only be enough to provide 50% of the power needs of the community. Energy will need to be brought into the island to provide power during periods when solar output is low. This will be brought in through the grid by renewable energy sources. In the middle of the day, when solar output is at a maximum, more energy will be created on the island than is needed. The extra energy will be exported out of the island to provide power to the grid. The overall goal of the development is to reduce the per capita carbon emission in the city by 60% from 3.5 to 1.3 tonnes (7740 to 3030 pounds) (Ward, 2008).

Transportation

The main goal of the transportation design is to reduce car use and promote public transportation, walking and biking. The transportation network throughout the island is orientated first around walking and biking and provides integration into the regional transportation system via ferry and bus. 90% of the residents will live within 1.2 km (0.75 miles) from retail services and within a 15-minute walk from an intermodal transit hub (Biello, 2008). Neighborhood serving retail is also planned with the hope that residents do not have to leave the island for their basic needs.

An on island transit system will also be provided with a small fleet of electric or alternative-fuel shuttles. The transit system will provide transportation to residents that live more than ½ mile away from the transit terminal. The transit terminal will provide transportation to San Francisco through a bus and ferry system.

Car use will be limited by a fee and pricing system. Parking management will be based on a policy that all auto users incur a parking charge. A congestion pricing program will be applied to people who choose to use their car to get to and from the island during peak travel periods. Ramp metering will also be used to limit the number of vehicles that can leave the island during periods of bridge congestion.

Water Use and Treatment

Potable water will be imported from San Francisco. Low flow faucets, shower heads, toilets with sensors and controls along with low water use appliances including dishwashers and side loading washers will be installed in all residential units to reduce water consumption. All of the water use practices will provide a reduction in water use from the existing 380-450 litres per capita per day (100-120 gallons) to 265 litres/capita/day (70 gallons) a 30% reduction. Figure 2.33 shows the water management system. It can be seen that the system is essentially linear with some 25% reuse.

After the water is used it will be sent to the WWTP. Treatment will include influent screening, a combined primary/secondary treatment process (either membrane bio-reactors or sequencing batch reactors), aerobic sludge digestion, clarification, sludge dewatering, disinfection and odor control. After the water is treated to meet secondary standards, 75% (5.3 mega litres per day - MLD (1.4 MGD)) of the water will be sent into the bay and the other 25% (1.3 MLD (0.35 MGD)) will be treated to tertiary levels using coagulation, filtration and disinfection. This 25% will then be recycled for irrigating the farm, as well as for flushing toilets in commercial buildings and washing boats in the marina. When the recycled water is taken into consideration, only 834,000 m^3 (218 million gallons) of water will be used every year. This value is equivalent to the amount of water produced by 51 cm (20 inches) of rain (average annual rainfall) falling on the island (Ward, 2008).

Stormwater management will center on xeriscape, permeable surfaces and pavements, green roofs and routing excess runoff to be treated in a wetland. The impermeable area of Treasure Island will shrink from 64 to 39% through these practices (Ward, 2008). Once the excess runoff is collected it will be

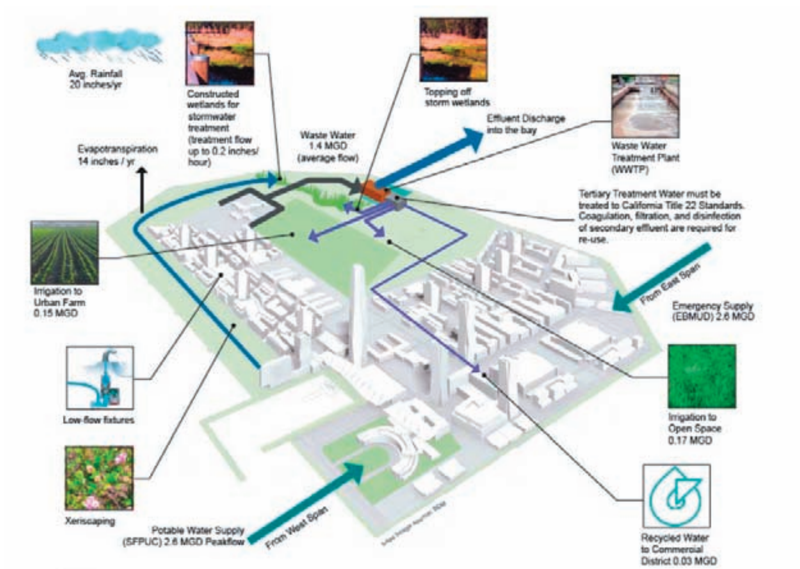

Figure 2.33 Proposed water cycle include water reduction strategies (TICD, 2006)

routed to a constructed treatment wetland. The treatment flow will be 0.5 cm/hour (0.2 inches/hour), which includes 80-90% of storms in the bay area. In the wetland the minimum retention time will be 48 hours. Stormwater in excess of the treatment flow will be collected and discharged into the bay directly.

Solid Waste

The Treasure Island development has a plan to divert 75% of the solid waste from landfills with an overall goal of 100% diversion by 2020 (TICD, 2006). Organic waste will be composted with an on-site aerobic digester capable of processing 6 tonnes per day of compost and used on the islands urban farm and community gardens. A community information program will be developed to inform residence and business on how to reduce the amount of waste. In addition to informing the residence a strong recycling program will be implemented with the 3-bin program. Separate bins will be used from compostable, recyclables and general waste in public areas as well as residential units.

Summary

The Treasure Island development including both Treasure and Yerba Buena Islands will combine high-density residential areas with large open community parks, neighborhood areas and a community organic farm. Renewable energy will provide 50% of the power required by the island by using technology such as PV cells, wind turbines, biogas digesters along with building design that reduce energy consumption. Walking and biking will be promoted through extensive bike and pedestrian paths, close proximity of residential areas to the transportation depot and commercial areas designed to fit the needs of the community. Stormwater will be treated with a centralized wetland and 25% of the wastewater will be recycled for irrigation and commercial use. With the installation of low flow appliances and fixtures, total water use will be reduced by 20%; however, the water use will be still very high and not commensurate with other ecocity development. Energy produced in the island central power plant will be mostly derived from conventional fuels and only 5% from renewable energy sources. On site composting of waste to be used on the island and an extensive recycling program will try to reduce trash exports by 100% from the island by 2020.

II.7 Sonoma Mountain Village (California, USA)

Overview

Sonoma Mountain Village will be located 64 kilometers (forty miles) north of San Francisco in the city of Rohnert Park, CA, USA (Figure 2.34). It will be created in an area formerly occupied by an industrial park and thriving to become the first North American community to be certified by the "One Planet Community" criteria and the fourth in the world (Peters, 2009). The construction and design of this village is being lead by BioRegional and Codding Enterprises at a total cost of $1 billion.

Figure 2.34 Layout of the Sonoma Mountain Village development (Sonoma Mountain Village, 2009)

The construction of the Sonoma Mountain Village Community is expected to begin in late 2009 with models projected to be available for viewing in early 2010. Homeowners are projected to start moving in by mid 2010 with the completion of the entire project being finished in 2020 (Sonoma Mountain Village, 2009). In total 1900 homes will be constructed on 0.8 km^2 (0.3 sq mi) of land with a mix of 900 apartments and condominiums and 1,000 single-family homes. These homes will vary between single family, rowhouses, affordable-by-design homes (smaller square footage), townhouses, multifamily

Location	Sonoma Village, CA, USA
Area of Development	0.8 Km^2 (80 ha or 200 acres)
Population Served	5000 people
Populations Density	62 people/Ha (25 people/acre)
Project Team	
Key Partners	BioRegional, Codding Enterprises
Lead Planners	Codding Enterprises
Architect	Farrell, Faber & Associates, Fisher Town Design, KEMA Green, Scott Architectural Graphics, MBH Architects INC., WIX Architecture
Contact Web Site	http://www.sonomamountainvillage.com/
Type of Drainage	
Sanitary	Subsurface connected to a centralized treatment plant
Stormwater	Raingardens, biofiltration swales, pervious pavements in alleyways, construction of stream to transport runoff out of village
Renewable Energy	photovoltaic arrays on building tops
Water Conservation	rainwater harvesting, water reuse, and use of low flow devices including ET irrigation technology.
Wastewater System and Management	Centralized.
Transportation	Promote biking and walking within the city, car share/carpool programs, rail transport to nearby cities.
Recreation, Leisure, Sports	Network of foot and bike paths, sports fields
Green Areas and Nature	Green areas throughout city.
Project Cost	$ 1 billion

Table 2.6 Characteristics of the Sonoma Mountain Village Development

Figure 2.35 Artistic rendition of public areas (Sonoma Mountain Village 2009)

Figure 2.36 Artistic rendition of the town square. (Sonoma Mountain Village, 2008)

condos, lofts, flats and luxury homes ranging between 56 to 420 m^2 (600 to 4,500 sq ft) and prices from $300,000 to $3 million (Sonoma Mountain, Village 2009). The total population after construction is complete is expected to be around 5000 (Sonoma Mountain Village, 2008).

The Community will include 500,000 square feet of commercial, retail and office space to serve the needs of the neighborhoods and surrounding communities (Figure 2.35). Currently 21 businesses will be located in the community as well as 27 sustainability-oriented and socially relevant technology start-up companies (Sonoma Mountain Village, 2009).

Following the ten principles of the “One Planet Living” concept (see Masdar report) the eco city principles for the Sonoma Mountain Village not only pertain to the final product, but also for the construction process. A number of measures are being conducted to insure that energy use and damage to the environment are minimized during the building phase, as they are when the city is complete. During construction vehicle access will be constrained to existing roads and new asphalt roads, storm drains will be protected with filter strips and settling areas as needed and any significant vehicle use off roads will be preceded by soil stabilization with gravel and the use of additional silt fences and earth dikes (Water Balance, 2006). All asphalt and concrete removed from previous construction will be reused onsite. Stockpiling of these materials will require appropriate containment areas to prevent oils and concrete dust from mobilizing. Temporary seeding and mulching will be used to stabilize bare soils throughout the projects. Silt fences, sediment traps, basins and biofilters will be used. (Water Balance, 2006)

Open Spaces

Open spaces, parks and communities areas will be located throughout the 0.8 km² land area including over 10 hectares (25 acres) of parks, many kilometers of trails for walking and bicycling, dog parks and an international all-weather soccer field (Sonoma Mountain Village, 2009). Landscaping will include groupings of plant species native to California and species adapted to the local climate. Throughout the development turf areas will be limited to neighborhood parks, plazas and private back yards minimizing the use of lawns or turf areas in residential front yards or sidewalk planting strips. Trees will also be planted along the streets and chosen for their heartiness, shade and beauty (Water Balance, 2006). Residents will have access to community gardens, fruit trees, and a year-round farmers' market (Peters, 2009). In addition to the local farmers market, 65% of all food consumed by the community will come from within 300 miles with up to 25% coming from within 50 miles promoting locally grown sustainable farming practices (Sonoma Mountain Village, 2008). In addition to all of the green spaces located on ground level, green roofs will be used throughout the community. In all 10 % of the land will be set aside for habitat and 20% of the land for green spaces with a total of 50% of the project area acquiring conservation easements using pollinator gardens on green roofs, native flowers, trees and grasses throughout the community (Sonoma Mountain Village, 2009).

Energy

The energy plan in the village community will center on solar energy and energy conservation. A $7.5 million, 1.14 MW, 5845 photovoltaic panel solar array was mounted on the roof of an existing building (Figure 2.37) within the community in 2006 (Peters, 2009). This array will be used to power the construction of the development and then be used to help power the community. When the community is finished the solar power output is expected to quadruple with excess energy rerouted to the utility grid.

The energy efficiency of the buildings designed will beat the state of California's current energy code by at least 50%. The use of ground source

Figure 2.37 Existing solar panels placed on building in 2006. (Sonoma Mountain Village 2008)

heat pumps, ultra efficient lighting and appliances, super insulated walls, floors and roofs along with solar hot water pre-heat systems will be used to accomplish this mark (Sonoma Mountain Village, 2008). By 2020 the energy use in buildings will have zero carbon equivalent emissions while average California homes CO_2 equivalent energy emission are around 8,240 tonnes (9,082 US tons) per year.

Transportation

The transportation goals in the community will center on the use of walking and biking as the primary transportation methods. Every resident will be no more than a five-minute walk to groceries, restaurants, day care and other amenities offering local, sustainable and fair trade products and services. These services will be located in the town square at the center of the community (Peters, 2009).

Narrow tree-lined streets, paths and convenient bicycle parking will be available throughout the village. Free bikes, electric vehicles that connect to the smart grid, a biofuel filling station, plug in hybrid car share programs, and a carpool concierge services will be used to reduce the car traffic throughout the village. A commuter rail will also be available for transportation from and to nearby cities with a station located within 10 minutes from the village (Peters 2009). Overall the goal of the community is an 82% reduction of green house gas emissions from traveling to, from and within the village (Sonoma Mountain Village 2008). A typical California resident emits annual 22,140 tonnes (24,407 tons) of equivalent CO2 whereas the people located inside this development are estimated to only emit 3,940 tonnes (4,343 tons) annual for transportation (Sonoma Mountain Village 2008).

Water Use

The goal for water used within the Sonoma Mountain Village is a reduction in water consumption by 60% from a general norm for single family homes in the region (Water Balance, 2006; Coddings Enterprises, 2007). This will be accomplished through water reduction devises, education, rainwater harvesting and reuse of water. The municipal drinking water supply will be used inside of all buildings and irrigation in private backyards. Reclaimed water will be used for irrigation of all public parks, medians, and street trees along with irrigation of all common areas, private front yards and for use in fire hydrants (Water Balance, 2006). Stormwater reuse will be used for habitat maintenance, groundwater recharge and as a supplemental irrigation supply for all landscape areas (Water Balance, 2006). There will be habitat protected bioswales acting as wetlands connected to a 15,100 m^3 (4 MG) underground reservoir from which water will be recycled for irrigation purposes (Kraemer, 2008). The savings, reclamation and reuse components of the water system are presented in Table 2.7.

In order to reduce irrigation watering needs, high efficient irrigation systems

Municipal Drinking Water Supply	Reclaimed Water	Rainwater	Graywater
All contact uses in buildings Toilet flushing in most existing commercial buildings Residential toilet flushing per Title 22 Private backyard irrigation	Toilet flushing in new commercial buildings All common area irrigation Cooling tower Fire hydrants	Habitat maintenance Groundwater recharge Common area irrigation Cooling tower	Small-scale private backyard subsurface irrigation

Table 2.7 Water saving reclamation and reuse in the Sonoma Mountain Village Development

will be used such as sub-surface drip tubing and weather track ET irrigation controllers. ET based irrigation controllers track weather conditions through the CIMIS satellite signals to determine the best time for watering. The system combines weather forecast and current weather conditions with pre-programmed soils and plant specific data to adjust water schedules as needed. This type of system can reduce irrigation water use by 50% and reduce the amount of runoff created through irrigation by 71% (Water Balance, 2006). The system will make use of a sufficient combination of bubblers, drip lines, targeted sprayers and subsurface irrigation to minimize the amount of evaporation and over spraying in areas. Rainwater harvesting will also be used in buildings with underground parking lots, or homes and next to public parks where enough area is available for large storage tanks (Water Balance, 2006). This water will also be used to meet the irrigation needs of the community.

Inside each building, water reduction strategies will be implemented as well. Shower heads will have flow rates of 5.7 litres/min (1.5 gpm) or less, commercial lavatories will be fit with 1.9 litres/min (0.5 gpm) flow restrictors, bathroom sinks with 1.9 to 5.7 litres/min (0.5 to 1.5 gpm) with 3 and 7.6 litres/min (0.8 and 2.0 gpm) in residential bathroom and kitchen sinks respectively (Water Balance, 2006). Toilets will use no more that 5.3 litres (1.4 gallons) per flush, urinals will be waterless and dishwashers and laundry washers will be energy star compliant (Water Balance, 2006). In addition fire suppression systems within buildings will use reclaimed water as opposed to municipal water. In all with extensive water conservation measures, water re-use of greywater and reclaimed water systems and a massive rainwater harvesting system no more water will be required beyond what is already being used by existing buildings despite adding around 2000 new homes (Peters 2009).

The Water Plan for the village (Coddings Enterprises, 2007) estimates average daily water use for the village as 1,186.5 m^3/day, of which 31% will be for irrigation (with reclaimed water), 60.5% for residential water demand and 8.5 % for commercial use, respectively. This would correspond to water demand of 237 litres/capita-day which is significantly lower than the typical municipal water use in California. Specifically for Sonoma County the average water use in 2005 was 605 L/cap-day (160 gpd). Of the 237 litres/cap – day, 22 % will be reclaimed water from treated effluent and stormwater, hence the average demand on the municipal grid will be 185 litres/capita-day.

Stormwater

Throughout the village stormwater management practices will be used to reduce pollutants and runoff coming from the development. Raingardens and biofiltration swales will be used as the initial primary catchment for the runoff from the main street network and from roof downspouts on large buildings. These systems will drain filtered water to the underlying aquifers, reducing runoff volumes while increasing groundwater recharge (Water Balance, 2006). Alleyways will be constructed with pervious pavements and combined with under drained substrate to reduce the amount of impervious surfaces in the development. Street trees will be used providing additional areas for the transient storage and percolation of stormwater in the soil structure (Water Balance, 2006)

Underground infiltration galleries will also be used to store and percolate runoff where space restrictions or other land use considerations limit the use of biofiltration or raingardens. A channel corridor will also be constructed running the length of the village along an existing railroad track. Along this corridor will be trails and attractive landscaping used with a channel system that will have overbank storage for flood flows to transport stormwater out of the village. In order to control peak runoff flows stormwater detentions will also be used (Water Balance, 2006). Throughout the development stormwater will mainly flow on the surface and through the soils rather than in pipes (Sonoma Mountain Village, 2008).

In order to reduce the amount of pollutants from contaminated stormwater, each homeowner will receive a manual welcoming them to the neighborhood and describing how to maintain their home. This manual will contain a section detailing all of the prohibited materials and the reasons why they cannot be used. These materials will prohibit use of synthetic fertilizers, but compost and naturally derived fertilizers will be allowed and will be used extensively (Water Balance, 2006).

Waste Management

Waste management throughout the community will start with the construction phase and continue through the life of the village. During construction all existing buildings and materials in the previous workplace for 2,500 workers will be reused (Kraemer, 2008). Existing buildings will remain simply incorporated into the design. All asphalt and concrete removed from the area will be stockpiled and reused during construction (Sonoma Mountain Village, 2008). The home manufacturing will be done on site in a near zero waste panelized home production facility. All of the new construction will utilize recycled steel framing from an on-site factory run by Codding Steel Frame Solutions. This new technology will allow for the building of 2,000 sq ft. homes with recycled steel from SUV's and used cars rather than trees (Sonoma Mountain Village, 2009). This facility will be run on solar power and create zero waste with the final steel frame products being 100% recyclable (Peters, 2009). The entire construction process will include 20% of the materials being manufactured on site with 60% coming from within 500 miles (Sonoma Mountain Village, 2008). Overall the amount of CO2 equivalent green house gas emissions for the one time construction of the development will be reduced from a California average for a similar community of 113,400 to 39,690 tonnes.

In terms of waste management, after the completion of development an intensive recycling program will be put into place resulting in only 2% of the waste entering landfills by 2020. This included addressing retail and grocery packaging, food waste composting, school education and creative contest to promote waste free living (Sonoma Mountain Village, 2008). Town-wide composting will be used to create soils for the community gardens, small parks and fruit trees throughout the village (Kraemer, 2008)

Summary

The Sonoma Mountain Village will incorporate the 10 One Planet Living (OPL) principles into the design of a small 5000 person village north of San Francisco. The community has applied for inclusion in the LEED-Neighborhood Development pilot program trying to obtain platinum LEED certification for the entire village as well as LEED certification for each individual building (Carlsen, 2007). The community is seeking endorsements from the Sierra Club Conservation Committee, the Greenbelt Alliance and the Accounting Housing Coalition in order to obtain outside certification on the sustainability of its designs (Carlsen, 2007). The development is scheduled to be completed in 2020 and upon completion could become the first development in North America to be certified as a One Planet Living community.

III. SYNTHESIS

The seven ecocity developments come from different geographical and social regions, China, Middle East, Northern Europe and California, and in different sizes, ranging from population of 5,000 to 500,000. Table 2.8 is the synthesis of the key comparative parameters. Several fundamental similarities and city features have been noticed.

Population Density

With the exceptions of Sonoma Valley Village, the smallest development, and Qingdao ecoblock, the development with the highest population density, the density of the remaining five developments varied between 117 to 170 people/

City	Population Total	Population Density #/ha	Water use L/cap-day	% water reclamation & recycle	Water System*	% Energy savings	Green area m^2/person	Cost US$/unit**
Hammarby Sjöstad	30,000	133	100	0	Linear	50	40	200,000
Dongtan	500,000 (80,000)++	160	200	43	Linear centralized	100	100	~40,000
Qingdao	1500+	430	160	85	Closed loop	100	~15	?
Tianjin	350,000 (50,000)++	117	160	60	Partially closed	15	15	60,000 – 70,000
Masdar	50,000	135	160	80	Closed loop	100	<10	1 million
Treasure Island	13,500	75 total area 150 built	264	25	Mostly linear	60	75	550,000
Sonoma Valley	5,000	62	185	22	Linear centralized	100	20	525,000

*Linear system is a once through flow system from which a portion of used water may be reclaimed and used for another use (e.g., drinking water for irrigation), Closed system returns highly treated reclaimed water back for reuse
** Based on average 2.5 members per household + Qingdao ecoblock ++ Phase I

Table 2.8 Synthesis table for the analyzed cities

ha. From the presentations and literature findings it was evident all design teams used some kind of a proprietary model which balances the population and its energy use based on probability of walking and biking instead of driving, energy insulation of buildings and exposure to sun, renewable energy sources and other determinants for GHG emissions from urban areas. Three sites, Dongtan, Tianjin, and Treasure Island were designed by Arup teams which presumably used the same model.

Literature indicates low density "American style" suburban areas with one oversized house on 0.4 ha (1 acre) land are the most wasteful regarding energy use and efficiency. It is the middle and higher income households with two or more automobiles living in low density suburbs that have the highest consumption of resources and the largest carbon footprint, much more so than those with similar incomes living in cities (McGranahan and Sutterthwaite, 2003; Newman, 1996). Hardoy, Marting and Sutterthwaite (2001) made an assessment that "one particularly wealthy, high-consumption individual or household with several large automobiles, a large inefficiently heated or cooled home, and with frequent use of air travel (for pleasure and/or work) can have a more damaging global ecological impact than thousands of urban dwellers in informal settlements (shanty towns) in low income nations" (also Newman, 2006). This type of low density habitat is becoming obsolete even in the US where many low density urban sprawl type developments have become less attractive due to the effects of the financial crisis of 2008 and 2009 and still continuing.

With the exception of shanty towns in developing countries, the high density developments, even though their carbon impact is less than that for very low density suburbs, still require a lot of energy mainly for commercial activities such as office lighting and heating, subways and other public transportation, tourists (hotels), high cost of pumping water to high elevations, long distance transfer of water from far away water resources, pumping and treatment of wastewater, and other energy uses that would be less in medium density smaller developments. Medium density smaller developments (less than 1 million people) are also more amenable to low energy transportation such as electric busses and water taxis, and installation of renewable energy sources that would be efficient on a per area basis.

The fact of medium design density development being the most optimal refutes, to some degree, the utility of the "low impact" subdivisions which in most cases have an objective of minimizing stormwater impacts and discharges and generally results in low density developments. It is revealing, in both approaches to urban development, i.e., low impact and ecocity, stormwater adverse environmental impacts can be minimized, even eliminated, but the mechanisms are slightly different. Low impact subdivisions store, infiltrate and discharge water with only minimal water reclamation and reuse which results in larger land requirements, lower density, and high energy and water use. It is also contradictory to IRM concepts that classify used water as a resource that can be reclaimed and reused both for energy and water supply.

Green House Gas Emissions

Dongtan, Qingdao, Masdar and Sonoma Valley designs are proving ecocities can fulfill the OPL criterion of zero GHG emissions from infrastructure, heating and cooling, electricity consumption and traffic. Obviously living organisms, including humans, and even anaerobic removal of biodegradable organic pollution, sludge and solid organic waster digestion also emit CO2 and produced methane is burned to CO_2. It is not clear whether or not these GHG contributions were accounted for but they are a part of the carbon neutrality concept. Tianjin is surprising because the energy used in the city will be derived from "clean coal" power plants. There is no such thing as "clean coal". China will be embarking on large scale building of nuclear power plants which would obviously reduce GHG emissions if built to replace existing coal fired power plants but they add more heat to the environment than the conventional fossil fuel power plants. Furthermore, energy savings amount in the city only to about 15% of the total energy use, leaving Tianjin with still a rather large carbon emission footprint. This is also the case for Hammarby Sjöstad and Treasure Island. Treasure Island designers claim 50% GHG reduction when compared with conventional carbon emissions but only 5% would be derived from renewable sources. Hammarby Sjöstad does not include wind energy, some energy savings are achieved by installing solar panels and photovoltaics, passive energy savings by insulation and sun exposure, and combustion of combustible solid wastes in a central Stockholm city incinerator.

The use of renewable energy sources (solar, wind and geothermal) could be optimized with respect to population density. Renewable energy production is related to the available area which will decrease somewhat with the increasing population density as available surface is lost to roads, roofs that are not suitable for installation of renewable energy sources, and open areas such as parks and green corridors. At very high density urban zones, the available area may be limited to flat roofs of buildings, mostly high-rises. Heat energy reclamation is planned in Hammarby Sjöstad.

Water Reclamation and Reuse

All cities use the latest technology for in-house water savings such as low flush toilets, showers, etc. Hammarby Sjöstad is almost a 100 % linear system with recovery of phosphorus. Water is received from the Stockholm water supply network and highly treated wastewater is discharged into the receiving water body. Stockholm is water rich and there is apparently no need for recycle yet they expect to reduce the per capita water use to the "magic" limit of 100 L/capitaday. All other cities use various degrees of water reclamation and reuse but start with a higher per capita water use reduced by reclamation of used water and stormwater.

A high density Qingdao ecoblock with 430-515 people/ha appears to be an anomaly which should be further researched as to the feasibility and sustainability of the concept regarding the used water reclamation. For one, locating wetlands that are supposed to provide treatment to partially treated black wastewater next to the high-rise buildings may not be acceptable in many countries because of health concerns. Qingdao's treatment of black water consist of "sequential batch reactors" described in the video (Green Dragon, 2008) as some kind of septic tanks, followed by wetland treatment. The architectural pictures of Qingdao wetland show small ponds and other standing partially treated black water which would not be allowed in most countries. The acceptable wetland type would have to have a fully subsurface flow (Kadlec and Knight, 1996; Novotny, 2003; Vymazal, 2005). Subsurface flow (SFS) constructed wetlands have been used extensively in the US and in Europe for wastewater treatment under the name root zone method, hydrobotanical systems, soil filter trench, biological macrophytic and marsh beds (Reed, Middlebrook and Crites, 1988) or vegetated submerged bed (VSB) systems (WEF 2001) . Based on the WEF (2001) manual (see also Novotny, 2003) the minimum area of the wetland serving 1500-1800 people will have to be about ½ hectare or one football field.

Second, the wetland will have a relatively large evapotranspiration during dry summer days which might not have been included in the water balance analysis. Average evapotranspiration in July for the region between Beijing and Qingdao is about 150 – 175 mm/month (Thomas, 2008) which would result in an evapotranspiration loss (not counting seepage loss) from the Qingdao one half hectare wetland during a warm dry summer day of 30 – 37 litres per capita (assuming 1500 people occupying the ecoblock) which is almost the same as the volume of the black water entering the wetland.

Surface Runoff and Clean Water Drainage

All ecocities use surface drainage for collecting urban runoff and clean water inputs. All cities will use extensively best management practices for urban runoff such as pervious pavements for infiltration, capture and storage in underground basins, and reuse for various purposes such as irrigation, fire protection, and some plan to tap into the groundwater resources for reclaimed water. All cities are planning reuse of the captured stormwater for irrigation and in some cities for reuse in the community for nonpotable water supply. Use of green roofs has not been planned on a large scale.

Water Centric Development Opportunities

Hammarby Sjöstad, Dongtan, and Tianjin are clearly water centric whereby water and canals are the architectural centerpieces of the development. In all three cases, water bodies inside the city (canals, lagoons) and adjacent to the city (Hammarby/Stockholm lakes, the Yangtze River, the Jiyun River) will have an aesthetic role, provide recreation and local transportation. By locating their advanced wastewater treatment plant at the fringe of the city and directly discharging their used treated wastewater into the Hammarby Lake connected to the Stockholm Bay without water reclamation, the city has missed its opportunity for water reuse. The other two cities in China considered using the water bodies inside of the city for discharge of reclaimed water and reuse in their mostly recreated canals. The central location of the water reclamation facility in Dongtan provides the best opportunity for reuse by simply connecting the points of intake to the nearest water body instead of underground piping. All three cites are relatively water rich. In Tianjin, it appears that the water reclamation facility will be on the outskirts of the city.

The desert city Masdar will apparently create small artificial streams transecting the city. It is not clear whether or not these streams will be used for conveyance of reclaimed used water. Qingdao, Sonoma Mountain Village, and Treasure Island will not have permanent streams, natural or artificial, planned within the ecocity boundary. Sonoma Valley Village is planning to create habitat bioswales with wetlands for stormwater conveyance transecting the village and connected to a storage basin from which water will be reused.

Because the Sonoma Village surface drainage system will carry primarily surface runoff, it can and most likely will have surface ponds while surface ponding may not normally be possible for a system carrying black water discharges such as that in Qingdao. Qingdao created two conveyance systems for reuse: one for the reclaimed black water via a chain of wetlands, the other for stormwater both ending in an underground storage facility, followed by reuse. The architectural rendering of the Qingdao ecoblock does not show any surface stormwater conveyance to the central storage basin.

Lack of Macroscale Assessment

The analysis has revealed some problems with the lack of macroscale of some key components of the triple bottom assessment. The literature data revealed that Arup, Codding Enterprises and most likely CH2M-Hill that provide engineering designs of the ecocities have models by which they can calculate the energy or water use by the city. However, a comprehensive environmental assessment model is not available. Such model or models are needed to test the following hypotheses:

- There is a quantifiable limit to water reuse at the macro, i.e., city scale. Sustainable urban water systems are characterized by a significant amount of recycling, supplemented by rainwater and/or make-up water import. This water import (and consequently export) required for flushing out conservative or poorly degradable contaminants not removed by the processes within the system, constitutes a key macroscale design parameter. Quantification of the amount of import is critical for the design of these systems, including assessing the needs for ecologic flow to sustain viable aquatic life of their water bodies.
- The reuse may lead to accumulation and exceeding of thresholds for good water quality for several key water quality accumulative parameters in the surface streams, canals and lakes of the water centric ecocities such as nutrients (nitrogen and phosphorus). This could happen in situations where the surrounding water bodies are already near such thresholds as it might be in cases of the Chinese ecocities of Tianjin and Dongtan. Figure 2.12 shows the city architects of Dongtan on the Yangtze River inadvertently anticipated eutrophic conditions to develop in the city canals.
- During the previous paradigm of building the cities when the size of the water/wastewater utilities territorial units was determined by the capital and OMR costs, the economy of scale led to large regional utilities that brought water from large distances, collected wastewater and conveyed it over a large distance to a regional WWTP. Water reuse and energy reclamation was not economical because it would have required another pipeline system and pumping to bring water and reclaimed energy back to the point of use, i.e., to the city. Breaking the system into a number of semiautonomous (with respect to water/stormwater/wastewater management) clusters (ecoblocks), water and energy reclamation and reuse will become a socially attractive, economically favorable (e.g., there may be no need for large underground interceptors and pipelines; potable water will not be used for irrigation) and environmentally beneficial (e.g., by providing ecologic flow) alternative. However, the optimal size of the cluster is not known. Is the Qingdao ecoblock size of 3.5 ha with 1800 people living therein the most economical, efficient, and sustainable cluster? Or, is the 50,000 people Masdar city/cluster the most optimal one. The cluster size, population density within the cluster, ratio of green and built areas, quantity of water reused and renewable energy produced are examples of decision variables used in the optimization.

Ecocity developments are now emerging in Asia (Abu Dhabi, China, Japan, Singapore), some European countries (Germany, Sweden, The Netherlands, UK), Canada (British Columbia, Toronto), and even in Africa and Ecuador. It appears the US is not competitive in what will become trillions of dollars in the world wide urban development and retrofitting market. Most developments, with very few notable exceptions, are now being conducted by companies from UK (e.g., ARUP), from Singapore, or multinationals, such as German Siemens, with offices in China or Singapore.

On the other hand, some key ecocity concepts have been and are being developed by a handful of US academic institutions funded by foreign governments or by foundations. For example, the government of Singapore awarded Massachusetts Institute of Technology $200 million to establish a Singapore branch of MIT partially involved in the development of new urban ecocity technology but most of the funds have to be spent in Singapore. The College of Environmental Design of the University of California Berkeley has received a private foundation endowment and is working, funded by China, with ARUP Corporation, also funded by China, on the development and implementation of "EcoBlocks" in Qingdao, Tianjin and elsewhere throughout China. The ecoblock is being presented as a great revolutionary breakthrough of modern urbanisms, especially for developing countries undergoing rapid urbanization.

For the US, there is a need for establishing a think tank, synthesis and dissemination center rapidly providing information to landscape architects, environmental engineers and developers on the most optimal, ecologically, hydrologically and GHG emissions designs, developing new concepts and keeping track of the worldwide developments in this evolving several trillion dollars worth worldwide market.

IV. Brief Summary

Currently, there are dozens of urban developments throughout the world claiming to be or become "an ecocity". A few, with various degrees of success, are thriving to become certified as "One Planet Living" community. In our analysis we have compared only a fraction of the most publicized developments. The analysis was hampered by a lack of peer reviewed technical articles; a majority of information sources were web based articles or documents by the developers and/or media admiring or criticizing such developments. Nevertheless, the picture that is appearing is far reaching especially in the context of sustainability and reducing global warming. As a matter of fact, accepting the "One Planet Living" criteria would lead to dramatic reduction of GHG emissions from urban areas, including transportation, which represent the major portion of the cause of global warming. Several of the assessed ecocities are near compliance with the OPL criteria.

Because of their frugality with respect of energy and water requirements, the "new cities" can be built in "hostile" environments such as arid or desert areas or decontaminated brownfields. This may relieve the pressure on valuable agricultural lands, wetlands and forests even in countries still undergoing excessive population growth. With the exception of Dongtan, all ecocities analyzed herein are being built on previously contaminated brownfields or poor quality inhospitable lands.

In developed countries, the direction will be more towards retrofitting the existing cities and reducing or even reversing urban sprawl by bringing people back from distant energy gobbling low density suburbs to the retrofitted and water and energy efficient cites. Unfortunately, in old municipalities, bringing new sustainable concepts into rebuilding and retrofitting may be running into resistance and obstacles caused by existing regulations and traditions.

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postscript: applicability to the united states

When the Baltimore Conference: Water for all Life was being organized in 2006 and 2007, it was noted that the U.S. had been largely disengaged from the international conversation about sustainable water resource infrastructure, and in particular, distributed and decentralized systems. Earlier conferences in Australia and Europe, sponsored by the IWA and other organizations, were attended by only a few Americans. In that regard, one of the goals of the Baltimore Conference was to bring international insights and case studies into the United States and to expand the circle of experts and advocates to include Americans.

Questions had been raised by potential supporters and participants in the conference as to the applicability of international examples and innovations for the United States. Several reasons were advanced as to why the U.S. may not adopt innovations from other countries, including: ample water supplies; higher-income in the U.S.; lesser cultural acceptance of "sustainability" products; less flexible political institutions. Examples of these concerns expressed at the time were: the U.S. has more than ample rainfall in most areas of the U.S. and the country can afford to pay for more expensive infrastructure than developing countries, in particular. Americans are averse to modifications in toilets, such as urine-separation or composting. Watershed management is stymied by the plethora of local governments, and the tradition of local control.

In this report, Glen Daigger, Cynthia Mitchell and Carol Howe have discussed strategies for overcoming barriers to the adoption of new technologies and designs. All have pointed out the need for a fundamental "systems" change in the way water is managed in cities. This kind of change requires a co-evolution of technologies, institutions, markets, and policies, which is not possible in the United States as long as there is general satisfaction with the current approaches. Glen Daigger also describes "force field analysis", which suggests both "advancing forces" and "restraining forces" are important, with the latter being of greater significance. Restraining forces include: stove-piped professional thinking, institutional constraints, existing practices, lack of public acceptance, economic evaluation procedures, and regulations.

2010 Update

In the three years since the Baltimore conference, much has changed. Indeed, it is arguable that the United States is entering another great period of questioning, experimentation, and ultimately, transformation in the way that water is managed, equal in scope to the building of central water and sewer lines in cities in the 1800's or to the focus and energy around passage and implementation of the Clean Water Act in 1972. There are numerous signs that this may be so.

Expanding Conversation and Constituency for Change

The first hopeful sign is the sheer number of multi-stakeholder workshops and conferences that have been convened recently at the national level. All start from the premise that there are looming water crises, including increasing droughts and storms that are expected with climate change, financial burdens from aging infrastructure and loss of ecosystem services, that must be addressed. All recognize that current technologies and institutions are not adequate to meet these challenges. Convening organizations have included the Aspen Institute (Aspen, 2009), The Johnson Foundation at Wingspread (The Johnson Foundation, 2010), a newly-formed Clean Water America Alliance (CWAA, 2010), and the US Environmental Protection Agency (EPA, 2010).

EPA's report on the April, 2010 summit, Coming Together for Clean Water, suggested the Agency would work to implement a number of paradigm-shifting approaches, including: encouragement of multi-benefit solutions, development of a more holistic and systemic approach for communities, breaking down of stovepipe divisions, and capitalizing on innovations such as green infrastructure, water/energy synergies and integrated water management.

WERF Research on Baltimore Charter Themes

Since the international conference in 2007, the WERF-hosted Decentralized Water Resources Collaborative hosted has also taken on key questions raised in the Baltimore Charter. The Electric Power Research Institute, a founding member of the DWRC, has funded two studies, one on green building and water, and a second on new elements of a water paradigm shift (EPRI, 2010). Another DWRC partner, the Coalition for Alternative Wastewater Treatment, has led projects on multi-stakeholder engagement in sustainable water management, industry and market strategies, and restoring the Water Commons through approaches that mimic and work with nature (CAWT, 2009 and 2010). Finally, WERF and the DWRC co-sponsored an inter-agency briefing in June, 2010, Integration as a new framework and strategy for water management (WERF, 2010). In all of these projects, case studies in this report have been highlighted, including the Solaire in New York City and Dockside Green in Victoria, B.C.

Expanded Interest in New Technologies

Several new organizations have been formed in the U.S. in the last several years to convene conferences and to promote new technologies in water efficiency, reuse, energy and nutrient recovery, and other arenas relevant to the vision of the Baltimore Charter, including in particular new technologies at building scale. These include the Water Innovations Alliance, the Alliance for Water Efficiency, and WaterSmart Innovations.

Legacy Systems

The international water community of professionals has recognized that the greatest challenges and opportunities for a more sustainable water infrastructure approach are in the proliferation of new cities in the developing world, where the model can be built "from scratch". At first blush, barrier to change is a lack of understanding on how existing "legacy" systems in the U.S. can be transitioned to a new approach. However, many of the innovations being discussed, such as water-efficiency appliances and green infrastructure are by definition at the building or site scale and would be additions to a centralized grid.

It is also the case that the U.S. may have an actual advantage in the poor condition of its aging infrastructure. The fact that many treatment plants and water and sewer lines are nearing their end of life can be turned to the country's advantage. "Run to failure" asset management principles suggest that it may be cost-effective to abandon old infrastructure and to replace it with something dramatically new. For example, leaking and corroded pipes in existing neighborhoods could be abandoned and decentralized infrastructure could be built with the redirected funds.

Disruptive Technologies in Federal Buildings, Schools, Military Bases

In a conventional private market, a new technology can establish a toehold of early adoption and quickly dominate the market, if customers like the new combination of price and quality. In the water sector, institutions and rules can prevent these "winds of creative destruction", as economists would call the breakdown of old markets. Much of the conversation about transforming water management has been about municipal water and sewer services, where resistance to change is apparent.

However, there are a number of important side markets in the U.S. that have begun to adopt integrated and decentralized technologies and designs, including schools, commercial office buildings, manufacturing plants, and, in particular the federal government. Military installations are adopting sustainability agendas which incorporate green infrastructure and wastewater reuse systems. And, the General Services Administration has announced a goal of reducing the energy and water footprint of all federal buildings and facilities over time.

As the number of these projects increases over time, the burden of water management will begin to shift to decentralized and integrated designs within the overall grid. At some point, it will be necessary to incorporate these installations in overall planning and municipal utilities will be forced to examine more carefully the role that such systems can play. A major concern will be that wealthier clients would have taken themselves "off the grid", leaving aging infrastructure for use only by poorer neighborhoods. At this point, the pressures for a more comprehensive approach will be strong.

Prospects Going Forward

All of these signs of ferment in the water sector suggest that a paradigm shift in design and management may be possible in the U.S. in the coming years. Overall, however, the lack of a perceived "crisis" in water means that government officials and civil society advocates fail to take on their necessary roles as change agents. As Cynthia Mitchell points out, innovation will remain in a "niche". The challenge and hope, therefore, is that champions for sustainable water management will emerge in the federal government and that a program of pilot projects, incentives, and other support is initiated at the federal level.

It is also necessary for a shift in attitudes and understanding to occur among environmental organizations, foundations, and other civil society organizations. The current assumptions that water problems are solved with more money and more enforcement must be replaced by an acknowledgment that the infrastructure system itself must be redesigned. So far, these ideas have not penetrated.

The Baltimore Charter remains as a radical challenge and guide to conversation and activism going forward. It is in the answers to these questions that a more powerful agenda can emerge: what fundamental life systems are in danger of collapse from the mismanagement of water, and what does it mean to mimic and work with nature at all scales?

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resources

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Note: This resources section is based on a paper, originally titled *Networking, Outreach and Research on Technology, Management, Research and Policies*, prepared in 2008 for the Coalition for Alternative Wastewater Treatment. It is organized by geographic area, and then by country.

Asia

1.1 Brief Introduction on Asia's Water and Sanitation Status

This report presents Integrated water management practices coverage data for Asia. Practice, Research, Policy and Leading thinkers and Experts are listed by country.

In Asia there is continued and growing pressure on water resources even as there are modern and traditional alternative technologies for water treatment and supply.

According to the United Nations Economic Commission for Asia and the Pacific, Asia accounts for the majority of people in the world without access to improved water and wastewater services (UNESCO, 2003) . The United Nations Human Settlement Program says that eighty percent of the global population is living without access to improved sanitation, and that Asia accounts for nearly two thirds of the world's population that needs better access to water supply (UN Habitat, 2006). Friedrich Von Schiller, in The World's Water Crisis: Fitting the Pieces Together quotes World Health Organization figures that indicate that only 47% of the population has sanitation services, by far the lowest of any region of the world. Schiller finds that only 31% of rural populations have improved sanitation and compares that with 78% coverage in urban areas.

The Global Water Supply and Sanitation Assessment 2000 Report (WHO, 2000) contends that population growth will increase pressures on already over-burdened services, especially in urban centers. To meet the international target of halving the proportion of people without access to improved services by 2015, an estimated 1.5 billion people in Asia will need access to sanitation facilities, while an additional 980 million will need access to water supply.

Peter Gleick argues that there are two primary ways of meeting water-related needs, the “hard” path and the “soft” path (Gleick, 2003). The hard path relies on centralized infrastructure such as dams and reservoirs, pipelines and treatment plants, water departments and utilities. Potable water is delivered and wastewater is removed. The soft path may also rely on centralized infrastructure, but “complements it with extensive investment in decentralized facilities, efficient technologies, and human capital.” The soft path can be more environmentally sensitive while it increases productivity of water use rather than relying solely on new supply. One element of this approach is to match the quality of water treatment to the users’ needs. It also requires participation and engagement with the community in implementing the approach.

1.2 Innovative and Decentralized Wastewater Management Practices in Asia

Decentralized wastewater management is receiving increased attention because of its cost effectiveness and efficiency and potential for cost effective and compact wastewater treatment processes. The trend is an emerging paradigm shifting from centralized conventional wastewater systems only to decentralized water and wastewater approaches.

The Bremen Overseas Research and Development Association (BORDA, 2008) asserts that, "the demand for reliable, efficient and low-cost wastewater treatment systems is increasing world-wide especially in densely populated urban regions where adequate wastewater treatment systems do not exist and uncontrolled discharge of wastewater endangers environmental health and water resources."

In the past, the conventional wisdom has been that centralized systems are easier to plan and manage than decentralized systems. There is some truth in this argument when professionals operate large facilities and municipal administrative systems are centralized. However, experience shows that centralized systems have been particularly poor at reaching outer growth areas far from urban core, particularly those that fall outside municipal boundaries.

In response to the deficiencies of centralized approaches to service delivery, in recent years there has been increasing emphasis on the potential benefits of adopting decentralized approaches to sanitation and wastewater management, which are considered to be particularly appropriate for development on the growing edges of urban areas. The capital investment for decentralized wastewater systems is generally less than for centralized systems in growing exurban areas, and they are also likely to be cheaper to construct and operate (Parkinson and Tayler, 2003).

Historically, problems of poor water supply and inadequate wastewater treatment have persisted because of limited resources and funding, and an absence of effective policies, planning, management practices and regulations.

Integrated waste management requires the involvement of all stakeholders, and these include policy makers (governments), investors (governments/ private sector companies), managers (public and private sectors) and users (communities/community organizations).

Highly engineered and mechanized conventional sewerage and wastewater treatment systems that require large capital investments, demand high maintenance costs, and are not feasible for the developing world (Cairncross and Feacham, 1993; Niemcynowicz, 1996; Edwards, 1996).

Ghosh (1991) postulates that the wetland treatment technology for wastewater treatment in developing countries offers a comparative advantage over conventional, mechanised treatment systems because the level of self-sufficiency, ecological balance and economic viability is far greater.

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Korea

2.1 Practice

From Policy Development and Direction of Rainwater Management in the Republic of Korea by Kim, Yongkyun and Mooyoung Han (2006):

"Until now, Korea has invested considerable funds in the construction of enormous dams, river maintenance, other structural and non-structural precautions, such as flood alarm systems, and disaster prevention education and training. In so doing, they have achieved a notable amount of progress."

Kim and Han note that damage due to typhoons, such as the loss of 11 trillion won caused by typhoons in 2002 and Typhoon Maemi in 2003, continues to grow.

The amount of water taken from natural river flow became insufficient to meet the increased and concentrated water demands caused by economic development, urbanization, and industrialization. Floods occurred more frequently in the region near rivers with increased urbanization. The construction of multipurpose dams was requested to secure water resources to meet the growing demand and mitigate flood damage.

The total amount of water supply made by dams reaches 13.3 billion m^3. Among this, 73% (10.3 billion m^3) of the dam water comes from multi-purpose dams, while the rest (3.0 billion m^3) comes from water supply purpose dams and irrigation purpose dams.

Source: Korea Water Resources Corporation, as referenced in Moon, Young-Il & Kwon, Hyun-Han (2003). Nonparametric dam risk analysis for dam rehabilitation in South Korea. Dam maintenance and rehabilitation. Llanos et al. (eds). 119-124.

2.2 Research & Policy

2.2.1 Things to be concerned in planning

Collected rainwater can be used for miscellaneous water uses such as flushing of toilets and irrigation water. Therefore, when a water supply system for non-potable uses is developed, roof area and rainfall data will be needed to size the system. For districts, large developments and cities matching supply and demand of water can be a challenge. A full-scale plan for supplying water for non-potable purposes is required.

2.2.2 Artificial rain-Current efforts and future plans

Since the research on artificial rain was started in 1955 by the Meteorological Research Institute (MRI) of Korea Meteorological Administration, more than 10 air and ground experiments have been completed. MRI and KOWACO have jointly established a Long-Term Master Plans for Utilizing Artificial Rain. Based on the Master Plan, the technology of artificial rain is being refined for practical use. In the future, weather controlling technologies including numerical rainfall prediction models, drought mitigation, hail preventing, and fog dispersing will be developed. Thereafter, based on the assessment results of experiments, equipment and human resources will be employed. The basis of utilizing artificial rain will be built through technological support and exchange with the Hydro-Electric Corporation(HEC) of Australia and professional organizations in the United States. Exclusive flight and observation equipment have been secured for promoting and putting into practice the artificial rain technology.

2.3 Leading Thinkers and Experts

2.3.1 Governmental groups

Ministry of Construction & Transportation

Ministry of Environment

2.3.2 Local government

Regional Construction Management Office

River Watershed Environmental Management Office

River Environmental Management Office

2.3.3 Public corporations

Korea Water Resources Corporation

Environmental Management Corporation

2.3.4 Mooyoung, Han

Professor, Seoul National University, Seoul, Republic of Korea

Professor Mooyoung Han is working on decentralized rainwater management and has been successfully involved in many projects, initiating the NGOs and public to consider rainwater management as one aspect of proactive and multipurpose water management practice. He is also assisting local governments in revising the law about water policies to include rainwater as an important water resource that should be properly managed and respected. He also has offered support and funds for many researchers and students to promote rainwater harvesting and has been successful in signing Memoranda of Understanding with developing countries as well as with developed nations like Japan and Germany to work jointly on projects in these areas of research.

Email: myhan@snu.ac.kr

2.4 Innovative wastewater management practices

2.4.1 Water Environment & Remediation Research Center

The Water Environment & Remediation Research Center is promoting research and development in the areas of water environment and environmental remediation. The major focus of the ongoing research activities is directed toward developing advanced water treatment processes, innovative biological treatment. The center also carries out cooperative research with industry, universities and government.

The centre is conducting research in the area of advanced wastewater treatment including the nutrient removal of small and decentralized wastewater, wastewater treatment with sponge media (SAT process) advanced biochemical wastewater treatment technology. For further information contact: Yong-Soo Choi

Email : yschoi@kist.re.kr

2.4.2 In-Facility Water Reuse

The Korean government has regulations on in-facility water reuse for buildings over 60,000m2 of total floor space. (Korean Ministry of Construction and Transportation, via Noh, et al, 2004)

2.4.3 Taesung Environmental Technology (TASET)

TASET (Taesung Environmental Technology) is involved in activities like Non-Metal Sludge Collector, Surface & Submersible Aerators, Dissolved Air Flotation, Screens, and Sand Filters in the city of Ansan. The details are to be found at website, http://www.taset.com/e_about01.htm

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Japan

3.1 Practice

Japan's relatively wet climate provides the country with considerable freshwater supplies. Water use in Japan is distributed for household use (18.4%), industrial use (17.4%), and agricultural use (64.1%). Lakes are a vital source of water for all of these uses.

In Japan, reclaimed wastewater is used for toilet flushing, industry, stream restoration and flow augmentation to create "urban amenities" such as green space (Asano, Maeda, Takaki, 1996). During the early 1980s, the Tokyo branch of the United Nations University conducted a special study on ecological engineering and integrated farming systems in China (Chan, 1993). Interest in these systems has been renewed. Recently, the Integrated Bio-Systems conference, jointly organised by the Institute of Advanced Studies (IAS) of the United Nations University (UNU-Tokyo) and the UNESCO Microbial Resource Centre at Stockholm, as an activity of the UNU/Project Zero Emissions Research Initiative, focused on the recovery and reuse of biological waste.

Source: http://www.idrc.ca/uploads/user-S/10276258240report27.doc

3.2 Research & Policy

3.3 Leading Thinkers and Experts

3.3.1 Murase, Makoto Ph.D.

Makoto Murase is the Chief of Rainwater Utilization Promoting Section, Sumida City Hall, Tokyo. He created the guidelines and subsidy systems program for rainwater utilization in Sumida City (1995). He contributed to establishment of the liaison council for local governments of rainwater utilization (1997) and contributed to "Rainwater Utilization Forum for Local Governments and Citizens" as vice secretariat (1998). He has advised Taiwan public officials about the design of rainwater utilization for Taipei Zoo, Taiwan (2000) and established the Rainwater Museum in Sumida City by People for Promoting Rainwater Utilization. (May, 2001). He wrote the book "Rainwater and You" in 1994 which was originally written in Japanese but later translated into English, Chinese, Korean, Portuguese, Vietnamese and published in Japan, China, Korea, Brazil and Vietnam respectively. Persian and Arabic version are expected in coming years.

Email : murase-m@jcom.home.ne.jp

3.4 Innovative wastewater management practices

Regarding wastewater reuse, in many Japanese cities onsite systems that recycle water for toilet flushing are required for buildings over a certain size. The treatment units are typically located in the building basement. System costs are considered cost-effective because potable water is in short supply.

Water reuse systems in Japan focus on urban reuse, including fairly small scale systems, because urban uses can afford higher costs for reclaimed water in the face of substantial water supply constraints in many areas. Uses include toilet flushing in high-rise buildings, industrial reuse, and stream flow augmentation for urban amenities. In some cities, reuse for toilet flushing is mandated in buildings over 3,000 – 5,000 square meters. Over 1,475 individual building or block-scale wastewater treatment and reuse systems for toilet flushing have been built as reported by Ogoshi et al in 2001.

3.4.1 In-facility Water Reuse Regulations

The governments of Tokyo and Fukuoka have regulations on in-facility water reuse for buildings over a certain size or over a certain daily water use. (Yamagata, 2002)

3.4.2 Foundation of IETC

From the UNEP-IETC website:

"In May 1991, UNEP's Governing Council took a decision to further strengthen UNEP's role in sustainable urban and freshwater basin management by calling for the creation of an International Environmental Technology Centre (IETC). The Centre was inaugurated in October 1992 in Japan and its offices in Osaka and Shiga officially opened in April 1994.

"IETC's projects on fresh water are being implemented by cooperating with International Lake Environment Committee Foundation (ILEC). Collaborations with other relevant organizations are also sought. International Water Association (IWA) provided suggestions to develop the scope and framework of these projects. Japanese Sewage Works Association (JSWA), Infrastructure Development Institute of Japan (IDI) and relevant Ministries of Japan provided useful information on the current practices in developing countries. Finally, IETC has established a collaborative partnership with UNDP - World Bank's "Water and Sanitation Program (WSP)" so that IETC's "Source Book" and "Resource Guide" will be complementary and comprehensive each other."

More information at http://www.unep.or.jp/ietc/background/Index.asp.

3.4.3 United Nations University/Project "Zero Emissions Research Initiative"

The conference on Integrated bio-systems jointly organized by the Institute of Advanced Studies (IAS) of the United Nations University (UNU-Tokyo) and the UNESCO Microbial Resource Centre at Stockholm, as an activity of the UNU/Project "Zero Emissions Research Initiative" focused on the recovery and reuse of biological waste.

For more information contact: Jacky Foo

E-mail: jacky.foo@gmail.com

Website: http://www.ias.unu.edu/research_prog/unuzeri/Default.html

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Singapore

4.1 Practice

An island city-state, the Republic of Singapore has a total land area of 648 km2. The primary domestic source of water in Singapore is rainfall, collected in reservoirs or water catchment areas. Additional water is from Malaysia. Water recycling (producing NEWater – the brand name for reclaimed water produced by the Singapore Public Utility Board) and desalination plants have been implemented. Thie so-called "four tap" strategy is intended to diversify water sources and reduce the need for foreign supply.

In An Integrated Approach for Efficient Water Use in Singapore, Senior Engineer George Madhavan noted, "About half of Singapore's land area is used for water catchment and all available major surface water resources have been developed. Surface run-off is collected in 14 impounding reservoirs, treated at six treatment plants and thereafter distributed through a network of 14 service reservoirs and more than 4,850 km of pipelines to serve the entire population."

Singapore is aggressively moving towards newer systems including a deep tunnel sewage system to ultimately retire the six wastewater treatment plants. According the Singapore Public Utility Board website, the system includes a "48 km north tunnel stretching from Kranji to Changi, a water reclamation plant with a capacity of 176 million gallons (800,000 cubic metres) per day, a 5 km sea outfall at Changi, and some 60 km of link sewers." Wastewater from this system will be treated and released in the Singapore Straits or diverted into NEWater plants for indirect and non-potable uses.

In 2008 Singapore held the grand opening for a barrage placed across the opening of Marina Bay. This barrage with tide gates will create a reservoir at the estuary of three Singapore rivers, creating a huge freshwater reservoir, control storm surges and flooding, establish a reliable lake level, and enhanced recreational opportunities. Once operational, this will increase the rainfall catchment to two-thirds of the country's surface area and provide significant new supplies for all water uses including potable.

4.2 Research & Policy

The Public Utilities Board (PUB) is the national water authority and has a priority to facilitate and participate in new research on water technologies.

More information at http://www.pub.gov.sg/Pages/default.aspx

4.2.1 The Research, Innovation and Enterprise Council (RIEC)

Lee Hsien Loong, Chairman of the RIEC

The RIEC approved three strategic research programmes: Biomedical Sciences Phase II; Environmental and Water Technologies; and Interactive and Digital Media. These three sectors target to provide a total of 86,000 jobs with value added of $30 billion by 2015.

To build up a concentration of research talent to foster innovation and creativity, the RIEC approved the concept to establish a Campus for Research Excellence and Technological Enterprise (CREATE), and the proposal to set up the Singapore-MIT Alliance for Research and Technology (SMART) Centre as the first centre within the Campus.

The RIEC emphasised the importance of building strong linkages with global institutions to enhance Singapore's connectivity to other centres of research in the US and Europe, and accelerate Singapore's thrust towards an inventive, innovative and entrepreneurial economy.

The RIEC held its second meeting from 15 to 16 March 2007 in Singapore.

More information at http://www.nrf.gov.sg/nrf/councilBoard.aspx?id=160

4.2.2 The International Development Research Centre (IDRC)

A public corporation created by the Parliament of Canada in 1970 to help developing countries use science and technology to find practical, long-term solutions to the social, economic, and environmental problems they face. Support is directed toward developing an indigenous research capacity to sustain policies and technologies that developing countries need to build healthier, more equitable, and more prosperous societies. The IDRC established a regional office in Singapore in 1971.

Email: asro@idrc.org.sg

Web: www.idrc.org.sg

4.3 Leading Thinkers and Experts

4.3.1 Madhavan, George

George Madhavan is a Senior Engineer in the Water Department, Public Utilities Board (PUB) of Singapore. According to Madhavan, "given Singapore's limited water resources and increasing water demand, adopting an integrated approach to use water efficiently is an integral part of the water supply management policy. The present unaccounted-for water figure of 4.7% and a low per capita consumption is testimony to the effectiveness of the measures adopted. The PUB will continue to strive and look into new ways to ensure that water is used wisely and efficiently. This is to ensure that the island of Singapore will continue to have an adequate supply of water to meet its future needs".

He is posted as Director of Corporate Develeopment for PUB.

Email: george_madhavan@pub.gov.sg.

4.4 Decentralized wastewater management in Singapore

4.4.1 Reports and Publications

Tchobanoglous, G. The strategic importance of decentralized wastewater management in the twenty-first century. Proceedings IDA Conference on Water Reuse and Desalination, Singapore (CDRom) Feb 25-26, 2003

4.5 References

Lee, Poh Onn (2005). Water Management Issues in Singapore. Paper presented at Water in Mainland Southeast Asia workshop. Retrieved from http://www.khmerstudies.org/events/Water/water.htm

Madhavan, George (1999). An Integrated Approach for Efficient Water use in Singapore, Proceedings of the International Symposium on Efficient Water Use in Urban Areas - Innovative Ways of Finding Water for Cities, Session 7, June, 1999. http://www.unep.or.jp/ietc/publications/reportseries/ietcrep9/ (Accessed in March 2008)

Hong Kong

5.1 Practice

Providing an adequate water supply for Hong Kong has always been difficult because there are few natural lakes, rivers or substantial underground water sources. The annual rainfall averages 2,214.3 millimetres but this is insufficient to meet current demands — the average daily consumption of potable water during 2002/03 being 2.63 million cubic metres. The principal functions of the Water Supplies Department are to collect, store, purify and distribute potable water to consumers, and provide adequate new resources and installations to maintain a satisfactory standard of water supply. The department also supplies seawater for flushing.

Dongjiang is Hong Kong's major source of water, and will meet all future increase in demand. In 1960, the agreement was reached with the Guangdong authorities whereby Hong Kong would purchase 23 million cubic metres of water each year. The supply from Guangdong stipulated under the latest agreement was increased to 810 million cubic metres a year in 2003. This will continue to increase by 10 million cubic metres per annum up to 2004, beyond which the annual supply quantity will be subject to further review. The designed maximum capacity of the supply system is 1.1 billion cubic metres per annum. The supply contract, costing HK$2 billion a year, has helped the city's economy grow without the interruption of a water shortage, although the payment constitutes only 0.15 per cent of Hong Kong's HK$1.3 trillion gross domestic product.

5.2 Research & Policy

Many economies have shifted production away from water-intensive industries such as steel production or chemical manufacturing, to industries such as service provision, telecommunications and computing. This has fuelled a further divergence between economic production and water use. Hong Kong, for example, has doubled its economic productivities per unit of water use over the past 30 years.

5.3 Leading Thinkers and Experts

5.3.1 Whyte, Fergal

Fergal Whyte, Arup

In the "Cities of the Future" – Urban Sustainability and Water" workshop – convened by CDM, the global consulting- engineering-construction-operations firm in collaboration with the International Water Association (IWA) as part of the technical programme of IWA's World Water Congress 10-14 September 2006 in Beijing – explored emerging, visionary concepts that relate urban sustainability to sustainability in the water environment, treating them as an integrated whole. In this workshop, Whyte described recent planning of new cities to address the phenomenon of urbanization, with environmental and social sustainability at the core of planning whilst also responding to the needs of economic growth and demographic trends. One example is the Dong Tan Eco City on Chongming Island near Shanghai, scheduled to commence construction in 2006 - 07. Some key elements of "water sustainability" in these new cities include limiting total water consumption, ensuring a supply of non-potable water is available for non-potable uses to make the best possible use of precious water resources, treating waste water to a standard suitable for its re-use for non-potable uses, and returning water to the environment only when it has been treated to an acceptable standard. "One of the key benefits of achieving these objectives is a natural healthy environment in which access to clean water plays a major part."

5.4 References

Chau, K. (1993). Management of limited water resources in Hong Kong. International Journal of Water Resources Development, 9(1), 65-73.

Whyte, Fergal (2006). Examples of New Approaches in Sustainable Water Resource Planning in Cities in the East Asia Region. A presentation to the Cities of the Future – Urban Sustainability & Water workshop, IWA World Water Conference, Beijing, China. Retrieved from http://www.iwahq.org/templates/dynamic/Conferences/ConferenceA.aspx?ObjectId=647568

India

6.1 Practice

According to the United Nations Environment Programme, "the National Water Policy of India states that water is a prime natural resource, a basic human need and a precious national asset. It recommends that water resources planning be done for hydrological units, such as drainage basins or sub-basins. As far as possible, the projects should be planned and developed as multipurpose projects. Provision for drinking water should be given priority over other uses of water. The integrated and coordinated development of surface and ground waters and their conjunctive use should form an essential part of all water resources development projects, with recycling and re-use of water being an integral part of water resources development. Emphasis is placed on the preservation of the quality of the environment and ecological balance in planning, development and operation of water resources projects. The National Water Policy stresses the use of freshwater augmentation technologies as one means of alleviating India's chronic water shortages."

6.1.1 Best practice on water in India

This case study describes a community water and sanitation project in the Cuddalore district of India. The project was selected as an example of best practice due to several aspects including:

- A demand-driven approach with community participation and demand driven gender balanced approach at all levels
- Well-formed grassroots-level institutions to carry on the program after the project was completed
- Training initiatives that included of Government staff
- Evidence of replication by other villages
- Increasing numbers of women taking leadership roles and demonstrating attitudinal changes
- Recognition of the importance of cost sharing and its effectiveness within community members (Sakthivel, 2004)

6.2 Research & Policy

The Ministry of Water Resources estimates average annual precipitation at 4000 Billion Cubic Metres (BCM) in the country. After accounting for natural processes of evaporation, etc. the average annual water availability in the country has been assessed at 1869 BCM. 1123 BCM is considered utilizable as surface or ground water, of which 681 BCM are being used.

Each State government undertakes the development and management of water resources within the State – these include creation of storage, restoration of natural water bodies, rainwater harvesting, groundwater recharge, and system management practices. In 2009, the Ministry reported that 225 BCM of storage have been created to date, with an additional 64 BCM of storage under construction. An additional 108 BCM of storage is in the planning and investigation stage. State governments are also responsible for the conception, planning, and implementation of irrigation projects and other schemese for utilization of water resources.

The national government provides assistance to the State governments through financial and management strategies, as well as encouraging conservation and maximal use of existing resources. (Press Information Bureau, 2009)

6.3 Leading Thinkers and Experts

6.3.1 Narain, Sunita

A dynamic advocate for water, environment, human rights, democracy and health, received the 2005 Stockholm Water Prize. Narain is the director of the Centre for Science and Environment (CSE), an influential Indian non-governmental organization in New Delhi.

CSE received the Stockholm Water Prize for its efforts to build a new paradigm of water management, which uses the traditional wisdom of rainwater harvesting and advocates the role of communities in managing their local water systems. In its citation, the Nominating Committee lauded CSE, under the leadership of Ms. Narain, “For a successful recovery of old and generation of new knowledge on water management, a community-based sustainable integrated resource management under gender equity, a courageous stand against undemocratic, top-down bureaucratic resource control, an efficient use of a free press, and an independent judiciary to meet these goals.” (International Reference Center, 2005)

6.3.2 Khurana, Indira

Indira Khurana has several years of experience in dealing with documentation, research and policy related to decentralized water management in India. She has published several articles and books on the subject. Khurana is currently Director of Policy an Partnership with WaterAid India

Her book, Making Water Everybody’s Business: Practice and Policy of Water Harvesting, is an excellent resource on decentralized water management: Co-authors include Anil Agarwal, Sunita Narain and Indira Khurana, CSE publication.

Email: indirakhurana@wateraid.org

For more information visit: www.wateraid.org/india and www.cseindia.org

6.3.3 Swajaldhara

A government programme on decentralized drinking water supply in rural areas and gives guidelines as well. As of 2009, Swajaldhara is being replaced by the Rural Drinking Water (RDW) Programme.

Website: http://ddws.gov.in/swajaldhara.htm

6.3.4 Leading organizations

WaterAid

Water and Sanitation Management Organization

6.3.5 Indian Institute of Technology: Delhi

Centre for Rural Development and Appropriate Technology (RDAT) Contact: Professor Padma Vasudevan

E-mail: pksen@am.iitd.ernet.in

6.3.6 Khan, Ahmad Ali

Ahmad Ali Khan, executive engineer at Jamia Hamdard University, New Delhi, has played a key role in developing, implementing and sustaining a 100-acre , diverse rainwater harvesting project at Jamia Hamdard University. The overall water management system of the University includes greywater recycling and a regulating system for tapwater use through the campus.

For more information visit: http://www.rainwaterharvesting.org/Urban/jamia.htm

6.3.7 Agarwal, Anil

Anil Kumar Agarwal, the founder of the Centre for Science and Environment (CSE), spearheaded the Jal Swaraj campaign, a comprehensive strategy to further the impact of CSE programs. His thoughts, ideas and opinions remain the driving force behind the movement. Agarwal conceptualised and edited the CSE publications Dying Wisdom, which explores the tremendous potential of India’s traditional water harvesting systems, and Making Water Everybody’s Business, which documents water harvesting technologies that are being practiced even today by communities in various parts of the country. These two widely-read books have gone a long way in putting the issue of community-based water management on the national agenda.

6.3.8 Bhatnagar, Madhu

Head of Environment and Value Education at the Shri Ram School in Vasant Vihar, Delhi, Madhu Bhatnagar is spearheading the campaign for better environment by mobilising students. Under her leadership, a rainwater harvesting system has been installed on the rooftop of the school.

6.3.9 Saigal, Krishan

Dr Krishan Saigal is a retired Civil Service officer, whose interest in the concept of rainwater harvesting began when he was heading the International Ocean Institute, an NGO promoting sustainable development of oceans and coastal areas. He initiated a number of roof-top rainwater harvesting projects in Dalit villages in Tamil Nadu, and as the head of the Panchsheel Cooperative House Building Society Limited, Saigal convinced the Society to implement the first rainwater harvesting system in a residential colony in New Delhi.

6.3.10 Jal Bhagirathi Foundation, Jaipur

Jal Bhagirathi Foundation is a trust committed to the principle of participatory management, where the work belongs to the community with the role of JBF being limited to that of a catalyst and facilitator.

Website: http://www.jalbhagirathi.org

6.3.11 DHAN, Madurai

Development of Humane Action (DHAN) Foundation, a not-for-profit development organisation, was initiated in October 1997 and incorporated under Indian Trusts Act (1882), in January 1998. DHAN Foundation is a spin off institution of PRADAN (Professional Assistance for Development Action based at New Delhi) one of the country's foremost development agencies. The Trust has been promoted with an objective of bringing highly motivated and educated young women and men to the development sector so that new innovations in rural development programs can be brought and carried to vast areas of the country and the people, especially the poor.

Website: www.dhan.org

6.3.12 S. Vishwanath

Rainwater Club

The Rainwater Club focus on the ancient technique of rainwater harvesting is fast reemerging on the development sector front as a potential weapon for 'water security' of people, villages and industries. It is related to soft path since it encourages water conservation and conduct workshops and training programs on rainwater harvesting and ecological sanitation.

Email:zenrainman@gmail.com

website: http://www.rainwaterclub.org/index.htm

6.3.13 The International Development Research Centre (IDRC)

Regional Office for South Asia

Email: saro@idrc.org.in

Web: www.idrc.ca/saro

6.4 Status and Professionals for Decentralized Wastewater Management

In India, like many developing nations, planning for domestic wastewater reuse is one area that has not received adequate attention, and to compound the problem, many existent treatment facilities are in poor repair (Chawathe and Kantawala, 1987). There are also cases where a mechanised waste management approach has replaced a low-tech or traditional solution, only to malfunction and cease to operate effectively (Lewcock, 1995).

In India, wastewater is currently being used for irrigation, gardening, flushing, cooling of air conditioning systems, as a feed for boilers, and as process water for industries (Chawathe and Kantawala, 1987). On-site sanitation has been accomplished through a variety of low-cost measures from bucket latrines to cess-pits, to composting toilets. Bucket latrines and manual collection systems are still in use today; however manual collection and disposal methods (i.e., the "conservancy system") are being phased out. (Giles and Brown, 1997).

Source: http://www.idrc.ca/es/ev-6540-201-1-DO_TOPIC.html

6.4.1 Research and Practice

6.4.1.1 Decentralized Waster Water Treatment – DEWATS

The Consortium for the Dissemination of Decentralized Wastewater Treatment Systems in India (CDD), is a network of private and public entities that developed and disseminated low-input modular water recycling systems for applications in settlements as well as in small and medium entities. Member organizations of the network operate throughout India and have successfully adapted DEWATS for a variety of target groups and circumstances.
Challenges for CDD is to meet the increasing demand for wastewater treatment in rapidly growing urban areas, integrate decentralized wastewater treatment in urban development planning and to maintain high quality standards of products and services.
The Municipality of Pune (PMC) is currently preparing a City Development Plan that will enable the city to submit a project proposal under the National Urban Renewal Mission. Within the City Development Plan, sustainability of basic services for the poor is a critical issue to be addressed.

BORDA and its network of partner organisations started in 1994 to develop reliable and cost-efficient wastewater treatment systems which could efficiently treat non-toxic organic wastewater according to legal environmental standards.

Today, more than 1000 stakeholders from the private sector, governments and NGOs have been trained by the BORDA-Network to facilitate dissemination, implementation and maintenance of DEWATS system resulting in the sustainable operation of more than 250 DEWATS plants.

DEWATS is a technical approach rather than merely a technology package. DEWATS applications are based on four basic technical treatment modules which are combined according to demand:

Primary treatment: sedimentation and floatation

Secondary anaerobic treatment in fixed-bed reactors: baffled upstream reactors or anaerobic filters

Tertiary aerobic treatment in sub-surface flow filters

Tertiary aerobic treatment in polishing ponds

DEWATS Donors & Sponsors
Commission of the European Union (CEU)
German Federal Ministry for Economic Cooperation and Development (BMZ)
Free Hazseatic City of Bremen (LafEZ)
Australian Agency for International Development (Ausaid)
Water and Sanitation Program SEA (The World Bank)
Website: http://www.bordasa.org/modules/cjaycontent/index.php?id=28#partnernetwork

6.4.1.2 BORDA-Bremen

Bremen Overseas Research and Development Association founded as non-profit organization in Bremen, Germany in 1977. The mission is to improve the livelihoods of disadvantaged groups within societies and to sustain the functioning of eco-systems through dissemination of demand oriented Basic-Needs-Services in the fields of decentralized sanitation, water- and energy supply as well as solid waste- and wastewater management.

Website: http://www.borda-net.org/modules/news/article.php?storyid=57

6.4.1.3 EXNORA International Foundation

EXNORA was established in 1989. EXNORA stands for EXcellent NOvel and RAdical ideas and its main emphasis has been on the generation of innovative ideas and implementing them, which would help transform the society. EXNORA, in the past ten years, has promoted the LIASE (Local Initiative and Self Help) concept in areas of environmental management and pollution control among citizens, with specific reference to Municipal Solid Waste Management.

The fundamental objective of EXNORA is to act as a catalyst in bringing about local initiative and community participation in overall improvement in quality of life. EXNORA encompasses several cities, towns and villages in the country. Over the years, EXNORA has grown from an anti-garbage campaign to a full-fledged people's movement for environmental protection and management. Some of EXNORA's major activities include Solid Waste Management, Citizens' Waterways Monitoring Programme (WAMP), Community Sanitation Improvement Projects, STudent Environment Programme (STEP), Tree Planting, Vegetable Roof Gardening and Rain Harvesting.

Email: exnora@gmail.com

Website: www.exnorainternational.org

6.4.1.4 FEDINA

The Community Based Sanitation and Slum Development (CBS-SD), India Programme aims at improving the living conditions of poor people living in urban and peri-urban slums in Indian Cities. The programme is marked by the implementation of CBS combined with DEWATS. On the Social front, this programme initiates the self-organization of the target community, thus building the community's capability to independently develop future projects for the improvement of living conditions.

Website: http://www.borda.de/homepages/india/fedina/

E-mail: fedina@iqara.net

6.4.2 Reports and Publications

Buechler, Stephanie. Local Responses to Water Resource Degradation in India: Groundwater Farmer Innovations and the Reversal of Knowledge Flows. The Journal of Environment & Development, 2005, Vol. 14, No. 4, 410-438

This study focused on farmer innovation in the face of the triple dynamic of groundwater depletion, water resource degradation, and increased supply of water in the form of urban wastewater used for irrigation. The research project analyzed innovative management practices of groundwater farmers near Hyderabad to cope with the problems and garner the benefits of increased wastewater availability. Groundwater farmers actively engaged in a constant process of innovation in cropping patterns, agricultural practices, water and electrical power-water management strategies.

Report available at: http://jed.sagepub.com/cgi/reprint/14/4/410

Contact : Stephanie Buechler

Email: stephbuechler@yahoo.com

6.5 References

Sakthivel, S. Ramesh & Fitzgerald, Roger (2004). The Soozhal initiative: A model for achieving total sanitation in low-income rural areas. Water and poverty – The realities, Water for all publication series 5. Asian Development Bank, eds. Retrieved from http://www.adb.org/Documents/Books/Water_for_All_Series/Water_Poverty_Realities/default.asp

Chawathe, S. D. & Kantawala, D. (1987). Reuse of water in city planning. Water Supply 15 (1): 17-23.

Giles, H. & Brown, B. (1997). And not a drop to drink. Water and sanitation services in the developing world. Geography 82 (2): 97-109.

International Reference Center. (2005). CSE of India wins 2005 Stockholm Water Prize. Retrieved from http://www.irc.nl/page/17531

Lewcock, C. (1995). Farmer use of urban waste in Kano. *Habitat International* 1995, 19 (2): 225-234.

Press Information Bureau, Government of India. (2009) Water flowing in the SEA. Press release December 16, 2009. Retrieved from http://www.pib.nic.in/release/release.asp?relid=56010

Rose, Gregory D (1998). *CFP Report 27: Community-Based Technologies for Domestic Wastewater Treatment and Reuse: options for urban agriculture*. Retrieved from http://www.idrc.ca/es/ev-6540-201-1-DO_TOPIC.html

United Nations Environment Programme, Division of Technology, Industry and Economics. (1998). *Sourcebook of Alternative Technologies for Freshwater Augmentation in Some Asian Countries*.

Pakistan

7.2 Research & Policy

The Pakistan Council of Research in Water Resources was established in 1964 under the name of Irrigation, Drainage and Flood Control Research Council (IDFCRC) within the Ministry of Natural Resources. It was brought under the control of Ministry of Science and Technology in 1970. The Council was renamed as Pakistan Council of Research in Water Resources (PCRWR) in 1985. PCRWR is a national research organization with the objective to conduct and promote research in all aspects of water resources. The Council is headed by a Chairman appointed by the Ministry for tenure of three years. The Chairman is assisted by a Technical Advisory Committee under whose guidance technical policies are designed and implemented. General administrative and financial policies are implemented under the instructions of the Ministry.

The council has undertaken a number of rainwater harvesting, groundwater recharge, and desalination projects, in addition to research, mapping, and analysis of national water resource and needs.

Website: http://www.pcrwr.gov.pk/

7.2.1 Pakistan Engineering Council

The Pakistan Engineering Council is a statutory body constituted in 1976. Some of its statutory functions relate to recognition of engineering qualifications for the purpose of registration of professional engineers and consulting engineers and promotion of engineering education, safeguarding the interests of its members and fostering of high professional standards in the country.

Website: http://www.pec.org.pk/

7.2.2 Pakistan Water Gateway

The Pakistan Water Gateway is intended to enhance access to information related to water resources and issues in Pakistan available on the World Wide Web. It is a pioneering web-based knowledge product archiving information on a range of such issues pertaining to Pakistan.

Essentially, the Pakistan Water Gateway is a reference repository for an evolving body of knowledge. It hopes to link national stakeholders - government, civil society, media, experts, donors and the general public - with their global counterparts, weaving a web of information and experience sharing.

The gateway addresses water as a resource in its many dimensions, serves to assess and disseminate shared experiences, publicize policies and guidelines and facilitate cooperation on water issues.

It provides links to the current national and international programmes and resources on water and serves as an interactive point for sharing and browsing web-sites of water-related organizations, government bodies and NGOs. The site also contains papers on critical issues and the learning of experts and institutions working on water-related themes, as well as the experience of communities in this regard.

Email: Shahzad@isb.sdnpk.org

Website: http://www.waterinfo.net.pk/

7.3 Leading Thinkers and Experts

7.3.1 Pakistan Council of Research in Water Resources

The Council sponsors regional offices throughout the country that specialize in regional water resources and needs, in addition to two national offices in Islamabad.

Website: http://www.pcrwr.gov.pk/

7.3.2 Inter-Islamic Network on Water Resources Development and Management (INWRDAM)

INWRDAM was established in 1987 as a water policy, applied research, and collaboration think tank. Projects include initiating joint research and development projects, helping member states with capacity building, and rendering consultant and adviser services for water development and management.

INWRDAM member states at present are composed of eight countries i.e Bangladesh, Egypt, Jordan, Mali, Niger, Pakistan, Tunis and Turkey. INWRDAM is a professional platform to the Islamic Countries for the exchange of information, knowledge and expertise in the water sector. Member states of the network coordinate and collaborate in activities to ensure proper planning of water resources, development, effective management, proper utilization and conservation of water resources as required for future economic growth in Islamic countries. Pakistan (with PCRWR as its agent) became a member in 1993 has conducted international workshops in 1998 and 2001 in which Water Resources Experts from different Islamic countries participated.

Website: http://www.inwrdam.org/

7.4 Scope of Decentralized wastewater management

7.4.1 Publications

Hasan, Dr. Arif. The Role of Mapping in the Development of a Decentralized Wastewater and Sewage System: The Case of Karachi. Workshop for Benefits and Responsibilities of Decentralised and Centralised Approaches for Management of Water and Wastewater, Stockholm International Water Institute

Nepal

8.1 Practice

From the UNEP Sourcebook of Alternative Technologies for Freshwater Augmentation in Some Asian Countries:

Although Nepal has one of the world's largest per capita water resources, most of the population does not have easy access to safe drinking water and, at times, there are acute shortages of water for all economic purposes. Urban settlements are mostly affected by the shortage of water whereas, in the rural areas, the problem is linked to lack of accessibility of water. The main sources of water in the country are rivers and springs in the hilly regions, and shallow and deep groundwaters in the Terai. Due to the shortage of water from the municipal supplies in the urban settlements, primarily in the Kathmandu Valley, there is a trend toward illegal extraction of underground water using shallow and deep wells, thereby lowering the water table and leading to the possibility of land subsidence and foreseeable tectonic effects. Associated problems are the decline in the yield and productivity of wells and the increasing incremental cost of lifting water from ever-increasing depths. For these reasons, Nepal has identified freshwater augmentation technologies to protect both water quantity and water quality to the extent possible.

Alternative technologies include the use of traditional technologies such as stone spouts and Pokharis, which were the only sources of water in the Kathmandu Valley in the past. However, there is a need to conserve and restore the ponds, aquifers, wells and stone spouts which have been neglected. Conservation and restoration of stone spouts and Pokharis is related to spring development and protection. Spring protection technologies are widely used in the central and eastern hills of Nepal. These are simple and ideal technologies for use where yield of the source is very low and water is drawn at the source itself. Likewise, rainwater harvesting has been popular where there are neither springs nor streams nearby to fulfill the water demand of the community.

Various distribution systems have also been developed in Nepal based upon traditional technologies. For example, bamboo piped water supply systems are not very common, but may prove an ideal system for remote areas where GI and HDPE pipes and fittings are not available and only bamboo is easily available and cheap. Use is also being made of hydraulic rams to pump water using the hydraulic power of the water itself, thus eliminating the need for diesel or electrical power to drive water pumps. The principle advantages of this system are its simplicity and lack of an energy cost in the operation of the system. This system is suitable in places where there is plenty of water, and the area to be supplied is situated at a lower level than the source area.

For more information:

http://www.unep.or.jp/ietc/publications/techpublications/techpub-8e/nepal.asp

8.2 Research & Policy

8.3 Leading Thinkers and Experts

8.3.1 Dr. Roshan Raj Shrestha

Chief Technical Advisor
Water for Asian Cities Programme
UN HABITAT - Nepal
UN House – Pulchowk
Email-mail: roshan.shrestha@undp.org

8.4 Decentralized wastewater management in Nepal

Promoting effective water management policies and practices - "Operational Research on Decentralized Wastewater Management and its Dissemination" is a part of Pilot and Demonstration Activities (PDA) program for water, the Asian Development Bank (ADB) managed program. This pilot and demonstration activity of Operational Research on Decentralized Wastewater Management and its Dissemination aims to demonstrate appropriate technologies for managing domestic wastewater, recycling the nutrient, and optimizing water at household level

Website: http://www.adb.org/Water/PDA/nep/pda-nep-200303.asp

8.5 References

Environment and Public Health Organization (ENPHO). (2005). Operational Research on Decentralized Wastewater Management and its Dissemination. Retrieved from http://www.adb.org/Water/PDA/nep/Project-Completion-Report-5-Nov-05.pdf

United Nations Environment Programme, Division of Technology, Industry and Economics. (1998). *Sourcebook of Alternative Technologies for Freshwater Augmentation in Some Asian Countries.*

Bangladesh

9.1 Practice

From the UNEP Sourcebook of Alternative Technologies for Freshwater Augmentation in Some Asian Countries:

From time immemorial, rainwater has been playing a significant role in the socio-economic life of Bangladesh. In fact, the entire agro-economic fabric of the country is built on the particular rainfall pattern (commonly known as the monsoon) occurring ion the country. Nevertheless, very few studies have been carried out on rainwater harvesting. Those that are available are studies by Hossain and Ziauddin (1992), Sarker (1994), and Uttaran (1995). The major constraint on the development of rainwater harvesting technologies is a low education level of the people and the poor economic condition of their households. The past studies have provided few innovations for users in the methods of collection and storage of rainwater. A joint Department of Public Health Engineering (DPHE) and UNICEF programme, that has been working in the southern area of Bangladesh since 1984 to provide better quality drinking water, has been reported that, despite filtering, the water remained salty during the dry season and that people did not want to use it. Of the 90 DPHE-UNICEF sand-filtration facilities serving communities of 50 to 60 users, 45% were found to be idle.

In contrast, rainwater harvesting by the erection of bunds around farms is the most common and one of the earliest methods of rainwater harvesting in Bangladesh. In this method, earthen bunds with height of 30 to 45 cm and width of equal dimensions are constructed around the field. Farmers have learned from experience to match their cropping cycle with rainfall pattern. Rainwater meets around 78% to 97% of land preparation water requirement for aman crops. In saline areas, rainwater is used in the aman paddies to dilute saline river water until the river water becomes sweet. Over the entire aman crop cycle, rainwater meets around 50% of water requirements with the residual being obtained from river water sources.

For more information: http://www.unep.or.jp/ietc/Publications/techpublications/TechPub-8e/bangladesh.asp

9.2 Research & Policy

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9.3 Leading Thinkers and Experts

9.3.1 PRISM-Bangladesh

Mr Mohammed Ikramullah,

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9.3.2 Publications

World Health Organization (WHO), Regional Office for South-East Asia. (1997). Arsenic in Drinking Water and Resulting Aresenic Toxicity in India and Bangladesh: Recommendations for Action. Retrieved from http://www.searo.who.int/

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Hossain, M.D. and Ziauddin, A.T.M. Rainwater Harvesting and Storage Techniques from Bangladesh, *Waterlines* 1992, January

9.4 Decentralized wastewater treatment

Duckweed is an aquatic macrophyte that is proving to be very efficient at the centre of a wastewater treatment system. Duckweed has a very high nutritional value of 35-45%, depending on the species, which makes it potentially profitable in for use in secondary processes (Skillicorn et al., 1993). Duckweed value, in terms of protein content, is similar to soybeans at $US 0.20/kg (1990 figures) (Oron, 1990, 1994). If grown on domestic wastewater free of heavy metals, duckweed can be used as an animal fodder and green fertiliser (Oron, 1990, 1994; Bonomo et al., 1997).

Duckweed-based systems work efficiently to actually suppress mosquito populations because duckweed forms a complete mat over the water surface that prevents mosquito larvae populations from reaching the water surface (Bonomo et al., 1997; PRISM-Bangladesh, 1998).

9.4.1 Duckweed-Based Pisci-culture: PRISM-Bangladesh

PRISM-Bangladesh, a non-government organisation based in Dhaka, Bangladesh, has developed a highly successful Duckweed (sp. Lemnaceae) cropping system for both domestic wastewater treatment and the production of fish protein (Skillicorn et al., 1993). PRISM has standardised and optimised the duckweed management and cropping system to treat the wastewater generated at the Kumandini Medical Complex in Mirzapur, Bangladesh. Experimental trials and data collection undertaken between 1989 and 1991 resulted in a strategy to optimise the production of duckweed for the cultivation of carp and tilapia and treat wastewater to a high efficiency.

Source: http://www.idrc.ca/es/ev-6540-201-1-DO_TOPIC.html

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Malaysia

10.1 Practice

10.2 Research & Policy

Malaysia sees rainwater harvesting as an answer to natural disaster. Prime Minister Datuk Seri Abdullah Ahmad Badawi has directed the Housing and Local Government Ministry to formulate a law by which water harvesting and storage systems would be required of all buildings, except for small, low-cost houses and other buildings.

10.3 Leading Thinkers and Experts

10.3.1 Mohamad Afifi Abdul Mukti

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10.3.2 Fatimah Mohd. Noor

Asst. Professor, Faculty of Civil Engineering, Universiti Teknologi Malaysia

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10.3.3 Publications

Rainwater Harvesting – An Opportunity Neglected, Water Malaysia 2005(10). Retrieved from http://www.mwa.org.my/?page=publication&act=read&cat=6&id=18

10.4 Decentralized wastewater treatment

Reuse and decentralization will be essential for meeting human needs for water and sanitation in both developing and developed countries. Membrane bioreactors (MBRs) will be an essential part of advancing such water sustainability, because they encourage water reuse and open up opportunities for decentralized treatment.

These were the conclusions of a Rockefeller Foundation-sponsored Team Residency held at the Bellagio (Italy) Study and Conference Center on April 23-26, 2003. The foundation invited 14 experts on membrane technology, water treatment technologies, and water sustainability from the United States, United Kingdom, Germany, Italy, Australia, Israel, South Africa, and Malaysia to explore the role of MBRs and other membrane processes in achieving sustainable water and sanitation. The foundation periodically brings together up to 14 participants from developed and developing countries to discuss topics of global importance. The format permits structured and unstructured time to explore common ground and forge shared solutions to tough challenges.

Website: http://www.scienceinafrica.co.za/2004/june/membrane.htm

10.4.1 Midaco (M) Sdn Bhd

MIDACO BI-ACT SCBA WASTEWATER TREATMENT SYSTEM

The BI-ACT SCBA WASTEWATER TREATMENT SYSTEM (Submerged Contact Biodisc Aerator) is compact and easy to operate. Skilled personnel are not required to operate the plant.

Address: 4080 AB, Jalan Sultan Yahya Petra
Kelantan, Kota Bharu 15200, Malaysia
Tel: 60-9-744-75-55

Email : proj@midaco.com.my

10.4.2 Pollution Engineerings (M) Sdn Bhd (PESB)

PESB undertakes turnkey projects for the Wastewater Treatment System (WWTS) and Domestic Sewage Treatment System (DSTS) which include design, fabrication, installation, construction, commissioning, operation and maintenance.

Website: http://www.pollution-engineering.com.my/index.html

Email : pesb@pollution-engineering.com.my

10.4.3 Chemical Waste Management

Specialists in turnkey water resource engineering (water and waste water treatment), solid waste management and infrastructure development projects in Malaysia.

Website: http://www.cwm.com.my/

Email : info@cwm.com.my

China

11.1 Practice in waste water technologies

China is phasing-out manual collection and disposal methods of wastes (i.e., the "conservancy system") (Giles and Brown, 1997). In China, 0.3 million tonnes of nightsoil are produced daily and collected by more than 200 million people; in most cases the nightsoil is transported out of the city for use as fertiliser in land-based agriculture or fish production (Bo et al., 1993).

China is one developing country that has made major advances in optimising approaches to recovering and reusing primary human and animal waste products to maximise production. Historically, China and Asia have always treated wastes as valuable resources - wastes are consistently returned to the environment to replenish earlier removal (Chan, 1993). The Chinese government has supported the emerging practice of ecological engineering that combines waste management with livestock rearing, aquaculture, agriculture and agro-industry, and uses locally-available natural resources in ecologically balanced systems for food production (Chan, 1993). Admittedly, sustainable traditions in China are under increasing pressure from industrialisation and urbanisation. However, as late as 1998, it appears that the Chinese government is actively promoting the efficient reuse of waste resources in integrated production systems such as aqua-culture (Wang et al., 1998). Currently, there are more than 2,000 active ecological engineering projects involving 10% of the Chinese population (Wang et al., 1998).

The formal and institutionalised system that has developed in China contrasts with the informal initiative that has transformed wetlands on the eastern edge of Calcutta, India, into a highly productive wastewater treatment and food production system. The Calcutta wetlands are more than 3,000 ha in size, and are the site of the world's largest traditional system for treating domestic wastewater and fertilising fish production ponds (Ghosh, 1991). Wastewater is purified through a variety of natural forces (chemical, physical and solar) which act synergistically to achieve wastewater treatment.

11.1.1 Biogas Technology

In China, the Chinese fixed-dome reactor has been widely used. Reports of built biogas digesters range from five to seven million (Nazir, 1991; Henderson, 1998). The cost in China to build a family size reactor from locally derived materials is approximately $US 80 (Henderson, 1988). The government has actively promoted the technology since the 1970s - mainly in rural areas.

11.1.2 Floating Aquatic Macrophytes

In a demonstration floating aquatic treatment system in Huangzhou City, China, Zhenbim et al. (1993) note that macrophyte systems appear to function as fixed film reactors with the root system (rhizosphere) acting as a substrate for bacteria to grow and decrease levels of BOD in the wastewater. Experiments have shown that bacteria and microorganisms are abundant in the subsurface (rhizosphere) of the macrophytes and that reductions occur as the water passes through the rhizosphere complex of the floating macrophytes (Zhenbim et al., 1993). These experiments demonstrated that BOD5, COD, TSS, N, P, viruses and bacteria could be greatly reduced and that the resulting water is suitable for use in irrigation and aquaculture.

In China, national policy has been developed that promotes the development of water efficient technologies, and encourages the reuse of reclaimed municipal wastewater in agriculture first, and then for industrial and municipal uses (Zhongxiang and Yi, 1991).

China has a several thousand year old history of using sewage-fed fish production as a part of a larger, and traditional integrated bio-recovery system, and that barriers regarding the use of human and animal waste in food production have apparently been bridged over the generations. However, it has been rumoured that China intends to phase out these systems because of health related issues as Japan and Taiwan have already done (Furedy, 1990).

Source: http://www.idrc.ca/es/ev-6540-201-1-DO_TOPIC.html

As the executive summary of this report states, "…emergent trends in low-cost, decentralised naturally-based infrastructure and urban wastewater management that promotes the recovery and reuse of wastewater resources are increasingly relevant. The concept of managing urban wastewater flows at a decentralised or 'intermediate' level, based on micro watersheds is explored. The reveals how innovative and appropriate technologies can contribute to urban wastewater treatment and reuse and reviews the effluent treatment standards that are currently accepted in order to protect public health and safety. The concept of planning integrated wastewater management strategies in conjunction with an urban agricultural 'waste-sink' is suggested as a rational approach to waste management and the conservation of valuable urban resources.

"A suggestion is made to integrate several of the basic Permaculture precepts the design of proposed wastewater treatment and resource recovery schemes where agricultural production is a central component. Two books are of note to aid in this research: Bill Mollison: Introduction to Permaculture and Permaculture: A Designers' Manual."

11.2 Research & Policy

China is ranked sixth largest in the world for the total amount of water resources. However, owing to the huge population, the annual water resources per capita are only about 1/4 of that in the world. Water scarcity becomes a restrictive factor in the social and economy development as well as the environment conservation in China

Water contamination control technologies and associated projects, one of the 12 major national special projects implemented during the 10th Five-year period(2001-2005), has worked on a range of key S&T issues concerning water contamination control, in an attempt to curb up the further deterioration of China's water environment.

Aiming at international cutting-edges and China's potential demands for water contamination control, a range of proprietary functional materials and innovative water treatment reactors were developed, including highly effective bacteria agents, nano-flocculant, molecular print absorbant, PE fiber pore membrane, aerobic reactor, anaerobic reactor, membrane bioreactor, and microwave plasma reactor. Of them, the nano-flocculant has been put into commercial applications, and exported in large volume.

Source: http://www.iwahq.org/uploads/sgs/sg%20on%20rainwater%20harvesting%20and%20management/full%20papers/Zhu%20Q-2.doc

Website links:

http://en.ndrc.gov.cn/policyrelease/t20050621_8427.htm
http://www.china.org.cn/english/China/188716.htm
http://www.fmprc.gov.cn/ce/cero/rom/kjwh/t156706.htm

11.3 Leading Thinkers and Experts

11.3.1 Zhu Qiang

Zhu presented "Integrated rural development with the rainwater harvesting approach" at the 5th IWA World Water Congress in September, 2006 at Beijing, China. He concluded that Rainwater Harvesting has been adopted since the late 1980 has brought about tremendous changes in the rural area of the dry mountainous area in China. In his paper, he also discussed the challenges that the RWH system is facing in the new millennium and the feasibility of meeting the goal of using RWH systems in an increasingly affluent society in China. He also discussed acceptable and affordable techniques for rural development.

Email: zhuq70@163.com

11.3.2 Li Yuanhong

Email: gsws@public.lz.gs.cn

11.3.3 Publications

Zhu, Q. and Li. Y. (2006). Effect of low-rate irrigation by rainwater harvesting on the dry farming, Poster presentation of the "Rainwater Harvesting and Management" Workshop, IWA Beijing 2006, (submitted).

Zhu, Q. and Li, Y. (2004). Rainwater harvesting – an alternative for securing food production under climate variability, Water and Science Technology 2004, 49(7): 157-163

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11.4 Wastewater management in China

11.4.1 Intermittent aerohydraulic gun (aeration gun, aeration water circulator)

This system mixes the epilimnion with the hypolimnion to improve the water quality of lakes and reservoirs.

Aeration water circulator research was conducted in China as part of a 2001 project by the Ministry of the Environment to study the applicability of decentralized water purification technologies of Japan to developing countries.

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Zhongxiang, Z. & Yi, Q. (1991). Water saving and wastewater reuse in China and recycle in China. *Water, Science & Technology*, 1991, 23 (10-12): 2135-2140.

Sri Lanka

12.1 Practice

The challenge of supplying adequate water and disposal of its excess to meet the societal needs and ensure equitable water access throughout the year, for citizens, both rural and urban, all fauna and flora, and other living forms, has been identified as one of the most critical problems facing the decision makers of Sri Lanka.

Presently Sri Lanka ranks high in the world in the annual renewable quantity of water, the rainfall volume being about 5900 cubic meters/capita, from which the annual discharge volume to sea is about 1400 cubic meters/capita, based on a population of 20 million.

12.2 Research & Policy

National Policy on Rain Water Harvesting in Sri Lanka was officially implemented on September 27, 2005 by the RWH Secretariat of the Ministry of Urban Development and Water Supply and the National Water Supply and Drainage Board jointly with the Lanka Rain Water Harvesting Forum.

Contact emails:

lrwhf@sltnet.lk (Office)

info@lankarainwater.org (Office)

The main objective of the National RWH Policy is to order to ensure that the 'City of Tomorrow' applies Rain Water Harvesting broadly, by the control of water near its source, in its pursuance of becoming a 'Green City' in the future.

12.3 Leading Thinkers and Experts

12.3.1 Ariyananda, Tanuja

Tanuja Ariyananda is the Executive Director of the Lanka Rain Water Harvesting Forum. Established at the beginning of 1996 by a small group of interested persons, the forum represents a range of government and non-government institutions. These include: the National Water Supply and Drainage Board (NWSDB), Intermediate Technology Development Group Sri Lanka (ITSL), Community Water Supply and Sanitation Project (CWSSP), Church of Ceylon, Board of Women's Work, NGO Water Supply and Sanitation Decade Services, Agrarian Research and Training Institute (ARTI) and the Open University.

Lanka Rain Water Harvesting Forum was officially launched on the 19th of March 1997 by the then Minister for National Housing and Public Utilities, Hon. Nimal Siripala de Silva as the chief guest. The Forum is registered under the companies act No. 17 of 1982 as a non - government, non profit making organisation under the Ministry of Social Services.

e-mail: tanuja@sltnet.lk (Executive Director)

Website: http://lankarainwater.org/

12.3.1 Bandaragoda, Tissa

Dr Tissa Bandaragoda, Former Regional Director (SEA) International Water Management Institute.

12.3.2 Samarakoon, Jayampathy

Dr Jayampathy Samarakoon, Team Leader, Integrated Resource Management Program (IRMP) for wetlands.

email: imp@ceanrm.ccom.lk

Thailand

13.1 Practice

Freshwater augmentation is practised in Thailand for three main purposes; namely, for agricultural, industrial, and domestic uses. The status of freshwater augmentation technologies in Thailand is summarized in Table below. The two most common and successful technologies are recycling of harvested rainwater in irrigation systems and rainwater harvesting for domestic rural water supply purposes.

TABLE. Status of Freshwater Augmentation Technologies in Thailand.

APPROACH	RAIN-FED SYSTEMS	MODERN SYSTEMS	TRADITIONAL SYSTEMS	INLAND FISHERY	INDUSTRY	RURAL
Recycling to maximize the use of existing resources	Planting suitable crops (e.g.,deep rooted beans) Planting cover crops	Well-known engineering techniques	Recycling among several small systems	Bottom dwelling fishes used to clean fish ponds	Well-known engineering techniques	Experimenatal desalination
Systems to augment existing sources	Traditional contour bunding	None known	Traditional bamboo or earthen weirs found throughout SE Asia		None known	Several facilities used (See the following Table).

Source: Sourcebook of Alternative Technologies for Freshwater Augumentation in Some Countries in Asia,

http://www.unep.or.jp/ietc/publications/techpublications/techpub-8e/thailand.asp

13.2 Research & Policy

Shifting waste resources up the food chain incrementally is one alternative in the search for methods to decrease acute public health risks and potentially avoid the sociocultural stigma associated with sewage-fed production systems. Barriers to a wide-scale use of waste-fed aquaculture remain in many parts of the world. The practice is still found in some Asian countries such as Thailand, China, and Vietnam. Furedy (1990) discourages abandonment of these systems and encourages their use in resource poor communities in conjunction with a high level of management for the protection of public health. She also suggests that sewage-fed fish production can be an asset to social development, and research only if the systems are designed as components of community development (Furedy, 1990).

13.2.1 Rainwater Harvesting - The Thai Rainwater Jar

Thailand's National Jar Programme, to supply of clean drinking water to rural areas, was launched in response to the United Nations' Water Supply and Sanitation Decade (1981-1990). The Program's objective was to promote the use of jars in rural households as a means of supplying clean drinking water. User participation was encouraged, although early in the program, rural poverty was endemic and villagers could only provide in-kind labour. Government subsidized the cost of research (to find suitable designs and construction techniques), training, and construction materials.

Jar construction techniques are similar to ferrocement tank construction techniques. The construction technique is simple and compatible with locally available skills. The technology has performed well as evidenced by its acceptance by the private sector; commercial jar manufacturers can be seen along highways throughout the country. Most rural households now have at least two jars, the service life of which is estimated to be 20 years.

Rainwater jars are successful in the rural areas of Thailand because the technology is simple, inexpensive and understandable to a majority of the rural population. However, this success depended on user and private sector involvement. Success also depends upon other factors; rainwater jars are not suitable everywhere.

Source: http://www.unep.or.jp/ietc/publications/techpublications/techpub-8e/jar.asp

13.2.2 Developments in Natural Sludge De-watering Technology

Water and Sanitation in Developing Countries (SANDEC) has recently undertaken a demonstration project in collaboration with the Asian Institute of Technology (AIT) in Bangkok, Thailand, to manage the sludge from on-site sanitation. The pilot demonstration will test the feasibility of using planted reed beds for sewage de-watering (Heinss and Koottatep, 1998). Developing small scale sludge de-watering systems in or near urban areas would increase the availability of organic inputs for local agriculture and reduce the need to haul sludge out of the urban environment (Strauss, Heinss and Montangero, 1998). The drawback of the system appears to be the large land requirements. The technology may, therefore, only be feasible where land can be secured or where decentralised systems are preferred (Heinss and Koottatep, 1998).

The most notable development derived from this research was an Upflow Anaerobic Filter (UAF) as an alternative to soak away septic tanks and space intensive septic leaching field. The UAF that was developed required no mechanical equipment and operation and maintenance were apparently simple. This is a potentially viable technology today in urban areas and its post-development impacts should be further explored. Based on the installation of the systems (sub-surface or above ground) it could be integrated into confined space neighbourhoods and service multiple households based on its design. The combined septic tank-UAF system was determined to be effective in removing microorganisms, particularly helminthic ova and bacteria from wastewater effluent. Currently, the septic tank-anaerobic upflow filter system is being used extensively in Thailand. The system is being used in newly constructed housing units that do not have access to central treatment plants. There are now several companies in Thailand and in the region that have commercialised this treatment system and now manufacture and distribute it. It is not apparent at this time to what extent the SIRDO has been implemented.

Source: http://www.idrc.ca/es/ev-6540-201-1-DO_TOPIC.html

13.3 Leading Thinkers and Experts

13.3.1 Sethaputra, Sacha

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13.3.2 Patamatamkul, Sanguan

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E-mail: sacha@kku1.kku.ac.th

13.3.3 Publications

Department of Health s.d. Manual for Caretakers of Village Pipe Water Supply Systems (Medium and Small Sizes), Rural Water Supply Division, Department of Health, Bangkok 2535. Department of Health s.d. Manual for Caretakers of Village Pipe Water Supply Systems, Rural Water Supply Division, Department of Health, Bangkok 2535.

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Jordan

14.1 Practice

Jordan faces significant water supply problems, but traditional systems of rainwater collection suggest possible decentralized solutions. The Family Cistern: 3,000 years of Household Water Collection in Jordan, presents background, current patterns of disuse, and future research and practice directions.

Source: http://istrianet.org/istria/architecture/urban/cisterns/cisterns-jordan.htm

14.2 Research & Policy

14.2.1 Gravel Water Filtration System

The main advantages of this system are its reliability, ease of operation and low maintenance costs. The gravel and filtration media is derived from local wadi and is therefore readily available and inexpensive. In addition to upgrading wastewater stabilisation ponds (WSP) effluent, variations of this system could be utilised on a small scale for urban wastewater treatment and also in combination with demand-accurate irrigation technologies such as closed-conduit systems (sprinkler, micro-sprinkler and drip irrigation) where suspended solids and algae need to be at minimum to prevent clogging of the pressurised system (Hillel, 1987; Bartone, 1991). In the Middle East and other arid and semi-arid regions, the combination of low-cost WSP treatment, effluent upgrading systems, such as the rock and gravel filter system and demand-accurate irrigation systems should be further studied for combination with urban and peri-urban agricultural production.

14.2.2 Wastewater from Olive Mills

The UASB technology is a viable technology for hot, arid regions such as the Middle East and can be effectively implemented in the treatment of wastes with extremely high BOD. This approach can increase the wastewater quality to an acceptable standards and allows for its discharge into municipal sewerage systems. Combining this technology with aerobic lagoons offers a high level of treatment for wastewater and sludge. Opportunities exist to reclaim these treated wastes as opposed to disposing of them, for use in agricultural production. In addition, the continued support in the development of low-cost, on-site alternatives for the treatment of industrial wastes is essential to the protection of existing surface and ground water supplies in the developing world. Facilitating, low-cost, industrial waste treatment to, at least, secondary standards prior to discharge, or totally separating combined domestic and industrial waste treatment, will enable incremental measures to utilise the less toxic domestic waste stream in a variety of agricultural production and landscape irrigation schemes.

14.2.3 The Maysara Project

The Government of Jordan and the Canadian International Development Agency (CIDA) have identified the community of Maysara, Jordan, as the site for a pilot duckweed-based wastewater treatment facility. The system will incorporate two UASB reactors as the primary treatment mechanism. Secondary treatment will occur in duckweed-based treatment channels of approximately 2.5 ha in total water surface area. The treatment facility will also demonstrate the recovery and windrow composting of organic solid in an integrated system to recovery organic resources. The project is expected to provide an example for community and private sector involvement in waste management. This facility will be designed to demonstrate that integrated waste management can pay for itself and can be an attractive community amenity.

Rock filters, when used in conjunction with WSPs, have been shown to upgrade WSP effluent. Research at a pilot-scale rock filter demonstration conducted at the Assamra WSPs in Jordan showed that effluent content reductions could be reduced greatly. TSS and BOD were reduced by 60%, TFCC by a maximum of 94% and T-P by 46% at a loading rate of 0.33-0.044 kgTSS/m^3 (Saidam, Ramadan and Butler, 1995). Wetland-based systems have also been shown to upgrade WSP effluent. Water hyacinth and duckweed systems inhibit the growth of algae by preventing sunlight from reaching the water column. Constructed wetland systems are able to remove a variety of contaminants, including the algae. If high levels of TSS are not an issue in an irrigation scheme and there is no risk of clogging irrigation equipment, high TSS may be advantageous as they will add organic matter to the soil matrix.

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Source: http://www.idrc.ca/es/ev-6540-201-1-DO_TOPIC.html

14.3 Leading Thinkers and Experts

14.3.1 Publications

Wåhlin, Lars. The Family Cistern: 3,000 Years of Household Water Collection in Jordan. In Ethnic Encounter and Culture Change, Sabour and Vikør, eds. (1997) Bergen/London, 233-49

14.4 References

Bartone, C. R. (1991). International perspective on water resources management and wastewater reuse - appropriate technologies. *Water, Science & Technology* 1991, 23: 2039-2047.

Hillel, D. (1987). *The efficient use of water in irrigation; principles and practice for improving irrigation in arid and semiarid regions.* (World Bank Technical Paper No. 64). Washington, D.C., 1987.

Rose, Gregory D. (1998). *CFP Report 27: Community-Based Technologies for Domestic Wastewater Treatment and Reuse: options for urban agriculture*. Retrieved from http://www.idrc.ca/es/ev-6540-201-1-DO_TOPIC.html

Saidam, M., Ramadan, S. & Butler, D. (1995). Upgrading waste stabilization pond effluent by rock filter. *Water Science & Technology* 1995, 31(12): 369-378

European Union

15.1 Practice

Due to the extensive market development and about 80,000 plants produced yearly, Germany is as before the leading country in Europe playing a significant role in the development of rainwater harvesting and rainwater utilisation. Developments in the field are also found in Austria, Switzerland, Belgium, Luxembourg and Denmark. The popularity of rainwater utilisation depends on the water price. The higher the price, the better is the amortisation of the rainwater utilization plant. Denmark (1.84 Euro/m^3) and Germany (1.73 Euro/m^3) have the highest costs for drinking water/mains water in Europe and, according to the US National Consulting Group (NUS), are world leading.

Further markets are developing slowly in France, Netherlands, UK, North Italy and East European countries. The development of a rainwater market in South European countries such as Greece, South-Italy, Spain and Portugal, which are partly afflicted with massive dry periods, is still currently at very low level and is influenced by region.

15.1.1 International working NGOs / NPOs for rainwater harvesting

fbr

fbr is a nation-wide professional association of people, companies, local authorities, offices, specialized trading companies and institutions interested or already actively involved in water recycling and rainwater utilization. The association is a registered non-profit-making organisation with headquarters in Darmstadt, Germany.

Website: http://www.fbr.de

International Rainwater Harvesting Alliance (IRHA)

The International Rainwater Harvesting Alliance (IRHA) was created in Geneva in November 2002 following recommendations formulated during the World Summit for Sustainable Development in Johannesburg two months earlier. The mandate consisted federating and unifying the disparate rainwater harvesting (RWH) movements around the world, to promote rainwater as a valuable water resource and to build on achievements in this field for the fulfillment of the Millennium Development Goals.

In partnership with the most eminent organisations and individuals in the field, the IRHA provides a lobbying and advocacy platform for RWH. It supports the growth of RWH solutions to water supply problems by providing a forum for its members to work together or share experiences for their mutual benefit, and thus for the benefit of people living with water scarcity.

Website: http://www.irha-h2o.org/

15.2 Policy

15.2.1 Legislation

In most of the European countries the requirements in the building legislation have changed considerably during the last few years. With regard to a uniform European set of rules it became necessary to water down e.g. strong directives for building work in Germany, resulting in federal and state building legislation having become less severe.

On the other hand existing legislation on environmental protection, energy savings measures and the responsible utilization of water have been increasingly made more severe.

15.2.2 Zer0-M: Sustainable Concepts Towards a Zero Outflow Municipality

The Zer0-M project aims to develop concepts and technologies to allow closed-loop useage of water flows in small municipalities or settlements. The Sustainable Water Management journal is meant to provide a platform for the dissemination of such techniques, or ecosanitation, as they are widely called. The main goal of the journal is to provide a hard copy information tool besides the internet-based means of exchange, which are not yet universally available.

Zer0-M Website: http://www.zer0-m.org

15.2.3 EMAS II programs

The EU Eco-Management and Audit Scheme (EMAS) is a management tool for companies and other organisations to evaluate, report and improve their environmental performance. The scheme has been available for participation by all economic sectors including public and private services since 2001. It functions similarly to the US Green Building Council LEED system.

More information: http://ec.europa.eu/environment/emas/index_en.htm

15.2.4 SWITCH (Sustainable Water management Improves Tomorrow's Cities' Health)

This 5-year EUR 22 million project (2006-2011), financed by the European Commission, will develop, apply and demonstrate a range of solutions for sustainable urban water management in 9 cities: Accra (Ghana), Alexandria (Egypt), Tel Aviv (Israel), Beijing (China), Bogotá (Colombia), Belo Horizonte (Brazil), Birmingham (UK), Hamburg (Germany), Lodz (Poland) and Zaragoza (Spain). In each demonstration city a Learning Alliance will be established. SWITCH has six themes:

- Urban water paradigm shift
- Storm water management
- Efficient water supply and water use for all
- Rational water use, (eco-) sanitation and waste management
- Urban water environments and planning
- Governance and institutional change

The SWITCH consortium of 32 partners including the IRC International Water and Sanitation Centre, is led by the UNESCO-IHE Institute for Water Education.

15.2.5 Interreg 2c

Refer to Fassnacht, Karl-Josef.

15.2.6 Interreg 3c

Refer to Knoppert, Wim.

15.3 Summary – European Union

15.3.1 Constitutional and Legal Context

The European Union continues on the path toward harmonization of national laws governing the development, use and protection of water and other natural resources. Harmonization is being achieved through negotiation and formal adoption of legally binding Framework Directives and Environment Action Programmes. These establish EU-wide policies and standards that serve as benchmarks for the introduction or amendment of state laws and guidance in the coordination of programmes. Oversight of the Water Framework Directive (WFD) is under the auspices of the European Commission. The European Environment Agency (EEA) is responsible for compiling and disseminating information that will assist member states in achieving Framework objectives and for progress reporting.

Promotion of sustainable water use based on the "long-term protection of available water resources" is an identified purpose of the WFD57. Specific policy requirements are still being developed surrounding water conservation and water-use efficiency. Member countries are currently required to conduct economic analyses of water use at a river basin level taking into account the principles of cost recovery for services including environmental and resource costs. The Integrated Pollution Prevention Directive of 1996 establishes "best available techniques" guidance and water efficiency targets for the pulp and paper industry and for the hog and poultry sectors of the intensive livestock production industry.

An objective of the Sixth Environment Action Programme (2001-2010) is "to provide products and services using fewer resources, such as water, and encouraging resource efficiency through more sustainable consumption patterns". It goes on to say that, "to achieve this objective, measures to improve the efficiency of water use in different economic sectors have to be implemented at national, regional and local levels".

EU Directive 97/11/EC obligates member countries to enact formal Environmental Impact Assessment (EIA) requirements as part of approval processes associated with large water withdrawals (≥ 10 million m^3/yr) and inter-basin transfers (≥ 100 million m^3/yr).

15.3.2 Water Availability and Water Use

Generally speaking the European continent is blessed with abundant freshwater resources but there are important regional disparities in the level of renewable supplies. The extent and severity of sustainability concerns reflect differences in geography, climate, population densities and the sectoral distribution of economic activity across the continent. Countries in the south with their sizeable agrarian economies, e.g. Spain, Italy and Turkey, experience more problems than their northern neighbours. Some eastern accession countries including Romania, Poland and Slovakia, which historically experienced sustainable water-use issues, have seen some reduction of concern albeit as a result of the partial collapse of their agrarian economies. Water-resource sustainability is becoming an issue in the United Kingdom with its relatively limited crop irrigation, relatively abundant precipitation and more temperate climate. France lies somewhere in the middle of the overall European experience since higher agricultural water demands are balanced off by higher annual water resource renewals. This is not to say that these countries don't suffer from localized problems with respect to maintaining a balance between water availability and water use.

Surface water withdrawals account for the largest portion of water takings in most countries. They constitute close to 80% of all withdrawals in the UK, 85% in France and 90% in Finland. Exceptions are Denmark, Iceland and Slovenia where ground water is the basis of more than 80% of total water withdrawals.

Ground water is the primary source of public water supply in rural areas of most European countries. Large scale ground water withdrawals, primarily for public supply, have resulted in worsening saltwater intrusion problems for the coastal aquifers of Denmark, southern Baltic countries and countries bordering the Mediterranean Sea. The last decade has seen a higher incidence and severity of drought-like conditions in parts of Europe leading to increased attention being focused on measures that will improve water-use efficiency and productivity.

15.3.3 Sectoral Water-Use Distribution within Major EU Regions

See the European Environment Agency Indicator Fact Sheet for Water Exploitation Index (WEI) for European Countries: http://themes.eea.europa.eu/Specific_media/water/indicators/WQ01c%2C2004.05 for Notes:

WEI or water withdrawal ratio is defined as the mean annual total abstractions of freshwater divided by the mean annual renewable freshwater resources.

Western (Southern) region consists of France, Greece, Italy Portugal, Spain

Western (Central+Nordic): Austria, Belgium, Denmark, Finland, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Sweden, Switzerland, United Kingdom

AC (Southern): Acceding countries of Cyprus, Malta, Turkey

AC (Northern): Bulgaria, Czech Rep., Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia

15.3.4 Water Pricing and Cost Recovery

The EU Water Framework Directive obliges all member states to have full-cost recovery pricing policies in place by 2010. Increased water prices are being viewed as "an enabling mechanism" in altering behavioural responses on the part of water users. Most EU countries now use water-rate structures that combine fixed and volumetric charges and have been progressively raising prices by several percentage points annually. Removal of pricing subsidies in Eastern Europe contributed to decreases in average domestic water use by as much as 32% in recent years. Domestic water bills range from 0.2% of household income in Oslo, Norway to 3.5% in Bucharest, Romania. As a point of reference, the World Bank has stated that the cost of water services should not exceed 5% of household income. Across Europe, municipal water prices tend to be lower in Mediterranean countries and in most countries with abundant water supplies. The highest prices are typically found in the cities of northern Europe. In-country differences are common as is the case in Spain where prices in the resort island areas are 2.0-2.5 times national average rates. The agricultural sector is acknowledged as presenting the biggest challenge in moving toward full-cost recovery. Current agricultural water prices are typically an order of magnitude lower than those found in the municipal and industrial sectors. While this may appear justified on the basis of lower servicing costs, it runs counter to the sector's status as the largest contributor to water quality degradation across the continent. Austria and the Netherlands are exceptions to this pricing disparity.

The EU Common Agricultural Policy provides for direct payments to farmers to assist with the implementation of resource and environmental protection measures. Payments are capped on the basis of crop types and acreages and require the adoption and ongoing use of environmentally acceptable production methods and practices.

See Median Prices for Industrial, Agricultural and Household Water Supply (late 1990s) European Environment Agency. (2004). Indicator Fact Sheet: Water Prices:

http://themes.eea.europa.eu/Specific_media/water/indicators/WQ05%2C2003.12/WatPrices_RevOct03.pdf

15.3.5 National law and directives

National law has to fit into the EU Water framework of regulations. EU countries are free to make there own law for buildings and watersheds, for water distribution and sewage systems. So all European countries continue to be different in terms of management, research and policies, of innovative and decentralized water practice.

15.3.6 Regional policy

In water distribution European countries have different traditions. For example France has two private companies (Veolia and Suez) that serve 80 % of the need, while Germany has 7.000 companies to serve the need of the population. This difference makes France look on decentralized water practice totally different than Germany. Grass root policy for innovative research and water practice came up in Germany with the energy crises in the years after 1970. In France no initiatives have developed decentralized water practice and innovative technology in a small scale. The central government of France gives incentives for rainwater harvesting, beginning 2007-01-01. In Germany it is up to the 16 lands and the communities to decide how to promote soft path technology.

15.3.6.1 Community based bylaw - Example Germany:

Five of the German lands made a framework of water-law to enable their communities to promote and to force decentralized water policy. These are Baden-Württemberg (Landesbauordnung § 74, 3, dated Jan. 1996), Hessen (Hessisches Wassergesetz, § 42, 3, dated May 2005), Bremen (Landesbauordnung § 87, 1, dated March 1995), Saarland (Landesbauordnung § 93, 2, dated March 1996) and Hamburg (Landesbauordnung, § 39, 4, dated June 1997).

Some communities use the possibility to make rainwater harvesting compulsory. This is mostly when a new area of dwellings is developed.

15.4 Summary - East Europe

15.4.1 Awakening arousing interest

The East European neighbors, the Czech Republic, Slovakia, Poland and Hungary in the first place are forced to raise the technical and environmental standards to the EU level. The interest in rainwater utilization is constantly increasing. Some commercial and public large projects have been already realized. Because of the low water price and low income of private households, the investments in private homes is still restrained. Wage differentials and governmental subsidies lead to the foundation of production facilities and branch offices of German rainwater firms in these countries.

15.5 Summary - Southern Europe

15.5.1 Little initiative

The development of a rainwater market in South European countries such as Greece, Italy, Spain, and Portugal, which are partly afflicted with massive dry periods, is still currently at a very low level and is influenced by region. Italy's north is famous for producing water pumps. German manufactures of RWH Plants are importing these products. Trading also brings back RWH systems made in Germany to Italy's north region. Another reason is tradition: The Alp Mountain areas of Italy, such as Piemont and Lombardia, have used rainwater as a natural resource for centuries.

Austria

16.2 Leading Experts

16.2.1 Fusko, Michael

Michael Fusko, PhD., was born in 1960, studied at the University of Vienna, Institute for Limnology, where he was involved in several nature conservation projects. Since 1988, he has worked at Die Umweltberatung association in Lower Austria, focusing mainly on water. There he is also a sub-editor of the magazine Die neue Umwelt [The New Environment]. He is engaged in several projects and seminars for Die Umweltberatung, and is the author of several papers on the subjects of rainwater utilization, water purification and wastewater treatment.

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16.2.1.1 Michael Fusko: Rainwater utilization and Austria's Current Status

The majority of Austria's fresh water originates from groundwater. Because of a secure and uninterrupted supply, little attention has been paid in Austria up to now to using rainwater. Questions about safe use with respect to public health have resulted in a general non-acceptance or rejection of the concept, especially by the authorities. The initiatives by the Umweltberatung association have heightened support for the concept, resulting in the installation of numerous systems by private consumers over the last few years. Using rainwater for flushing toilets and irrigating gardens is presently accepted as state-of-the-art. However, its application in the commercial and the municipal sector is still in its infancy. Limited financial subsidies are available for these systems. The intention is to introduce mandatory engineering and hygienic standards in future, so that rainwater utilization efforts will be accelerated.

Czech Republic

17.1 Practice: Arousing interest

Czech Republic is being forced to raise its technical and environmental standards to match EU standards. The interest in rainwater utilisation is constantly increasing. Some commercial and public large projects have been already realised. Because of the law and moderate water price rainwater harvesting is still limited. In spite of low but increasing income of private households, the investments in rainwater harvesting in private houses is rising as a result of planned increase of VAT on houses as well as the future acceptance of Euro. Wage differentials and governmental subsidies lead to the foundation of production facilities and branch offices of German rainwater firms in the country.

17.2 Leading Experts

18.2.1 Macek, Lubomír

Lubomir Macek was born in 1959, finished his Diploma and Dissertation Studies at the Department of Sanitary and Environmental Engineering of Faculty of Civil Engineering, Czech Technical University. He worked as Assistant Professor in the same department until October 1999, specialising in Water Supply Engineering and Hydraulic Modelling. Since October 1999 he has worked as director of the Czech private company Aquion. Aquion has existed since 1993 and specialises in water consultation and engineering, hydraulic modelling, rainwater harvesting, etc.

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Website: http://www.aquion.cz.

Denmark and Scandinavia

18.1 Leading Experts

18.1.1 Johannson, Hendrik

Hendrik Johannson was born in 1949, is a graduate industrial engineer, who headed the agency for the WAVIN company in the northern district of Norway. Today, he is the proprietor of NyrupPlast A/S Co., located in Nyrup, approximately 60 kilometers west of Copenhagen. For the past 10 years he has played an important role, through his contacts in the Department of Environment, Health, and Housing, in the introduction and distribution of rainwater harvesting systems. He is an advisor to the Technical University of Denmark and a member of the Fachvereinigung für Betriebs- und Regenwassernutzung (fbr) in Darmstadt, Germany.

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18.1.1.1 Hendrik Johannson on Conditions in Scandinavia

Rainwater utilization has been discussed for many years in Denmark. Rainwater use is fully endorsed, and there are very few restrictions regarding the installation of systems. In Sweden, Norway and Finland, the subject continues to be discussed; however, the market situation in the individual countries varies greatly. Contrary to Denmark, water rates in these countries are very low. As one moves further north, the number of days with frost increases. There is insufficient groundwater to meet water requirements of cities in the areas with an annual precipitation of less than 650 mm. Since the supply of fresh water relies heavily on groundwater reserves, rainwater utilization will play an increasingly important role. Scandinavians are eagerly observing how rainwater utilization will develop in central Europe.

France

19.1 Practice: Powerful water suppliers

The official attitude in France is determined by the water suppliers, who for reasons of economical self-interest similar to German suppliers look with criticism at rainwater utilisation. However, there exist regions in France (south of France, Grenoble area, Elsass, North of France), which struggle with the challenges of low precipitation and a sinking groundwater table. The government has reacted in the form of decreed restrictions such as prohibition of car washes during midsummer (Périgord, 2005) and prohibition of irrigation in appurtenant structures (Grenoble, 2005). Interest in rainwater utilisation is present among the local authorities, planners and architects. However, the state of knowledge and recognition for rainwater utilisation is very low at the present time. Exemplary is ARENE, the Energy and Environmental Agency in Paris and the surroundings, which has defined the building standard HQE. It stands for ecological building quality. The proper dealing with water is thereby one of their central themes.

19.2 Policy

19.2.1 Subsidy for Rainwater Utilization

As a result of the National Drought Management Plan France gives subsidies to everybody realizing Rainwater Utilization or another kind of water recycling. The form is a 40% tax payback up to a limit of 5,000 Euro during the time period of January 01, 2007-December 31, 2011.

19.3 Leading Experts

19.3.1 Hurpy, Isabelle

Doctor in Environment of a French University, with a previous scientific background, she is a consultant for collectivities about the environmental quality of their planning and building projects. First involved in renewable energies and bioclimatic conception, she has found a new field of activity with rainwater management since 1994, with a broad range of research, projects, workshops, and lectures. Among her publications: «Effets de serres» with F. Nicolas architect, about bioclimatic conception of building in 1981, «L'urbanisme et les maîtres de l'eau: nouvelles conceptions, nouvelles expressions» in the book of "Nouveaux Paris", architectural exhibition, Paris 2005.

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19.3.2 Oliva, Jean-Claude

Geologist (engineer) by training, journalist by profession, his work has focused on "science and democracy," which had led him to specialize in water and sustainable development. He is currently the animator of the Université populaire de l'eau et du développement durable [Popular University for water and sustainable development] at Ivry (south of Paris). And in 2006 Oliva organized a European colloquium on alternative management of water and rainwater harvesting for the general council of the Marne valley. He has edited and contributed to many publications: L'eau, res publica ou merchandise [Water, res publica or merchandise], La Dispute editions, Paris 2003; Eau dans la ville et développement durable [Water in the city and sustainable development], Presses des Ponts et Chaussées, Paris, 2003, Un autre monde, une seule planète [Another world, only one planet], Editions Naturellement, 2002. He is also a member of the association of journalists for nature and ecology. (JNE).

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Activities:

European Conference: *Une autre gestion de l'eau est-elle possible* at Crèteil/France on 2006, March 22. Supported by Departement du Val-de-Marne and Departement Seine-Saint-Denis

Université populaire de l'eau et du développement durable. Every Tuesday evening 19. – 20.30. Organized by Agence de développement du Val-de-Marne, 23 rue Raspail, 94200 Ivry-sur-Seine/France.

19.4 Summary

19.4.1 Water Availability and Water Use

France is considered a water-rich nation with large annually renewable freshwater supplies and significant ground water reserves. Even the driest regions rarely receive less than 600 mm of precipitation on an annual basis. Total annual freshwater withdrawals are in the range of 32,000 million m^3, 85% of which come from surface water sources. Thermal power plants account for 60%, public water supplies 18%, agricultural uses 12%, and industrial uses 10% of total withdrawals. Water usage for crop irrigation has been on the rise in recent years particularly in western and south-western regions of the country where increases of as much as 75% have occurred since 1981. Consumptive use has been estimated at 4,000 million m^3 annually or about 12.5% of total withdrawals. Crop irrigation accounts for 68% of consumptive use, public water supply 24%, industries 5%, and power generation 3%. In contrast to the norm of abundant supplies, hot and dry conditions have been prevalent in recent years. Record setting drought conditions in 2003 required widespread introduction of water use restrictions.

19.4.2 Water Management

The national or state role in water management is primarily focused on the regulation or authorization of water takings and wastewater discharges for the expressed purposes of protecting public health and safety and the health of aquatic environments. These powers are vested in the Water Department (Agence de l'eau) of the Environment Ministry. Under the Water Law (1992), the river basin unit figures prominently in how water is managed. Each of France's six major basins is overseen by an elected committee comprised of key stakeholders representing state and local governments and water users. The committee establishes basin objectives and a programme of interventions. Programme delivery is the responsibility of a financially independent state Water Agency with powers to raise revenues through both water charges and effluent charges. Monies are made available through loans and subsidies to assist communities, industries and farmers implement works deemed necessary and eligible within the current 5-year water management plan. These plans (created at the watershed and sub-watershed level) are expected to reflect all standards and measures as laid out in the EU water framework. France has perhaps the most comprehensive and far-reaching system of water pricing among all study jurisdictions. Volumetric charges are levied not only as a basin (Water Agency) charge tied to the magnitude of the abstraction but also as a state tax reflecting the extent of consumptive usage. The state tax is determined through a system of consumptive use coefficients assigned to the particular sector. The basin abstraction charge is higher (2-3.5 x) for ground water withdrawals and is also higher in water-short areas and areas where the source water is of higher quality. Under provisions of the Water Law, wastewater reclamation and reuse in crop and landscape irrigation is both permitted and encouraged both to address water shortages and reduce pollutant discharges to surface waters.

The drought conditions experienced in 2003 led to the development of a national Drought Management Plan. It provides for the establishment of a national committee to be mobilized as required by Ministerial Order. The committee will ensure the development of guidelines for assessing drought risk and will disseminate the guidance required to ensure uniform approaches to the implementation of water-use restrictions. Actions are underway to modernize existing monitoring networks used to measure water availability and demand. The Irrimieux Initiative jointly launched by the Ministries of Agriculture and Environment in the 1990s required crop irrigators to install volumetric metering. It also provides them with up-to-date weather and climate data to assist with irrigation scheduling and determination of appropriate application rates and offers guidance on other best practices.

Germany

20.1 Practice

20.1.1 World-wide impulse

Through the International Rainwater Conference 2001 in Mannheim, the fbr contacts have considerably widened. Over 400 participants from 68 countries met for the first time in Germany in order to discuss the role of rainwater utilisation in settlements and urban developments.

From press releases it can be understood that Germany, like other developed countries, can hardly maintain the predominant conventional system of combined/gravity sewer in the long run. In a current state-wide study, the German Association for Water, Wastewater and Solid Wastes (DWA) estimated the costs for the rehabilitation of the sewer system at about 50 to 55 Milliard Euro. The Fraunhofer Institute ISI in Karlsruhe prognoses that in a few decades, the drinking water quality cannot be anymore guaranteed with the conventional structures of the water supply systems. Assistance can be brought about by shifting the drinking water “production” to the consumer. Raw water which then flows in public supply networks will consist largely of rainwater similar to the pilot project Knittlingen.

It is quite clear that service water and rainwater utilisation have become internationally significant. Germany is leading in this field and drives technical standards, public relations, advanced training and system dissemination. fbr firm members are increasingly exporting their products with much success. In order to accommodate this fact, the fbr takes over in 2006 the European office of the International Rainwater Catchment Systems Association, IRCSA.

20.1.2 City of Hamburg

1988 Hamburg was the first German federal state to introduce a grant program for installing rainwater utilization systems in buildings. Approximately 1500 systems for private homeowners were financed over the course of the following seven years.

The Hamburg Environmental Protection Office mailed out questionnaires to get a sense of the experience the owners had in operating these systems. The replies from 346 operators produced the following result: 94% of the respondents reported that they were generally happy and had no reservations about recommending rainwater utilization for domestic purposes to others; 43% reported some problems, which were generally related to mechanical equipment, which, at the time, consisted of a jet pump and a pressure vessel. They also reported leaks in cisterns built from prefabricated concrete rings, filters that required excessive maintenance, and unreliable controls on the equipment used for augmenting municipal water in systems. This survey revealed the necessity to develop special components for rainwater utilization systems that would ensure uninterrupted system operation without breakdowns or high-intensity maintenance.

For more background, see 21.4.1 Hartung, Hinrich

20.2 Research

20.2.1 fbr

fbr is a German nation-wide professional association of people, companies, local authorities, offices, specialized trading companies and institutions interested or already actively involved in water recycling and rainwater harvesting. The association is a registered non-profit organisation and a non-governmental organisation with headquarters in Darmstadt, Germany.

The purpose of fbr is to promote water recycling and rainwater harvesting, save drinking water and reduce sewage by rainwater utilization. Its responsibility lies in the creation of a provision against future contingencies, while at the same time taking into account all aspects of environmental protection, science and research. Within the association, members are active in work groups dealing with all topics of water reuse.

fbr conducts conferences, trade fair presentations, and work groups, produces a member newspaper, fbr serial publications, and information database, , and provides research aid, representation of interests, member counselling, and press releases. Organizational focus topics include saving drinking water, technical Regulations, water quality, eco-balances, rainwater management, water recycling, and rainwater utilization.

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20.2.1.1 International Activities

fbr is a partner in the European Union research program Zer0-M, concepts towards a zero-outflow municipality. Zer0-M is one of ten MEDA Water Projects for sustainable water management.

Website: http://www.zer0-m.org

20.2.2 Holländer, Reinhard

Priv. Doz. Dr. rer. nat., is a microbiologist and hygienist. He is the Head of the Department for General Hygiene at the State Testing Laboratory in Bremen. He has taken a strong interest in rainwater utilization, both on a personal and a professional basis, and he has dealt with various aspects and questions in this area in several publications and in numerous papers. Dr. Holländer received his doctorate in 1976, and presented his post-doctoral thesis on the subject of microbiology in 1984.

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20.2.2.1 Holländer on Rainwater utilization and hygiene

In our high-tech society, rainwater utilization appears to be an anachronism. However, there are many reasons why this technology, which has frequently been forgotten by many, should be revitalized, thus enabling us to fully utilize our natural resources. One frequently hears about hygienic concerns in connection with rainwater use. These apprehensions arise out of fear that waterborne diseases, such as typhoid, cholera or dysentery, will be transmitted. It appears that these arguments are frequently made as a pretext for protecting special commercial interests. But because of the present high standards of hygiene in today's society, and because freshwater and wastewater systems are kept strictly separated, waterborne diseases, as we know them from the past centuries, do not present a threat. When rainwater harvesting systems have been correctly installed and are properly used, such health risks are unfounded, as is evidenced daily by the thousands of systems that are in use.

20.2.3 Lücke, Friedrich Karl

Prof. Dr. Lücke is a microbiologist and obtained his PhD. from the University of Bonn.

He was head of a research laboratory of food microbiology from 1978-1989. Since then, he has taught microbiology, food and environmental hygiene and food technology as a professor at Fulda University of Applied Sciences, Germany. He was involved in various research and development projects related to the microbiology and hygiene of cistern water and recycled greywater. He is a member of national and international societies of microbiology (including the American Society for microbiology).

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20.2.4 Hiessl, Harald

Dr.-Ing., graduated as a hydrologist from Freiburg University and earned his doctoral degree in water resources engineering from Technical University Karlsruhe, Germany. In 1988 he joined the Fraunhofer Institute for Systems and Innovation Research ISI in Karlsruhe. From 1996 to 2004 he was Head of ISI's Department of Environmental Technology and Environmental Economics. Since 2005 is Head of ISI's Department of Sustainability and Infrastructures. His research work focuses on system innovation of urban water infrastructure systems, sustainable and integrated urban water resources management. He has in-depth experiences with planning, implementation and evaluation of demonstration projects for sustainable water infrastructure concepts. His special methodological competencies are in systems analysis, sustainability assessment, technology foresight, and scenario analysis.

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Website: http://www.isi.fraunhofer.de

20.2.4.1 Selected Publications

H. Hiessl; D. Toussaint. Options for Sustainable Urban Water Infrastructure Systems: Results of the AKWA 2100 Project. 2003, pp. 757-759. Proceedings of the 2nd International Symposium on ecological sanitation "ecosan - closing the loop"-including the 1st IWA specialist group conference on Sustainable Sanitation April 7-11, 2003, Lübeck, Germany. Hrsg. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, ISBN 3-00-012791-7, Eschborn, 2004.

H. Hiessl; D. Köwener, M. Corley (1999): Eco-efficient water related services for private households: New business opportunities for utilities. In: European Water Policy - from the Water Charter to the Framework Directive: IX H2Oblettivo 2000 -International Conference, FEDERGASAQUA, pp. 539-548, 1999.

20.2.5 Trösch, Walter

Professor Dr. is Deputy Leader of Fraunhofer-Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart. He is also leader of the department Environmental Biotechnology and Biochemical Engineering. He works mainly in the field of regenerative energy from organic waste, urban water- and waste water treatment, renewable primary products from micro algae, recycling of P- and N- resources from waste water and system analysis of bioprocesses. Walter Troesch is Professor at Hohenheim University on the area of Environmental Biotechnology and Sustainability.

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www.igb.fraunhofer.de

20.2.5.1 Selected Publications

A. Meiser, U. Schmid-Staiger, W. Trösch (2004). Optimization of eicosapentaenoic acid production by Phaeodactylum tricornutum in the flat panel airlift (FPA) reactor. *Journal of Applied Phycology,* 2004, vol. 16; 215-225

W. Trösch. (2005). Wassertechnologien für eine nachhaltige Zukunft in: *Erde 2.0 – Technologische Innovationen als Chance für eine nachhaltige Entwicklung*, S. Mappus, Ed. 2005. 216-240.

M. Mohr, W. Trösch. (2005). *Nachhaltiger Umgang mit Wasser - Forschungsprojekt DEUS 21: Dezentrales Wassermanagement für eine Neubausiedlung Wasser*, Luft, Boden, 17-21.

W. Trösch, B. Kempter-Regel. (2005). Full scale application of high rate digestion to improve stabilisation. Proceedings 2nd IWA Leading-Edge Conference on Water and Wastewater Treatment Technologies

20.2.6 Ecosan

In Germany the University of Hamburg-Harburg and the National Ministry for Developing Countries both care for ecosan topics. The Ministry is publishing the gtz-ecosan-newsletter.

Email: ecosan@mailserv.gtz.de

Website: http://www.gtz.de

20.2.6.1 Werner, Christine

Dipl.-Ing. (civil engineering) is head of the ecosan program of the German Development Cooperation Agency GTZ in Eschborn, Germany. She has 20 years of international experience in water and sanitation. In 1999 she has initiated the GTZ ecosan program which is promoting the global dissemination of recycling oriented sanitation concepts. The program supports the knowledge management on ecosan and has conducted more than 100 pilot projects in developing countries. She is a member of the International and the German Water Association, International Ecological Engineering Society and Indian Innovative Ecological Sanitation Network, she also was in the WHO expert group WHO for the revision of the guidelines for the reuse of wastewater and excreta and has published together with the UNESCO the guideline on “Capacity building for ecological sanitation”.

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Website: http://www.gtz.de/ecosan

20.2.6.2 Otterpohl, Ralf

Univ. Prof. Dr.-Ing. has a degree of RWTH Aachen in civil engineering with specialisation in water management. He did a doctorate on mathematical modelling and computer simulation of wastewater systems. Through modelling he realised that the mass-flows in conventional systems are far from ideal. Therefore he founded the consultancy Otterwasser in Lubeck that specialises in computer simulation and in innovative wastewater concepts – primarily in source separation of blackwater and decentralized systems. Currently he is full professor and director of the institute of wastewater management and water protection at Hamburg University of Technology. He is chair of the IWA (International Water Association) specialist group ‘Ecological Sanitation’.

Email: otterpohl@tuhh.de

Website links:

http://www.tuhh.de/aww

http://www.ecosan.org

20.2.6.3 Geller, Gunther

Dipl.-Ing., is head of Ökolog, an ecological engineering consulting company in Augsburg, Bavaria and president of the Ecological Engineering Society for the German speaking countries (IOEV). He is specialist for constructed wetlands and author of a manual about these systems (in German), having done a lot of practical and scientific work in this field. In one of the projects running he is the head of a joint research project, enabling a holistic sustainable development of the campus of the biggest private university in Ghana, establishing water cycles, ecological buildings and a study in ecological engineering among others. He is spreading the lessons learnt also by giving lectures in universities and in a just starting MA program in ecological building with Bauhaus-University Weimar.

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http://www.ioev.de

20.2.7 Fachhochschule Fulda

Department Oecotrophologie, Prof. Dr. Friedrich-Karl Lücke

See 21.2.3, Lücke, Friedrich Karl

20.2.8 Kolb, Walter

Dr., studied landscape management at the Technical University in Hannover and in Munich. Since 1967, as the head of the Department of Landscape Management in the Bavarian State Institute for Viticulture and Horticulture in Veitshöchheim/Würzburg, he has conduced feasibility studies regarding the design, building and maintenance of green areas. His work emphasized analyzing methods for designing green buildings, as well as investigating the efficiency and performance of green surfaces for the treatment of rainwater.

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http://www.lwg.bayern.de/bildung

20.2.8.1 Kolb: What are the long-term effects of roof gardens in the treatment of rainwater?

The use of roof gardens can reduce the peak runoff from buildings by 50-90%. This results in cost savings in the installation of sewer pipes and it also has a balancing effect, as it retains water and reduces the potential for flash floods in streams and in rivers. This makes it feasible to use seepage water from roof gardens as process water in conjunction with rainwater utilization systems. In this application, the roof garden acts as a biofilter, ensuring high quality process water. Tests have shown that when low-sorption roof substrates are used, some contamination with humic substances can be expected. This could cause a small amount of turbidity and thus impair quality. However, we are currently working to solve this problem. Rainwater is too precious to waste! In future, rainwater should either be evaporated through the vegetation that grows on the property, or used as process water, or disposed of by seepage and percolation through green areas.

20.2.9 Meggeneder, Marcel

Dr.-Ing., is Operations Manager for gas and water supplies at Stadtwerke swb Netze Bremerhaven. Before his doctorate in Construction Engineering in 2003, he worked as a scientific assistant at the Institute for Residential Water Management and Waste Management Technology at the University of Hanover, among other things on projects in rainwater utilization. Majoring in water supplies, he teaches at the University of Hanover.

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Website: http://www.swb-gruppe.de

20.2.9.1 Meggeneder on Process water availability

The biggest challenges Expo Lake presented, apart from the construction itself, were the dimensional design requirements. To solve this problem, the University of Hannover developed a simulation model using climatic values from 1980 to 1995 as well as the dimensions of the paved surfaces that were connected to the basin. Using as variables the most important parameters (park areas, number of toilets, reservoir capacity), it was possible to calculate the optimum value between supply and demand and determine the size of the reservoir needed. In addition, the various simulation runs produced the following individual daily parameters: the water required for irrigation, the level of water in the basin, the volume lost by evaporation, the amount withdrawn from the basin, the time the basin was empty, and the volume of municipal water makeup required.

20.2.10 ITWH Hannover

This Institute of Engineers is planning projects for Rainwater Harvesting, founded by Prof. Friedhelm Sieker (refer to d, Leading thinkers and experts, Sieker). They developed software KOSIM and PEN-LAWA. One of the first institutes between university and business (which was some decades ago impossible to connect).

Website: http://www.itwh.de

20.2.11 Fassnacht, Karl-Josef

Dipl.-Ing. (TU), born in 1954, studied civil engineering at the technical University of Munic (TUM). He specialized in water and wastewater management. He works also Owner-manager at the Fassnacht Ingenieure GmbH. This engineering company designs systems for water management and wastewater treatment. Karl-Josef Fassnacht and his company was a pioneer in designing and building new rain water systems in the southern part of Germany. The company realized many innovative projects in this region. He also is a wanted man for talks on rainwater management designs.

Email: Kj.fassnacht@fassnacht-ingenieure.de

Website: http://www.fassnacht-ingenieure.de

20.2.11.1 His publications (selection)

Fassnacht, Karl-Josef, Dipl.-Ing. (2002). Naturnahe Regenwasserbewirtschaftung für das Gebiet „Engelberg-Nordhang“ in *Leonberg,* 18. February 2002, 18 February. (A project of Interreg Rhine-Meuse Activities IRMA, a part of Interreg 2c-program of European Union).

20.3 Policy

20.3.2 Legislation

Under ruling German law consumers must connect to and use water supplied by public mains water supply utilities only. As of June 1980 exemptions are possible if:

- the mains water supply utility is informed
- the mains water and non mains water pipe systems are strictly kept separate
- non mains water pipes and fixtures are clearly colour marked different from those for mains water.
- If the novel European Drinking Water Directive becomes law January 2003 it additionally stipulates that:
- rain water systems not installed in private dwellings must, for optional use, additionally have a mains water connection to the washing machine
- the Department of Health has been informed of the installation of the system.

Whether it is possible to specify rainwater utilization in new building areas in Germany is separately covered by individual building regulations in each of the 16 federal states. As such it is possible to specify rainwater utilization plant by the individual communal authorities in the states of Baden-Württemberg, Bremen, Hamburg, Saarland and Thuringia.

There are no financial benefits on taxation or direct subsidies from the German federal government. There are however stateside grants in federal states of Bremen, North Rhine –Westphalia, Saarland and Schleswig-Holstein. Independent of these, rain water utilization is financed by a great number of municipalities in all German federal states by their own grant programs.

Each German municipality itself sets the kind and amount of rates payable for the use of mains water and waste water disposal in accordance with their own Municipality Rates and Taxes Legislation. Ever more German municipalities now divide the disposal rates in separate portions for waste water and storm water disposal. The latter can be saved as long as stormwater of sealed surfaces remain on the property of the house owner. Apart from the direct financial grant this method has become an effective tool to further promote the use of rain water utilization.

20.3.4 GTZ

GTZ is an international cooperation enterprise for sustainable development with worldwide operations. It provides viable, forward-looking solutions for political, economic, ecological and social development in a globalised world. GTZ promotes complex reforms and change processes, often working under difficult conditions. Its corporate objective is to improve people’s living conditions on a sustainable basis.

The main client is the German Federal Ministry for Economic Cooperation and Development (BMZ). The company also operates on behalf of other German ministries, partner-country governments and international clients, such as the European Commission, the United Nations and the World Bank, as well as on behalf of private enterprises. Currently 300 development projects and programmes in 126 countries are implemented. Of 10,600 employees, some 1,000 people are employed at the Head Office in Eschborn near Frankfurt am Main.

The primary focus of international cooperation is on so-called Technical Cooperation. Far from being only centred on transferring technical knowledge, this primarily involves communicating knowledge that enables people to shape their present and future on their own. For this, individual initiative and the capabilities of people and organisations are strengthened. Development projects and programmes cover a wide range of themes and tasks. These include advising the government in Tajikistan, vocational training in Argentina, protecting the tropical forest in Indonesia and preventing AIDS in Kenya.

GTZ was established in 1975. It is organised as a private company owned by the German Federal Government. We work on a public benefit basis, using all funds generated as profits exclusively for projects in international cooperation. GTZ publishes numerous specialist texts and information brochures on its work.

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Website: http://www.gtz.de/en/

20.3.5 Bartenbach, Annegret

Annegret Bartenbach is head of the Office for Environmental Protection in Pleidelsheim, Baden-Württemberg. In addition to being responsible for the promotional program for rainwater utilization systems, she also provides technical support to the Departments of Nature Conservation and Environmental Protection, as well as the municipal water, wastewater, and building departments.

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http://www.pleidelsheim.de/netshaking/4.513/?id=16

20.3.6 Reichmann, Brigitte

Brigitte Reichmann is a civil engineering graduate from the Technical University at Dresden; since 1992, she has been an engineering advisor in the Senate administration for Urban Development and Berlin. She is responsible for developing standards and criteria for the urban environmental pilot project, including managing the project and coordinating ongoing research.

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http://www.stadtentwicklung.berlin.de

20.4 Leading Experts

20.4.1 Hartung, Hinrich

Hinrich Hartung is a hydrobiologist; his goal is to protect our natural freshwater resources. After working in the field of applied nature conservation and renaturization of wetlands, he joined the Office of Environmental Protection in Hamburg in 1991. There, in an effort to preserve groundwater resources, he developed methods for reducing water consumption. His search for potential savings, large-scale introduction of water-saving techniques, and usage-based cost-type accounting for all users of municipal water, is just as important as his long-standing endorsement of rainwater utilization systems.

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Website: http://www.hamburg.de/ressourcenschutz/

20.4.2 König, Klaus W.

Klaus W. König was born in 1956 and works as a freelance architect and consulting engineer in Ueberlingen on Lake Constance in Germany. He has participated in numerous projects in the areas of building construction and modernization, ecological construction techniques and healthy living. He has been intensively involved with the subject of rainwater utilization for 20 years. Since 1997, he is a member of the Committee for Rainwater Utilization Systems at German Institute of Standardisation (DIN). He is a member on the Board of fbr, the German professional association for water recycling and rainwater utilization, which is located in Darmstadt / Germany. He holds regular seminars to train architects, specialty engineers, tradesmen and public service employees.

Email: mail@klauswkoenig.com

Website: http://www.klauswkoenig.de/

20.4.2.1 Publications by Klaus W. König

König, Klaus W. (2003). Rainwater Harvesting: public need or private pleasure? *Water 21,* International Water Association IWA, London: UK. 56–58.

König, Klaus W. (2000). Berlin's Water Harvest. *Water 21*, International Water Association IWA, London: UK. 2000, February, 31-32.

König, Klaus W. (2002). Rainwater Harvesting, a part of urban water management in Germany. *The Rain Water Harvesting CD*, CD Margraf Publishers, Weikersheim: Germany, 2002.

König, Klaus W. (2001). On Rainwater in Cities: a note on ecology and practice Proceedings International Symposium, Istanbul Technical University, Water Foundation, July 2001, pp 107 – 116

König, Klaus W. (2001). *The Rainwater Technology Handbook: Rainharvesting in Building. Fundamentals, practical aspects, outlook*. Includes materials and tools for planning and design. WILO-Brain, Dortmund: Germany 2001.

20.4.3 Bullermann, Martin

Martin Bullerman has been an independent consulting engineer for environmental planning at the engineering consultancy of Bullermann Schneble GmbH in Darmstadt since 1989. He is active in the fields of water management for housing projects, process water concepts, drainage systems for housing projects, site remediation, and public relations in the area of environmental protection. He is a co-founder and chairperson of the fbr Association. He is also the author of numerous trade publications and brochures, and provides expert opinions on the above topics; he is also a member of the working groups at DIN, ATV, fbr and DVGW.

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20.4.3.1 Bullerman on The water infrastructure of the future

In industrialized countries, innovation in supplying public water and in wastewater disposal is usually synonymous with improvements in the centralized potable water supply through pipe distribution systems to consumers; domestic wastewater is usually discharged into a central wastewater treatment facility via a sewer system. In the light of increasing demand for potable water and the alarming load on wastewater treatment facilities, this progress is increasingly questionable, not only from an economic point of view, but also from the operational aspect. In my opinion, the future belongs to a decentralized infrastructure, which is flexible enough to adapt to technical progress when environmental policy, local conditions, and/or individual user needs change. An important aspect of this is the centralized management of rainwater, through utilization, evaporation, retention, and seepage. Because the impact of rainwater utilization on water supply and disposal is ideal, such utilization occupies a special position. It will thus play an important role in optimizing the water infrastructure of the future.

20.4.4 Dreiseitl, Herbert

Herbert Dreiseitl became intensively involved with water, right from the beginning of his artistic pursuits. In 1980 he established a studio in Überlingen, where pilot trials can be carried out on a 1:1 scale. Meanwhile, he and his team are working on miscellaneous projects combining art with open space planning, urban hydrology, and environmental engineering. He is a member of the Bundesverband Bildender Künstler (Federal Association for the Visual Arts), and belongs to other architectural and engineering associations. In addition to managing his office, he also publishes books, gives presentations, and works with committees and professional associations, such as fbr.

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20.4.5 Käser, Martin

Martin Käser graduated with a degree in mechanical engineering from the University of Stuttgart, where he focused on energy systems for mechanical equipment in buildings (TGA). Since 1992, he has been the project manager for TGA at IFB Dr. Braschel AG in Stuttgart. In that capacity, he served as a consultant to the principals of building projects, handling all engineering aspects of buildings. He places special importance on applying new technology, which includes rainwater utilization. Since 2005 he has been the president of Ingenieurbüro Technische Gesamtplanung.

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20.4.5 .1 Kaiser: The "weakness" of rainwater is its strength

When we consider substituting rainwater for fresh water, we should explore expanded use and applications, in addition to using it for flushing toilets or in laundries. One additional application, for instance, is using it for fighting fires. The convention of using the municipal water supply for fire fighting requires measures to ensure that hygiene is maintained in potable water systems. If rainwater is used, these problems will no longer have to be addressed, since a rainwater system and a municipal water system would be two separate systems. Hence, the danger of bacteriological cross contamination between the municipal water supply and the pipework of the fire fighting system no longer exists. This example is proof that the so-called "weakness" of rainwater as being unsuitable for potable purposes, can be its strength at times.

20.4 6 Lienhard, Martin

Civil engineer Martin Lienhard was born in 1962. He started his career as building site manager and planner in nationwide working companies and engineers offices. Since 1998 he is director of Technical Department at Mall Umweltsysteme in Donaueschingen, Germany.

Mall is a leading company in production of rainwater utilization systems mainly fabricated as concrete precast vessels. He is a member of the Committee for Rainwater Utilization Systems at German Institute of Standardisation (DIN).

Email: martin.lienhard@mann.info

Website: http://www.mall.info

20.4.7 ZVHSK

Technical requirements in Germany are, since 1993, covered by the workbook of the Central Association Sanitary-Heating-Air Conditioning (ZVSHK). This was updated in March 1998. Its title: Workbook for Rain Water Utilization Plants – Planning, Installation, Operation and Maintenance.

At present a DIN standard is being prepared to supersede this workbook. The committee members have agreed on the classification under DIN number 1989 and to divide its con-tents into four parts:

Part 1: Planning, installation, operation and maintenance
Part 2: Filter and treatment plant
Part 3: Rain water storage tanks and backflow safety measures
Part 4: Automatic control and monitoring systems

20.4.8 Heinrichs, Franz-Josef

Franz-Josef Heinrichs is responsible for the Department of Sanitary Engineering of the Central Association for Sanitary Engineering, Heating and Air-conditioning in St. Augustin. As part of his work, he represents the technical interests at the regulatory institutions and authorities in charge of water supplies, drainage, and gas installation. In addition, he creates specific codes and information brochures for the sanitary engineering business. He also acts as a technical consultant for companies working in the area of sanitary engineering, heating and air-conditioning. He also attends special trade events and participates in discussions by panels of experts, where he promotes the practical implementation and application of engineering codes.

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Website: http://www.wasserwaermeluft.de

20.4.8.1 Heinrichs: Applicability for planners and artisans

In cooperation with experts on rainwater utilization technology, a ZVHSK directive for planning, construction, operation and maintenance was devised; this was first published in 1993, and, due to rapid innovation, was updated in 1998. Rainwater utilization has meanwhile become a permanent feature of domestic installations, which gave rise to the creation of an official DIN engineering standard for this technology. This was incorporated in the DIN 1986 standards series for drainage systems, and in DIN 1988 for potable water installations; thus the DIN 1989-1 standard, which is applicable to the design, construction, operation and maintenance of rainwater utilization systems, is about to be published. The requirements for the inspection and testing of components in rainwater utilization systems are specified in additional sections of this standard. Further innovation in components and application technology has made rainwater technology in the last 10 years an important economic factor in industry and trade.

20.4.9 Amft, Andreas

Andreas Amft is a graduate industrial engineer with a major in marketing at Wavin GmbH in Twist. Since 1992 he has been in charge of international product and marketing management of water supply technology at WILO GmbH in Dortmund. Ecological concepts in the areas of sanitary engineering, rainwater management and gray water utilization are all part of his responsibility. He is also a member of the DIN NAW V 8 Committee for Rainwater Utilization Systems, member of the Federal Association for Storage Vessels and a board member of the Association for Quality Control of Rainwater Systems in the RAL.

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Website: http://www.wavin.com/com/index.html

20.4.9.1 Amft: Ecology and economy

The goal of modern and ecologically responsible corporations in industry should be to promote the change to ecologically compatible water management in stages; this implies developing environmentally compatible technologies while preserving natural resources and then making the systems available at competitive prices. Anyone who takes ecology seriously will have to carry out some strenuous groundwork rather than engage in wild activism or look for quick profits. If, in addition, some industries have the opportunity to initiate new business that would serve as an example of how the ecology and economy can harmonize. In the sector of rainwater technology, this opportunity exists in the sanitary engineering industry. It would be up to the politicians to attract investment in ecological technology and demonstrate the benefits to the national economy. If all parties are aware of their responsibilities, the idealistic targets along the path to environmentally compatible water utilization can be attained.

20.4.10 Alt, Franz

Dr. Franz Alt was born in 1938. Studied political science, history, philosophy and theology. Received his doctorate in 1967, was then journalist, reporter and moderator for television programs such as ‘Zeitsprung’ (Time Leap), ‘Quer-Denker’ (Creative Thinkers) and ‘Grenzenlos’ (Without Limits). He received numerous international media and environmental prizes. Since 1975 he has published over 20 books with 2 million copies in eight languages, mostly on the topic of solar energy.

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http://www.sonnenseite.com/

20.4.10.1 Alt: The right way to use precious water

Wastewater must be recognized as a resource that can be put to productive use. We must eliminate the foolish distinction between water and wastewater. Water is water. Industry will learn – with the help of political regulations - to recycle water. Water can be reused up to ten times and even more. We need the type of water recycling that Bahn AG is using for flushing the toilets in ICE 3 trains. Such savings through more efficient technologies would not reduce economic output, but would contribute to a greater quality of life. Today we don’t really think about water when we see a car, but manufacturing that car required about fifty times its weight in water. A typical Californian cattle ranching operation requires 20,500 litres of water to produce one kilogram of beef for hamburgers and steaks; the same operation, however, requires only 1,000 litres of water – only one twentieth of that amount! – to produce one kilogram of wheat. Vegetarians thus save water and protect the atmosphere. The eating habits of rich people today are very much related to the hunger and starvation of the poor.

21.4.11 Pöttgen, Guido Th.

Guido Th. Pöttgen studied law at the Westfälischen-Wilhelms-Universität in Münster. Clerked at the State Court in Dortmund. Since 1996, attorney in private practice at the law firm Rössl & Pöttgen, Chemnitz. Among his areas of specialization is the legal side of process water and rainwater utilization, in which context he has taken on various court cases. Other focus areas: private construction law, engineering and architectural law, and corporation law.

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20.4.11.1 Publications by Guido Th. Pöttgen

Pöttgen, Guido Th. and Götsch, Enrico (2002). Neue Trinkwasserverordnung eröffnet Betriebs- und Regenwassernutzung neue Wege. In *gi Gesundheitsingenieur. Oldenborg Industrieverlag – Zeitschriften* 4/2002 http://www.pvl.nl/download/32gep-endfasung.pdf

Pöttgen, G. and Sperfeld, D. (2002). Wäsche waschen mit Regenwasser darf jeder! www.fbr.de/publikation/fbr_ws_2_02.pdf

20.4.11.2 Pöttgen : Law and legislation

In Germany, environmental consciousness and the requirement that water be used sparingly are regulated through the general connection and utilization requirement. The water supply companies are required, through alteration of statutes, to give the consumer the option of limiting water consumption to a use desired by him or a partial need within the scope of economic acceptability and in the absence of contrary public interests. However, on the basis of existing application requirements, suppliers often reject exemption requests, citing standard reasons. Although public health concerns do not stand in the way of the use of rainwater for various household purposes, according to recent case law and literature, and references to economic unacceptability can usually be rejected, for the consumer the result is often unnecessary and prolonged legal proceedings which make it substantially more difficult to plan environmentally conscious action. Endeavour to establish comprehensive case law that induces suppliers to refrain from unjustified rejection of requests and discourages prolonged legal proceedings.

20.4.12 Sämann, Udo

Dr.-Ing., has his doctorate in engineering. After completing studies in hydraulic engineering, he became a co-founder, partner, and CEO of an interdisciplinary engineering consulting firm with a focus on environmental protection. As a result of his intensive involvement in the sector of rainwater utilization, he has been continually engaged in the presentation of papers on that subject, several of which were published in professional journals. He received his doctorate from the University of Witten/Herdecke, in 1997; the subject of his thesis was rainwater management. He currently works as an independent hydraulics engineer for Ärzte ohne Grenzen, e.V. (Doctors without Borders), and Wasser für Menschen e.V. (Water for People), both German NGOs working abroad in developing countries.

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Website: http://www.wa-me.de/index.html

20.4.12.1 Sämann: The focus is on mankind

Open discussions regarding sensible and economic use of water and the possibility of substituting rainwater for fresh water started as early as the mid-80s. The arguments in favour of conserving water – including my own – were based on the main objective of environmental protection and arguments that favoured locally decreed water policy. However, after working with Doctors without Borders, I have come to realize that the most important issue is life and the survival of mankind per se. The main element that makes a difference between life and death – in refugee camps, in emergencies, and in times of deficiency – is the availability and quality of water. This is precisely why it is so important that this precious resource is treated with great care around the globe, using the vision presently set forth by the industrial nations as an example.

20.4.13 Schoch, Steffen

Steffen Schoch has a degree in business economics with a major in marketing, from the College of Advanced Vocational Studies in Stuttgart.

He is the chief executive of the marketing organizations of German Cement Producers in Leonberg, Leipzig and Berlin. Rainwater is a frequent topic of his presentations in public forums and in the seminars he holds in communities, and at horticultural shows and events. He is presently the chief executive of Wirtschaftsregion Heilbronn-Franken GmbH, a company with offices in Heilbronn, Baden-Württemberg that promotes local marketing, and regional business and tourism.

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Website: http://www.heilbronn-franken.com/DATA/KONTAKT/kontakt_steffen_schoch.php

20.4.13.1 Schoch: Water is our future

Because the availability of water is a major consideration in determining the areas we develop, people are liable to fight over water resources. Clean drinking water is a basic requirement for health and prosperity. Thus, two primary objectives of the public, businesses, and politicians must be to secure an adequate and suitable water supply and ensure proper disposal of wastewater. This is why we must safeguard and protect our water resources by harvesting and using rainwater for toilets and irrigation, as well as in laundries, car washes, and public and private water displays. Water displays and fountains in public areas are particularly useful in making the public aware of how valuable this precious commodity, water, is.

20.4.14 Zeisel, Joachim

Joachim Zeisel is a process engineer with a focus on water purification and wastewater technology, who has specialized in the implementation of water saving concepts for cities. He has made some significant contributions in the development of gray water/recycling technology and rainwater utilization. He gives presentations at home and abroad and is an active member of the International Ecological Engineering Society and of the International Ecological Engineering Society and of the fbr Association.

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20.4.15 Rautenberg, Joachim

Joachim Rautenberg is a graduate civil engineer who majored in domestic water supply engineering. His professional career extended from wastewater treatment to water supply technology. Since 1992, Joachim Rautenberg has been the engineering superintendent of Fernwasserversorgung Franken (long-distance water supply in Franconia); this facility supplies fresh water to 141 municipalities and localities throughout the region. Joachim Rautenberg is a founding member of the Fachvereinigung Betriebs-und Regenwassernutzung fbr, where he is actively working with the group specializing in hygiene/water quality.

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20.4.15.1 Rautenberg: Rainwater utilization and public water supply

In locations where water resources or existing distribution systems can no longer cope with increasing demand, substituting rainwater for fresh water, especially in non-critical applications, is a sensible alternative. It is imperative that systems must be properly designed and installed by experienced and competent technicians who can perform the required maintenance on a regular basis. However, even in areas with an excess of water and where the municipal water supply net is adequate, the value of implementing rainwater utilization must not be ruled out. As long as the proponents for rainwater utilization realize that these systems are not intended to present an end in themselves, and as long as the water supply companies appreciate that rainwater utilization systems, which incorporate percolation systems to deal with the excess runoff, can also be useful for horticulture and contribute to replenishment of groundwater resources, then private rainwater utilization and public water supply should not be considered a conflict, but rather a useful supplement.

Italy

21.1 *Practice*

Italy's north is famous for producing water pumps. German manufactures of RWH Plants are importing these products. Trading also brings back RWH systems made in Germany to Italy's north region. Another reason is tradition: The Alp Mountain areas of Italy, such as Piemont and Lombardia, have used rainwater as a natural resource for centuries.

Luxembourg

22.1 Research

22.1.1 Resource Centre for Environmental Technologies (CRTE)

22.1.1.1Reponsible person: Schosseler, Paul

Dr., got his PhD degree in physical chemistry at the Swiss Federal Institute of Technology Zurich in 1998. Since 2005 he has been head of the Resource Centre for Environmental Technologies (CRTE), Luxembourg, where he has been working for six years on projects related to the sustainable management of the urban water cycle. Main fields of interest are innovative process technology, process optimisation, using modelling/simulation tools, as well as ecological sanitation concepts, with focus on the multi-criteria evaluation of these concepts, taking into account environmental and socio-economic aspects.

Email: Paul.schosseler@tudor.lu

Website: http://www.crte.lu

22.1 Policy

22.1.2 Urbany, Guy

Guy Urbany is a chemist who worked for nearly 20 years in the Department of Environmental Management in Luxembourg, specializing in water analysis. He also participated in a study at the University of Metz of water polluted by heavy metals. Since 1992, he has been the authorized representative for environmental management in the town of Düdelingen. He is the chairperson of the Association of Environmental Representatives, Emweltberodung Letzebuerg, which works in cooperation with the Department of Environmental Management. He is a member of the Technical Committee for Regional Planning and Cooperation.

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Website: www.ebl.lu

22.1.2.1 Urbany: Local authorities must set an example

Rainwater – a blessing for mankind and nature alike – also has disadvantages. However, these disadvantages have been caused by man. We have caused changes in climate and sealed too many open areas. We build in floodplains and then are surprised if they become flooded when it rains! Most communities do not have separate sewer and storm water systems. The result is that excessive amounts of clean rainwater are discharged into wastewater treatment plants, exceeding their volumetric treatment capacity; then, in turn, untreated effluent overflows and contaminates streams and surface water. The economic damage of this anthropogenic intervention into the natural hydrological cycle is enormous, but politicians, who think only in terms of elections and do not apply the necessary foresight, ignore it. The only remedy is to decentralize rainwater management. To limit further damage, the private and public sectors must coordinate and implement innovative techniques, such as rainwater utilization, rainwater percolation, and curtailment of surface sealing. Local authorities must set an example by promoting these measures.

Netherlands

23.1 Research

23.1.1 Knoppert, Wim G.

Wim G. Knopert graduated from the Technical University for Hydrology and Environmental Conservation in Nimwegen; thereafter, he studied environmental engineering at a local university. From 1990 until 1992 he was employed as a hydrologist at KIWA (a national institute for testing products and materials for use in the potable water supply), and thereafter worked for the Provincial Administration of Gelderland. Between 1997 until 1999 he worked at the Ministry of Transport and Hydraulic Engineering. He has returned to the Provincial Administration of Gelderland, where he is presently head of the Environmental Department for Urban Renewal and an independent consultant for environment, water and transport.

Email: w.knoppert@prv.gelderland.nl

Website: http://www.gelderland.nl

23.1.1.1 Knoppert: Courage for sustenance

Building and urban development involves more than simply selecting the right materials. New concepts are complex, and thinking along specialized lines is no longer enough. This applies equally to devising new plans for supplying water to consumers, including the utilization of rainwater: engineers must think expansively and design systems that manage water from its source right up through the wastewater treatment plant to its final discharge. This comprehensive approach can generate new ideas. For instance, the concept of supplying B-quality water, which the consumer can subject to secondary treatment or polishing filtration, and then decide upon its ultimate use. And now it is even possible to produce clean, potable water from domestic waste treatment systems. This latter application will naturally require intensive investigation and testing. New ideas always take time to be accepted. In this vein, for instance, approximately 95% of households in the Netherlands are currently connected to natural gas, which has many known environmental advantages; as current experience has shown, the danger of gas explosions was a much exaggerated counter-argument during the ’50s and ’60s. Let’s hope that we can apply these same concepts to water, and learn how to make the right decisions for the long-term.

23.1.1.2 Publications

Local & Regional Policies was accepted as a part of Interreg 3c program of the European Union.
http://www.interreg3c.net/sixcms/detail.php?id=6413&_searched=&_currfloaterlang=

23.1.2 UNESCO - IHE Institute for Water Education

Is situated at the city of Delft. The process to establish the UNESCO-IHE Institute for Water Education was concluded by a decision of the 31st General Conference of UNESCO in November 2001. On 18 March 2003, at UNESCO Headquarters in Paris, representatives of the Netherlands Government, of the former national structure - the IHE Delft - and of its funding arm, the Foundation, joined the UNESCO DG, Koichiro Matsuura and other senior Secretariat officials to put their signatures to a set of agreements by which the newly-created UNESCO-IHE Institute for Water Education (UNESCO-IHE) will come into operation.

UNESCO-IHE is instrumental to the strengthening of efforts by other universities and research centres in increasing knowledge and skills of professionals working in the water sector. The 190 Member States of UNESCO will have access to the knowledge and services of UNESCO-IHE in human and institutional capacity-building, which is vital to their efforts in the achievement of Millennium Development Goals, the Johannesburg Plan of Implementation and other global water objectives.

Website: http://www.unesco-ihe.org/about/contact.htm

23.2 Policy

23.2.1 Residential Water Use Standards

The Netherlands is at present considering stipulating a system to save the use of mains water in new residential buildings. Estimating and planning models with water-costs -coefficient (WPC, Water Prijsstatie Coeffizient) are to be established for future standards.

The Netherlands Ministry for Housing, Land and Environment (VROM) has commissioned the planning offices CEA and BOOM to investigate the possibilities and chances of such standards. Within the framework of these investigations questionnaires have been sent to Austria, Denmark, Germany, Great Britain and Sweden.

23.3 Leading Experts

23.3.1 Boelhouwer, Wim P.

Wim P. Boehouwer, educated in Mechanical Engineering and Marketing Management, worked in international and senior management functions for 15 years with Philips in the Netherlands. This was followed by similar functions for 22 years with Wavin. Retired from Wavin in 1999, to establish his own company AquaEst. The objective is to globally promote the benefits and value of rainwater as an additional source of water. In the meantime AquaEst has established a Dutch consortium to develop Rainwater Treatment Technology, in co-operation with the Technical University of Twente in the Netherlands. The purpose is to improve the quality of rainwater so as to meet the standard set by the World Health Organisation. Is currently representative for IRCSA in the Netherlands and a member of the German fbr.

Email: willempboelhouwer@compuserve.com

Website: http://www.aquaestinternational.com/home.htm

23.2.1.1Boelhouwer: Rainwater Harvesting-Now is the time for global marketing!

Rainwater Harvesting is slowly becoming seen as an important source of water. But it still has a long way to go before it is perceived as the norm for providing a quality supply and has yet to win a substantial share of the global market for drinking water. Despite a global network of interested parties there remains a fundamental need to increase awareness of rainwater as a quality source amongst a wider international audience. Until now, little or no widespread, professionally planned marketing of these ideas has taken place. Limited attention has been paid to positioning and marketing Rainwater Harvesting. Consequently, the business community has yet to grasp this opportunity and exploit its potential. The correct marketing mix must be created to make appropriate technology available at an affordable price. Local needs must be met, as must the need for distribution of products on a global basis. And the idea of rainwater as a quality, uncontaminated source needs to be promoted globally, giving it the stature it deserves and making Rainwater Everybody's Business possible.

Slovakia

24.1 Practice

24.1.1 Arousing interest

Slovakia is forced to raise the technical and environmental standards to the EU level. The interest in rainwater utilisation is constantly increasing. Some commercial and public large projects have been already realised. Because of the low water price and low income of private households, the investments in rainwater harvesting in private homes is still limited. Wage differentials and governmental subsidies lead to the foundation of production facilities and branch offices of German rainwater firms in the country.

24.2 Research

24.2.1 Valasek, Jaroslav

Jaroslav Valasek is a professor at the Slovak Technical University in Bratislava. From 1994 to 2000 he held the chair of TGA (Building Engineering Equipment) at the Faculty for Structural Engineering at Bratislava Technical University, specializing in sanitary engineering. He is the spokesman for the Commission for Water and Wastewater Management at the Slovak Institute for Engineering Standards. Presently, he is focusing on rainwater utilization in combination with constructing roof gardens for industrial factories. He has been a member of the Fachvereinigung Betriebs- und Regenwassernutzung e.V., Darmstadt, since 1998.

valasek@svf.stuba.sk

24.2.1.1 Valasek: Go-ahead for rainwater utilization in factories

Simple methods of utilizing rainwater have been practiced in the Czech and Slovak Republics for some time now. However, because the price of municipal water is so cheap, it is not cost-effective to use modern systems. Unfortunately, the price of water was determined by the state based on political motives rather than economic rationale. In the year 2000, the cost of fresh water translated into approximately 0.35 Euro/m^3. I am nevertheless convinced that in the near future we will experience an increased use of modern rainwater and gray water systems. This trend is confirmed by my recent experience in planning new housing.

24.2.1.2 Selected Publications

Valasek, Jaroslav. (2005). ZDRAVOTNOTECHNICKÉ ZARIADENIA BUDOV Bratislava, *Jaga* 2005.

Switzerland

25.1 Practice: IRHA Geneva

For more than 3 years IRHA has been increasingly acknowledged as a voice in the field of RWH. It has established relationships with many RWH organisations, NGOs, CSOs, UN agencies, international & government agencies, companies & individuals worldwide.

Supported by the Swiss Agency for Development & Cooperation

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CH-1219 Châtelaine
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Fax: +41 22 797 41 59
Email: secretariat@irha-h2o.org
Website: www.irha-h2o.org

25.2 Research

25.2.1 EAWAG Dübendorf

Eawag is a Swiss-based and internationally linked aquatic research institute committed to an ecological, economical and socially responsible management of water – the primary source of all life. It carries out research, teaching and consulting and forms a link between science and practical application.

Environmental Engineering
Überlandstr. 133, 8600
Dübendorf
Switzerland
Website: http://www.eawag.ch/index_EN

25.2.2 Sustainable development and efficiency

The department "Urban Water Management" orients its research at current and future problems within the whole range of water management issues of the man-made urban water cycle. In contrast to the disciplinary research of the engineering department, cross-cut working groups through Eawag are formed within SWW to study the respective problems, which are compound for engineers, natural and social scientists of Eawag and external specialists. The department is an interdisciplinary centre of competence and partner for technical-industrial specialists in urban water management as well as for political, social and administrative stakeholders.

Apart from the traditional problems such as hygiene in urban settlements and water protection issues, the sustainable and efficient use and management of resources are focused in the research of SSW. Here the term "resources" is interpreted broadly and covers physical, natural, financial and human resources.

Website: http://www.eawag.ch/organisation/abteilungen/sww/schwerpunkte/index_EN

Department of Environmental Engineering (ENG) The environmental engineering division works on current and future aspects of urban hydrology, wastewater and drinking water treatment, as well as water pollution control. Special emphasis is given to engineering science aspects. Together with the division urban water management (UWM) our goal is, to develop sustainable concepts of the water and nutrient cycle in urban settlements. Projects are carried out in close cooperation with the practice, e.g. professional associations, federal and cantonal environmental protection agencies, wastewater treatment plants and drinking water supply units. The participation of the professorship of sanitary engineering at ETH-Zürich in the environmental engineering division ensures a close cooperation of both institutions in research and teaching. Several collaborators of the division are involved in teaching at ETH Zürich. The department organizes regularly practice oriented courses for advanced training of professionals and post diploma students at the Eawag (Peak) and together with professional associations. The consulting work concentrates on problems in Swiss urban water management.

Website: http://www.eawag.ch/research_e/ing/e_index.html

25.2.2.1 Responsible person: Boller, Markus

Prof. Dr. sc. techn. ETH, is presently head of the department for Urban Water Management at the Swiss Institute of Aquatic Science and Technology (Eawag). During more than 35 years of research, consulting and teaching activities concerning all technical aspects of urban water management, his interests are focused on the development of new technologies for water and wastewater treatment and the transfer of innovative technologies from scientific studies to practical application in Swiss and international water practice. In the last years, pollutant mass transport in urban water systems, stormwater management, future concepts in drinking water production and alternative sustainable technologies for wastewater management are main research topics. He is author of numerous scientific publications and popular articles and member of many national and international professional organisations and committees and active in teaching at ETH and advanced courses for continuing education.

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Website: http://www.eawag.ch/organisation/abteilungen/sww

25.2.3 ETH Zurich

Boller, Markus

See 25.2.2

United Kingdom and Wales

26.1 Practice

26.1.1 The future of rainwater harvesting in the UK

The industry is small but progressing rapidly. Turnover has doubled every year for the last 3 years and is now £1,000,000 (US$1.8 million) a year. This current growth rate is expected to continue for the next 3 years at least. The UK Government is supporting rainwater harvesting in the commercial sector as one of a series of measures to reduce water use. Businesses that install approved rainwater harvesting systems can write off the cost against tax. Future legislation that requires rainwater harvesting in new developments will continue to drive the industry onwards. UK-RHA say systems are already in use on major housing developments around the UK, but do not seem to be featuring in debates surrounding the areas worst affected by water shortages. Where used, rainwater harvesting systems have been widely welcomed by Planning and Building Control Officers.

26.1.2 UK-RHA

For some time, several companies distributing rainwater-harvesting systems have co-operated to create a focus point for those interested in rainwater harvesting. The UK Rainwater Harvesting Association was formed on 1st December 2003, composed of ten founding members: Celtic Water Management Ltd, Conder Products Ltd, Construction Resources, Gusto Products Ltd, Hanson Building Products, Klargester Environmental Ltd, Polypipe Civils Ltd, Rainharvesting Systems Ltd, Waterbank Ltd, and Water Support Services (Yeovil). The UKRHA will enable easier cooperation with members and partners, help and assist developers, as well as promote the development of the industry. (Source: Demand Management Bulletin No. 63 Feb. 2004, Environment Agency UK)

For more information contact Terry Nash

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Website: www.ukrha.org

26.2 Research

26.2.1 Fewkes, Alan

PhD, is a Senior Lecturer in Building Engineering Services at Nottingham Trent University. He has been actively involved in research related to water reuse and recycling for eight years. Initial research concentrated upon the in-building reuse of rainwater. A rainwater system was monitored and data collected to verify and calibrate a model for sizing rainwater collection systems. Current research has been extended to cover both rainwater reuse and grey water recycling in collaboration with Imperial and Cranfield University.

Website links:

http://www.ntu.ac.uk

http://www.cranfield.ac.uk

26.2.1.1 Fewkes: A Sustainable Future

In the UK the majority of the population receive water via a mains network and dispose of wastewater via a piped sewerage system. A number of problems have been linked to centralised supply and disposal systems, these include; increasing water demand, resources not located in areas of high demand and increased surface water run-off volumes and discharge rates due to urbanisation. An alternative and more sustainable strategy is the use of decentralised technologies. For example the use of planted or green roofs results in partial water retention and reduced peak runoff flows into the storm sewer network. Storm water sewer connections can be eliminated completely if techniques of on site infiltration are used. Rainwater collected from roofs can be used for non potable applications potentially reducing the utilisation of potable water. The major application for rainwater utilisation in the UK appears to be for WC flushing and garden watering. The benefits include conservation of water resources, relief of demand on public water supplies and potential attenuation of peak runoff into the storm sewer network.

26.2.2 Thomas, Terry

Dr., has headed since 1985 a unit, in a university engineering department, that researches low-cost technologies for developing countries. He has been variously an electrical, control, transport and mechanical engineer, and worked in a dozen tropical countries over 40 years. Roof water harvesting sits alongside other research interests, like building materials and landmine clearance, whose common ground is their potential to meet basic needs and generate artisanal incomes.

26.2.2.1 Thomas on Substantial Benefits from very low cost Systems

The old technology of roofwater harvesting (RWH) gave way to other methods of supply because they were cheaper (if applied on an urban scale), could give more water and were more amenable to commercial control. In some places these alternatives are now reaching the limit of their capacity. In other places they fail to serve the urban poor or those living in low-density rural communities. If rainwater harvesting is treated as one source among several, it is possible to obtain substantial benefits from very low cost systems incorporating water storage equivalent to only a few days usage. For this reason RWH is moving briskly beyond a limited role as a 'supply of last resort' in semi-arid areas to being a cheap and accessible source, to be used alongside others, in more humid areas, both tropical and temperate.

26.2.2.2 Selected Publications:

Thomas, Terry. (No date). Domestic Roofwater Harvesting, Research Programme http://www.eng.warwick.ac.uk/dtu2/rwh/index.html

Martinson, D. Brett & Thomas, Terry. (2005). Low-cost inlet filters for rainwater tanks. Paper for IRCSA XII, New Delhi, November 2005. http://www2.warwick.ac.uk/fac/sci/eng/research/dtu/rain/martinson-filters.pdf

Way, Celia & Thomas, Terry. (2005). Slow sand filtration within rainwater tanks. Paper for IRCSA XII, New Delhi, November 2005. http://www2.warwick.ac.uk/fac/sci/eng/research/dtu/rain/way_-_ssfilter.pdf

26.2.3 Hills, Sian

Sian Hills holds a BSc in Environmental Science and has been an active participant in environmental research and technology management for 20 years. Currently she is the International Development Manager in the Research & Development Department at Thames Water. She is responsible for managing the Company's research into water resources, reuse and climate change, including the Millennium Dome recycling project. The role also involves developing overseas research programmes in appropriate locations, such as South Australia.

Email: Sian.hills@thameswater.co.uk

26.2.3.1 Hills on Rainwater use in Thames Water

London receives lower rainfall than many other major world cities, an average of 613 mm per year. With a population of over 11 million in the region, efficient management of water resources is vital, and Thames Water is already using 55 % of available rainfall. As a result of population growth, climate change, and more single-person households, demand for water is still increasing. A plan has been adopted by Thames Water, covering the development of new resources as well as demand management. Research into water recycling, including investigations into more efficient use of rainwater, is a key part of this strategy. Work is being carried out at all scales, both in the UK and overseas and ranges from individual house systems, to projects the size of the Millennium Dome and larger. The work also involves innovative approaches to secure wider public participation and acceptability of water conservation measures.

26.2.3.2 Selected Publications:

Birks, R., Colbourne, J., Hills, S. & Hobson, R. (2004). Microbiological water quality in a large in-building, water recycling facility. *Water Science & Technology* 2004,Vol. 50 No 2 pp 165–172.

Hills, Sian. (2004). Scientists go in search of the perfect shower. News release, Thames Water 2004, December 10. Retrieved from http://www.thameswater.co.uk/cps/rde/xchg/corp/hs.xsl/4658.htm

26.3 Policy

26.3.1 Infrastructure of water supply in the UK

There is no national water supply network and much of the existing distribution pipe work is over 100 years old. Leakage from failing Victorian cast iron mains is a serious issue. Most water suppliers still have a leakage rate above 20% and some regularly fail to meet Ofwat leakage targets. There are areas of North London where leakage is running at 60%. The UK has a history of water not being charged for by volume. Although all commercial buildings are now metered, just 22% of domestic properties are. Households pay a fixed rate, regardless of water used, based on the “rateable value” of their home.

In England and Wales water was privatised in 1989. In Scotland and Northern Ireland it is still provided by the state, although there is an expectation that water will be privatised in these countries soon. There are 10 major water and sewerage providers in England and Wales, with a further 14 small companies that provide water only. As most consumers do not have a choice of supplier, the water industry works, in effect, as a private monopoly. The water companies are charged with preventing inadequate pressure, supply interruptions, restrictions on the use of water, and flooding from sewers. They are regulated by Ofwat (a Govt appointed agency), which is seen by the vast majority of consumers as having little regulatory or enforcement authority.

26.3.2 Increasing water shortages

Due to increasing demand and reduced rainfall in some years, water shortages are increasing. The south and east of the UK are especially vulnerable. Dry summers (preceded by winters with below average rainfall) in 2003 and 2005, resulted in the threat of water restrictions in 2003 and actual water restrictions in areas of the southeast in 2005. During the summer of 2005, there was high media coverage of the need for individuals to reduce their water consumption.

26.4 Leading Experts

26.4.1 Hassell, Cath

Cath Hassell has been involved with the plumbing industry for over 25 years and in environmental building for 8 years, set up ech2o, an environmental consultancy, in 2002. Among her specialisations are sustainable urban drainage systems, rainwater harvesting, grey water recycling, water efficient appliances, composting toilets and constructed wetlands.

Email: cath.hassell@ech2o.co.uk

26.4.1.1 Hassell: Rainwater Harvesting in England

With drier summers and increasing development predicted in the south and east of England over the next few years, demand has to be reduced as part of the efforts to achieve sustainable water supply. Rainwater harvesting can be seen as an important method in reducing requirements for potable water and storm water flows.

26.4.1.2 Selected Publications

Hassell, Cath. (2005). Rainwater harvesting in the UK – A solution to increasing water shortages? Paper presented at the International Rainwater Harvesting Conference, New Delhi, 2005. Available at http://ech2o.atspace.com/PDFs/DelhiAbstract.pdf

26.5 Summary

26.5.1 Water Availability and Water Use

While England and Wales are traditionally considered as having wet climates, total accumulated precipitation can vary widely from year to year. Drought-like conditions occur with some regularity during the summer period. This combined with a large and growing population living on a small land base can exert tremendous pressure on available surface and ground water supplies. The population is expected to increase by 2.8 million persons in the period 1996 to 2016. Total annual water withdrawals from all sectors combined are about 16,000 million m^3. Public water supply and thermal power plant withdrawals each account for about 42% of total abstractions (see figure). Industrial and commercial-aquaculture takings make up most of the remainder. With only 108,000 ha or 0.6% of all agricultural lands being irrigated and much of that for higher-value crops, the UK's agricultural crop-water use component is the smallest among jurisdictions included in this study. Trends in Sectoral Water Withdrawals in England and Wales (1971-2002) Environment Agency. (2002). Your Environment- Environmental Facts and Figures. See online at www.environment-agency.gov.uk/yourenv/eff

26.5.2 Water Management

Water management in the UK has gone through a succession of reforms in the past few decades that have seen responsibilities fully devolved to watershed authorities and then partially centralized again. The provision of public water supplies is generally the responsibility of private water companies. These companies typically provide water services to several communities and report to watershed-based regional offices of the Environment Agency.

26.5.3 U.K. Environment Agency Regional Offices

The 1991 Water Resources Act and the more recent U.K. Water Act (2003) both incorporate provisions for regulating water-use sustainability. The former requires measurement and reporting of abstractive water usage within Catchment management areas. It also established a Water Demand Management Department within the Environment Agency with responsibilities to further the science and practice of demand management and drought management. The Water Act strengthens requirements for sustainable use. Water companies are required to document the measures they are taking and the progress made in managing the water distribution system and in encouraging water-use efficiency among their customers. The Environment Agency has the power to revoke or amend water licenses if the water use is found to be damaging the environment. The Water Industry Act (1991) regulates the prices that water companies charge customers. In addition to bringing needed price stability and certainty to the industry, the Act facilitates application of universal metering and cost recovery on actions taken to implement conservation and water-use efficiency. Price structures are reviewed every five years. Water Supply Regulations which accompany the Act set minimum national efficiency standards for toilets, washers and dishwashers and specify other plumbing requirements intended to minimize water waste. On the surface, these mechanisms together with the Water Act requirements would appear to require water companies to aggressively pursue water conservation. Recent government and independent reviews have, however, shown that the privatized water industry has been slow in introducing changes seen as a threat to its profit margins.

Since 2001, the Catchment Abstraction Management Strategies (CAMS) process has required the establishment of water budgets for designated river basins. The budgets will be used to determine sustainable abstraction levels and aid in the identification of actions needed to regulate water withdrawals in the face of future growth. Throughout England and Wales, a Water Abstraction Licence and/or a Water Impoundment Licence is required for any non-domestic surface or ground water taking in excess of 20,000 L/day. The UK's 'Waterwise' and 'Envirowise' outreach and education programs offer detailed and regularly updated advice and technical assistance to homeowners, industries, commercial establishments, institutional facilities and farmers on selecting and implementing best technologies and practices for water efficiency.

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Environment and Public Health Organization (ENPHO). (2005). *Operational Research on Decentralized Wastewater Management and its Dissemination*. http://www.adb.org/Water/PDA/nep/Project-Completion-Report-5-Nov-05.pdf

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Ghosh, D. (1991). Ecosystems approach to low-cost sanitation in India: Where the people know better. In E*cological engineering for wastewater treatment*; C. Etnier and B. Guterstam, Eds., Bokskogen: Gothenburg, Sweden, 1991; 63-79.

Gleick, Peter H. (2003). *The World's Water: The Biennial Report on Freshwater Resources*; Island Press: Washington, D.C., Vol. 3.

Heinss, U. & Kopottatep, T. (1998). *Use of reed beds for faecal sludge dewatering: A synopsis of reviewed literature and interim results of pilot investigations with septage treatment in Bangkok, Thailand*. Swiss Federation Institute for Environmental Science and Technology (EAWAG), Water and Sanitation in Developing Countries (SANDEC) and Asian Institute of Technology (AIT), 1998.

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