Sustainable Water Management in the City of the Future

'Economics in the SWITCH project'

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SWITCH Deliverable Briefing Note

SWITCH Document Delivery WP 6.4.4 **'Economics in the Switch project'**
Audience This document is targeted at an audience both inside and outside the SWITCH consortium: policy makers, local government officials, engineers, accountants, state or federal planners, etc. The audience consists of urban water managers that would like to know how to use economic and financial analysis in the choice of their projects.
Purpose The purpose of the document is to review how the different working packages have dealt with financial and economic tools available to analyze the implications of these alternative approaches to sustainable urban water management. It aims to find out whether the proposed system is an economically viable alternative to the existing system by making a comparison between the alternative approaches. The expected results of the research should help decision makers to select the more suitable solutions.
Background Economic and financial tools were used in different parts of Switch, but no effort had been made to compare the results of using such tools and their contribution to a better understanding of the issues.
Potential Impact The research provides an analytical framework to look at issues in integrated urban water management and link them to different economic and financial tools to gain a better insight in the issue at stake.
Issues 1. Not all issues have been covered and not all issues can be understood better by using economic and financial tools 2. More tools and more sophisticated tools are possible. The question is to what extent they help to analyze the issues
Recommendations 1. To think in a more systematic way which issues can be tackled with which economic and financial instruments and look at the data requirement from the start 2. To train water specialists in using economic and financial tools 3. Some issues keep coming back, but require a multi-disciplinary approach, a combination of economic and financial tools and a better regulatory environment

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1. Introduction

How did Switch researchers and learning alliances deal with economic and financial issues while coming up with suggestions for Sustainable Water Management in the City of the Future? In this report the main financial and economic issues in integrated urban water management (IUWM) will be listed. A framework for integration will be suggested linking the issues to the tools of economics and finance used to a number of key technologies suggested in the framework of the Switch project.

There is also a distinction between positive economics (dealing with what questions) and normative economics, dealing with what ought to be questions and which by definition then is value-laden The purposes of economic analysis are three-fold:

1. To simplify the nature of the choice to a level that we can comprehend (positive theory)
2. To enable us to understand the key elements of that choice (normative theory).
3. To communicate that understanding to all stakeholders so as to form a framework in which they can debate, argue and negotiate their concerns.

Economics helps to answer questions like: Why are we doing this? What are the alternatives? What sacrifices do we have to make for this option?-Does it work? For an economist these concerns are translated into options and the economist would like to help to determine the best choice, taking as point of departure what would mean least cost to society. An issue may be whose or what cost perspective do you take? The whole-of-society perspective (include cost to all relevant parties), or the perspective of the local government, the farmer, industrialist or household trying to use a water saving option? Secondly it is important to look at the distributional consequences of certain options: who really benefit from it? In this report a systematic distinction will be made between the perspective of an individual and the interests of society as a whole.

The second section will provide a definition of economics and water economics. Section 3 deals with the distinction between macro and micro economics and between neo-classical and institutional economics. Then we list the most important issues in IUWM and the different disciplines dealing with it and their major tools. This leads to a chapter suggesting a framework of integration of economics and technical sciences. The challenge of this report is the integration of economics and technical sciences: Applying the framework what does it teach us about the projects undertaken in the framework of the Switch project? In the first part the contribution of economics to solving water issues will be discussed and a definition of water economics will be provided and an analytical framework for dealing with the issues will be developed. In the second part this analytical framework will be applied to six Switch issues, to show what contribution economics did make in these cases. In the last section some conclusions are drawn.

Part I The contribution of economics and a definition of water economics

2. A definition of economics and water economics

The easiest definition of economics is the study of the economy. The economy is then defined as the social organization whereby resources are converted to intermediate products, capital stock or final consumer products. This does not help much to understand how economics can help in the water sector. To understand what economics can contribute to water management it is important to know what economics really is and which tools it can provide. Four definitions of economics can be given, economics is:

1. "The science which traces the laws of such of the phenomena of society as arise from the combined operations of mankind for the production of wealth, in so far as those phenomena are not modified for the pursuit of any other object" (Mill, 1848).
2. "The science which studies human behaviour as a relationship between ends and scarce means which have alternative uses" (Robbins, 1935)
3. "The study of how men and society end up choosing, with or without the use of money, to employ scarce productive resources , which could have alternative uses, to produce various commodities and distribute them for consumption, now or in the future, among various people and groups in society" (Samuelson, 1970)
4. "The application of reason to choice" (Green and Newsome, 1992)

Green (2003) starts his Handbook of water economics with an overview of the literature and concludes that economics is about choice. He then spends a lot of time on rationalizing how we are making these choices. Choices may imply a conflict: a disagreement for example on the formulation of the objectives or the weights given to different objectives. These objectives are considered as given in economics and are formulated by others, for example the politicians. However, the preferences of consumers or entrepreneurs need to be taken into account. Usually they are assumed to strive for maximum utility (consumers) or profit maximalization (entrepreneurs). However, utility substitution is possible, meaning that different goods & services can substitute each other because:

a. they have the same positive effect on your satisfaction, or they are
b. Functional equivalent or substitutes: goods & services may replace each other, while not exactly being the same: natural butter and margarine, or
c. Finally we can have exchange substitutes, meaning one can be bought or sold for obtaining the other

Green (2003) also points to space created monopolies: for example the network of a water company. Hence there may be conflicting objectives, because of mutual exclusivity in space or time: you can not be at two locations or do two things at the same time. Finally economics has to deal with externalities: the cost or benefits that relate to water service but are external to the utility or private company providing water and or sanitation and are not part of the utility's cost or benefits of its services.

My preferred definition of economics is based on Russel (1954): "the use of reason linked to the choice of means to some end". This would lead to economics is:
about dealing with scarce resources, which implies using tools to make a rational choice between alternative uses of these scarce resources.

We can now give a definition of water economics. As a parallel to the definition of economics one could say: water economics concerns the economics of the water sector. However, I prefer a definition which is more instrumental: water economics deals with issues in the water sector using the tools of economics to use reason to make choices between different options, which require scarce resources, in particular the available water resources or the environment. For water economics it is important to understand the behaviour of the major actors.

3. Some distinctions: micro and macro, neo-classical and institutional economics

3.1 A distinction between micro and macro economics

In the literature there is a distinction between micro and macro economics. In table 1 some of the differences between the two specializations are highlighted. First a summary of what micro and macro economics do:

- Micro economics studies the economic behaviour of individuals (workers, farmers and entrepreneurs) and in particular their economic decision making
- Macro economics looks at the level of society what needs to be done to guarantee economic stability and development. It is concerned with the organization of the factors of production, such as land, labour and capital and mainly provides the economic context for water related projects.

The problem is that at the micro level individuals, farmers and entrepreneurs may act rational because they have clear objectives, but at the macro level the objectives are set differently and the result of aggregation. For example at the national (macro) level the saving rate is what all people in a country together save as percentage of their total income. At the micro level it is what you set apart for later. You know what you are going to do with that money. At the national level the money can be used by the government, or it may be channelled through the banks to the private enterprises, or it could go abroad if higher returns are expected elsewhere. This leads the macro issue: do savings lead to investment and growth? It is far away from your decision to keep the money at home or put it in a bank.

Table 1 Differences between micro and macro economics

Micro economics	Macro economics
• Concerns the behaviour of individuals: decisions how to use time and money • Looks what is really happening at the micro level of the markets • Is it easier to study activities at this level: farmers, entrepreneurs and households can be asked what they want and how they use their money for consumption or investment purposes • Incentives work very directly at the micro level • Micro economic policies may use models based on the behaviour of micro economic actors	• Concerns the 'whole' economy for example: growth, inflation, savings and investments! • Looks at national aggregates and international economic relations • Difficult to link developments directly to the behaviour of the economic subjects. This is called the micro-macro problem in economics • Works with aggregates such as the GDP, national interest rate and balance of payment • Macro policies work indirectly and require agreements from the politicians and the financial experts

3.2 Neo-classical (main stream) economics and institutional economics

An important distinction in economics is between neo-classical (main stream) economics and institutional economics (see table 2 below).

Table 2 Different layers analyzed in institutional economics

Level: four different layers	Purpose of each layer
1. Embeddedness: informal institutions, customs, traditions, norms and religion	Often non-calculative; spontaneous, based on social theories
2. Institutional environment: formal rules of the game, especially property (polity, judiciary, bureaucracy)	Get the institutional environment right; first order economizing (for example defining property rights)
3. Governance: the way the game is played, especially aligning governance structures with transactions	Get the governance structure right; second order economizing (designing institutional arrangements)
4. Resource allocation and employment (prices and quantities: incentive alignment	Get the marginal conditions right; third order economizing, neo-classical theories

If neo-classical economics is more or less familiar to people reading the newspaper (or Samuelsson, 1970), institutional economics requires some more explanation. According to Adam Smith, the classical economist par excellence, competition serves the public interest. It leads to specialization and distribution of labour which increases the productivity of an enterprise. I agree with this statement, but still like to argue in favour of paying attention to the role of institutions, in particular in those markets which do not function well.

The issue of the value of water can show the difference between the two schools. It is important to distinguish the price paid and the subjective value. In the past value was based on the object. The real classical economists (Smith, Ricardo and Marx) considered the value of a good to be the result of the labour put into it (labour value theory). Currently value is considered instrumental value (or imputed value), it is linked to the possible use of the object. Green (2003) gives an example of this 'imputed value'. You can buy a hat to be beautiful or to avoid catching a cold, etc.! These are examples of the functional value of a hat. Other things that have a value may not have a price (your child for example).

Institutional economics is about the role of institutions and attaches an important role to the government in the functioning of the economy. Scott (1995) gives a definition of institutions as consisting of: "cognitive, normative, regulative structures that provide stability and meaning to social behaviour". Institutions are rule-based and Green (2003: 46) points to the fact that they have geographical and functional boundaries. Examples are share cropping arrangements in Bangladesh or the functioning of water boards in Egypt. The following table shows that their role can be analyzed at four different levels. The challenge is to assess the institutional effectiveness of different institutional arrangements.

The idea of institutional economics is that institutions influence the resource allocation process, while neo-classical economists will say that the market does the job and solves all problems. Neo-classical economics likes to limit the role of the government, while in institutional economics there is an important role for the government in defining the rules of the game (legislation) and seeing to it that the rules are implemented.

Table 3 summarizes the major differences between neo-classical and institutional economics. Both emphasize different issues, different motivation of the major actors and make other assumptions to explain the functioning of an economy. Finally, the two schools have different limitations and look differently at the future. On the one hand, the Neo-classical economics will see busts and booms as part of the dynamics of the capitalist system and point out that it may mean spoiling scarce resources, because a lot of firms go bust and disappear, but the best ones survive.

On the other hand institutional economics will point to the importance to maintain certain institutions or to change them in a careful way. Typically the reaction to the last financial crisis by the two schools is very different. The neo-classical economists were happy to see the financial sector being bailed out and to notice that they could continue their culture of paying big bonuses and high salaries, while institutional economists argued that the government should improve regulation to avoid another crisis and to limit excessive risk taking and payment of big bonuses in the financial sector. Financial regulation at the national and the international level was their key suggestion and the United States did exactly that at the national level and the European Union at the EU level, even if it meant that other financial centres (on the Bahamas, in Singapore or Hong Kong) would become more competitive (although also more risky because less regulated).

Table 3 Differences between Neo-classical and institutional economics

Comparison	**Neo-classical (main stream) economics**	**Institutional economics**
1. Major issue	Creating wealth	Understanding institutions
2. Motivation	Self interests, the individual is rational in its choice	Role of institutions and government is serving society
3. Assumptions	Full information Full or perfect competition Assumed invisible hand Markets do the job, demand and supply determine price	Assumes market failure Institutions can be studied, but change over time, although slowly: path dependency Important role for community to change institutions
4. Limitations	No interest in distribution Static, no dynamic version	Difficult to understand the functioning of institutions & dynamics change over time
5. Optimality	Pareto optimum of an allocation: no possible improvement	If right institutions function properly
6. Special	Emphasis on division of labour and the resulting specialization Bankruptcy & periodic crisis as the price of capitalism	Differences exist from one country to another Importance of regulation

Neo-classical economics analyzes how collective choices are made. The theory assumes that we have all ordered utility functions and the utility and profit maximisation can be the basis for decision making. By expressing our demands in the market the optimal level of production is achieved if the marginal benefits of producing one more unit equal the marginal cost (the price to be paid) for that product. Before dealing with the tools of economics we will first list some of the major issues in the water sector.

4. Related issues, disciplines and economic tools

4.1 Financial and economic issues in IUWM

Before suggesting different disciplines to deal with IUWM the question will be asked: what are the major financial and economic issues in IUWM?

1. How to assess the cost and benefits of different options over a longer period of time
2. How to compare the cost and benefits of different options?
3. How to obtain finance for different proposed solutions?
4. How to recover the cost? (tariffs, betterment or property tax, connection fees, etc.)
5. What is the institutional framework necessary to achieve this?
6. What is the value of water or the environment?

4.2 Economic tools which can be used to deal with the issues

Once we know the issue and have knowledge about the tools we can think of combining the two. An example of this suggestion is given in table 4. It list the most frequently used economic and financial methods and tools for urban water management, linked to an important issue. Sometimes it is difficult to say what is a method (a way of doing things) and what is a tool (an instrument helping to achieve the desired results).

Table 4 Theories, methods and tools for urban water management

Issue	Methods (more abstract)	Tools (more concrete)
Required water governance structure in a decentralized water or waste water system?	Action and strategic planning Economic and financial analysis (cost benefit analysis) of proposed structure	Integrated problem analysis Ways to organize the participation of stakeholders Environmental management tools
Increasing the water related productivity of industries or agriculture	Research methods Systematic monitoring and evaluation	Use of private finance for investments and using IT for constant monitoring Developing integrated solutions
Possibility of achieving a higher efficiency of utilities by using the New public management theory	Policy analysis Comparative analysis Planning of reforms Monitoring and evaluation	Institutional analysis Planning administrative reform Monitoring the results and using benchmarking systems

Source: Van Dijk (2006).

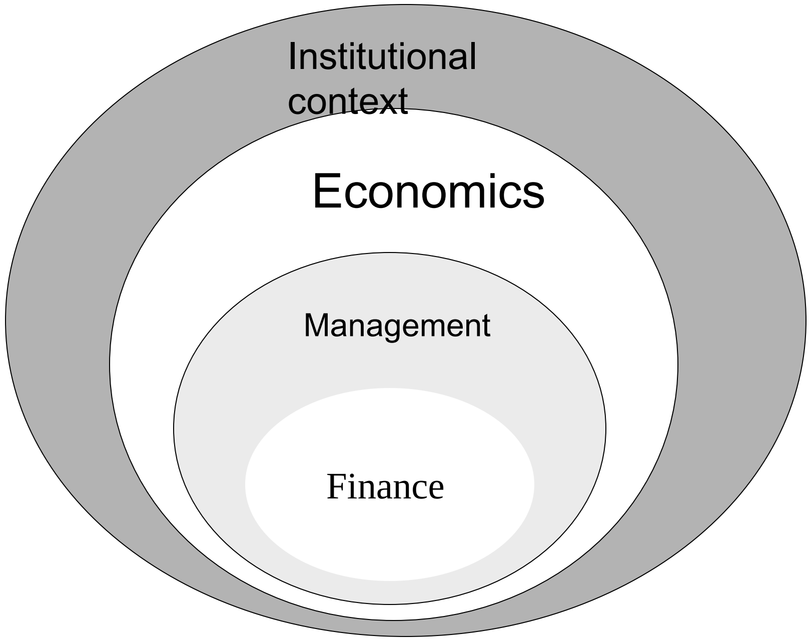

Figure 1 Different disciplines can contribute to understanding water related issues

However there are more tools, in particular if related disciplines are taken into account. Figure 1 illustrates how different disciplines can contribute to understanding water related issues. The institutional context sets the conditions for successful IUWM. Economics can help because it can analyze the positive and negative effects for society as a whole. Management is important when ideas need to be implemented and day to day activities are important. The bottom line is the financial analysis, which calculates what it means for an investor or a household to adopt a certain technology. All the major actors are involved, the government, the private sector and the households and each one of them uses management techniques and financial analysis to make ends meet.

What are the available tools for IUWM? Table 5 gives a list, relating the tools to different economic and management disciplines, ranging from using an institutional perspective to zooming in into the financial aspects.

4.3 The challenge, integration of economics and technical sciences

The main financial and economic issues in IUWM have been listed and a framework for integration of economics and technical sciences is suggested, by linking the issues to the economic tools available. The issues are also linked to a number of key technologies suggested in the Switch project for improved urban water management. We can now analyze what this means in the framework of the Switch project.

Table 5 Different economic tools for IUWM from different disciplines

From an institutional perspective	**From economics**
1. Carry out an institutional analysis: which institutions can be found locally and how do they function? 2. It is important to achieve multi stakeholder involvement and popular participation 3. Analyze the effectiveness & efficiency of institutions 4. Suggest different institutional options to the stakeholders and decision makers	1. Demand and supply curves to determine a price 2. Cost benefit analysis (IRR or NPV) 3. Life cycle costing: whole life cycle cost & whole life maintenance cost 4. Cost effectiveness, if no estimate of the benefits is possible 5. Multi-criteria analysis 6. Incorporate external effects in the price of a good or service 7. Policy impact analysis 8. Environmental assessments
From management **1.** Action & strategic management **2.** Decision support models **3.** Planning techniques (scenarios) **4.** Linear programming **5.** Business plans **6.** O&M, HRM & Financial managem **7.** Sectoral, f.ex. urban management **8.** Transition management	**From finance** 1. Financial analysis 2. Financing options for projects 3. Cost recovery options 4. Scoring and ranking alternatives 5. Financial policies 6. Effects of (dis) incentives, such as taxes & subsidies

Six examples of different issues will be selected for which were studied in the framework of the project and we will show how economic tools helped to get a better understanding of the issue. The cases are listed in table 6. The format for the analysis of the five cases is:

1. What was the issue?
2. Where has it been studied?
3. What are the technological options?
4. Which economic tools have been used?

What have they contributed to a better insight in the issue?

Table 6 Major issues in IUWM in the Switch project and the economics of it

IUWM issue	**Major economic tool used**
1 Reduce water consumption based on forecasting demand using models	Cost effectiveness of different reduction options expressed in cost and saved water
2 Simplify sanitation: separating grey and brown water for decentralized treatment	CBA, an economic, social and environmental analysis of this option
3 Introducing rainwater harvesting (RWH) to avoid using scarce ground water	Financial analysis to find out when this would be a viable option
4 Transitioning: introducing changes to make rain water harvesting systems viable	Analyzing price elasticity to determine how much tax or subsidy is necessary to make RWH financially viable
5 Improved and more Sustainable urban drains (SUDs) in times of climate change	Use Life cycle costing to choose, because it is difficult to calculate the benefits
6 Sustainable drinking water options for the urban poor	Business plans to identify financing options and cost recovery systems for piped and non-piped drinking water systems
Reserve topics a. Centralized versus decentralized WW treatment b. City water model How does finance affect the allocation of water? c. Strategic planning d. Sustainability: eco cities	a. Different scales of production b. CBA & Life cycle costing c. Urban planning techniques d. Integrated economic and environmental friendly approaches to urban development

Part II Applying the analytical framework to six Switch issues showing what economic tools were used

1. Water demand management: Cost effectiveness of different reduction options

1.1. What was the issue?

In many cities there is not enough water and instead of increasing the supply we could also focus on diminishing the demand for water. Water is demanded for different purposes, such as the industry, recreation, drinking water, navigation, irrigation and hydro power. Some of these uses are conflicting, some are complementary. The issue is how to reduce water but the focus can be on the utility or on the consumers. There are many different options to achieve this (table 7), but the question is how to choose the most cost effective option.

Table 7 Technological options for water demand management

Technological options at utility level	At consumer level
1. Reuse of treated sewerage 2. UFW network strategies (leak detection & elimination, pressure management, etc.) 3. Data management 4. Infrastructure replacement 5. Performance monitoring 6. Training and capacity building 7. Research and development	1. Ability to stipulate and enforce prohibitions (e.g. hosepipe bans) 2. Tariff structure, metering , billing and collection 3. In house retrofitting (dual flush toilets, low flow showers, etc) 4. Rainwater harvesting 5. Supplementary point sources (wells, boreholes) 6. Water re-uses (grey water for gardens) 7. Water recycling by consumer 8. Water wise gardening 9. General school education

1.2. Where has it been studied?

Water demand management was studied in Switch cities like Alexandria and Accra, but also in other cities such as Kampala (Uganda) and Zaragoza (Spain). A decision support tool has been developed to facilitate the choice between different ways of reducing demand.

1.3. What are the technological options?

Table 7 makes a distinction between technological options at the utility level and options at the consumer level. In the framework of Integrated Water Resource Planning (IRP) it is suggested to work through five stages: after planning the overall process and analysis of the situation will be made resulting in a forecast of future demand. It is possible to use different scenarios for the development of water demand. In the third stage a response is developed by identifying, designing and analyzing different potential water reduction options. After choosing the most attractive option follows the implementation and the monitoring and evaluation stage.

1.4. Which economic tools have been used?

Different tools have been used, such as the Vensim-based water demand management options model, which provides a simple tool for urban water planners and policy makers. Research has been undertaken on agent based modelling for determination of residential water demand operating under different scenarios; and detailed case studies on the potential of water tariffs as effective demand management tools in low-income countries.

The demand management model allows comparing cost effectiveness of different water demand management options over a longer period. The options are compared in terms of water saved and costs. In the end the cost of saving one m^3 is the criterion to compare the different options and to choose.

1.5. What have they contributed to a better insight in the issue?

The demand management model allowed comparing and choosing between different options to save water. The biggest benefit of water demand management is the water that does need to be produced. It means there is no need for the resources, the transport, the cleaning and the transport! To also include such benefits in the calculation would have required a complete cost benefit analysis, which is much more complicated as will be shown in the next case. Comparing cost effectiveness of different water demand management options over a longer period is relatively easy, especially if the options are compared in terms of water saved and costs.

2. Sanitation: Centralized or decentralized waste water treatment

2.1. What was the issue?

Urban water scarcity is a problem in the Middle East, but also in Northern China. Different technological options exist and different technological measures have been implemented in Chinese cities for preventing and solving the problem. Switch researchers studied separating grey and brown water and treating the grey water (grey water is waste water generated in households, excluding the water containing human excreta or urine, but including water from kitchens, bathrooms and washing rooms) on the spot (decentralized waste water treatment) and looked into the financial viability of rainwater harvesting (RWH, the next case).

2.2. Where has it been studied?

Liang and Van Dijk (2010) studied the economic aspects of separating grey and brown water and treating it on the spot. They try to determine whether this is financially attractive and how decentralized compares to centralized WWT in Beijing. The examples of decentralized treatment are the Qingzhiyuan (Qing) project and the Beijing Normal University (BNU) project, both in Beijing, where legislation requires major buildings to separate grey and brown water and to build and operate plants for treatment on the spot. The first project is located in a residential area in Beijing and serves around 2500 people. The BNU project is located at a university campus and serves around 30000 people. As the wastewater treatment technology of the Qing project is similar to that of the BNU project, it is possible to make a direct comparison between these two projects. Data for the estimation were collected through interviews with the project managers.

The examples of centralized WWT in Beijing are the only two systems currently in operation, the Gao Bei Dian and the Jiu Xian Qiao projects. The Gao Bei Dian wastewater reuse plant is the first centralized wastewater reuse plant in Beijing, constructed in 2000. The Jiu Xian Qiao project started more recently.

2.3. What are the technological options?

Different technological options for decentralized and centralized WWT exist, but in the current comparison the difference of scale is the main difference. The Qing project collects around 55 m^3 per day while the treatment capacity is around 65 m^3 per day and the capacity of the treatment capacity of the BNU project is 400 m^3 per day.

The total expected amount of the reclaimed water of all the planned centralized wastewater reclamation plants in Beijing is 0.66 million m^3 per day. But actually the reclaimed water is less than 60% of the expected capacity. Every day around 200,000 m^3 reclaimed water of the Gao plant is transferred to 'The First Electricity Factory' to serve as cooling water. About 100,000 m^3 water is delivered to 'The Sixth Water Factory' each day to be processed again for quality improvement and then the water goes to residential use, green irrigation, industrial use and agricultural irrigation. The Jiu Xian Qiao wastewater reclamation plant has a designed treatment scale of 60,000 m^3/day, which is smaller than the 300,000 m^3/day capacity of the Gao plant, but the technology is quite similar.

2.4. Which economic tools have been used?

A. The method: CBA

An economic and financial evaluation of cost and benefits of waste water treatment has been undertaken, in particular an economic, environmental and social CBA. The equations below show the evaluation process:

$$\mathrm{C}=\mathrm{C}_{\mathrm{O}}+C_S+C_E$$
$$\mathrm{B}=\mathrm{B}_{\mathrm{O}}+B_S+B_E$$

$$\sum_{t=0}^{t=n}\frac{B_t-C_t}{(1+\lambda)^t}=0 \text{ ---> IRR}=\lambda$$

In the equations, C means total cost, B means total benefit. Then Co, Cs and C_E are economic cost, social cost and environmental cost. Correspondently Bo, Bs and B_E are economic, social and environmental benefits. C_t is the cost at year t, and B_t is the benefit at year t. n is the time span of ther economic evaluation. λ is the internal rate of return. The ratio of economic benefits to cost is the criterion to determine the economic feasibility of a plant. If the ratio is larger than 1, the plant is economically feasible.

B. The variables included

The following table shows the economic, social and environmental effects of decentralized wastewater reuse that have been considered for the cost benefit analysis.

Table 8 The economic, social and environmental effects of decentralized WWT

Economic cost	Initial investment Operation and maintenance cost
Environmental cost	Noise pollution Air pollution
Social cost	Health risk
Economic benefits	Cost saving on constructing pipes Cost saving on water distribution Cost saving on water purification Reuse of pollutants
Environmental benefits	Increase of water availability Increase in the level of rivers Avoidance of overexploitation of water-bearing resources
Social benefits	Raising social awareness

For the centralized systems the following benefits and cost were included (table 9).

Table 9 Economic, social and environmental effects of centralized wastewater reuse

Economic cost	Same as table 8
Environmental cost	Same variables plus the generated carbon dioxide emission
Social cost	Same variables plus the cost of resettlement of people
Economic benefits	Cost saving on fertilizers and the cost of the reuse of certain pollutants
Environmental benefits	Same variables
Social benefits	Same plus improving employment

The main differences between cost and benefits for decentralized and centralized systems are the inclusion of the environmental cost of the carbon dioxide emission generated by the centralized plants because of the huge consumption of electricity. Large scale WWT plants also imply substantial expenditures for resettling inhabitants who used to live on the site, or where the sewer pipes are being constructed. Finally an economic benefit of centralized WWT is the employment created

C. The results

Liang and Van Dijk (2010) found that the decentralized wastewater reuse systems are economically but not financially feasible, while for the centralized systems studied both the economic and financial feasibility is assured. Table 10 compares the data for the two decentralized and the two centralized systems. Their capacity and the financial and economic feasibility are given, which shows a very clear difference in terms of the capacity and the financial ration of benefits to cost.

Table10 The comparison of financial and economic feasibility

	Decentralized		Centralized	
	Qing plant	BNU plant	Gao plant	Jiu plant
Capacity (m^3/day)	65	400	300,000	60,000
Financial ratio of benefits to cost	0.13	0.38	1.6	1.7
Financially feasible	No	No	Yes	Yes
Economical ratio of benefits to cost	4.7	5.4	7.2	5.5
Economically feasible	Yes	Yes	Yes	Yes

In terms of the results of the economic and financial feasibility of the wastewater reuse in Beijing central region, centralized wastewater reuse systems are more economically and financially competitive than decentralized systems. However, the difference in economic feasibility between the BNU and the Jiu plants is very small.

Table 11 Comparison of environmental and social effects (thousand Yuan)

	Decentralized		Centralized	
	Qing plant	BNU	Gao plant	Jiu plant
Environmental cost	32.6	10.9	19240	380
Environmental benefits	402.6	2818	3225260	645050
Social cost	13.2	13.2	7130	4900
Social benefits	21.4	290	5900	5000

Table 11 compares the environmental and social effects. For decentralized systems the value of social benefit is larger than the social cost while for centralized systems the value of social cost is close to the value of social benefit. The residential resettlements due to the pipe construction in centralized system lead to a relatively high social cost, which is avoidable in decentralized system. The results of environmental comparison illustrate that both centralized and decentralized wastewater reuse systems are environmental friendly despite that centralized systems lead to the environmental cost of carbon dioxide emissions and decentralized systems can cause a lot of noise. The centralized systems and decentralized systems lead to different social effects, such as health risk and residential resettlement. The results of both systems illustrate that the values of social benefits are higher or close to the social cost.

Table 12 The comparison of initial investment (million Yuan)

	Decentralized		Centralized	
	Qing plant	BNU plant	Gao plant	Jiu plant
Initial investment	2.9	3.7	323.5	77
Pipe construction	2.6	3.1	313	58
Demolition and relocation	0	0	108.4	29.2

Table 12 presents the initial investment and the cost of pipe construction of the centralized and decentralized wastewater reuse plants. The initial investment of the centralized plants is much larger than the initial investment of the decentralized plants. For example, the investment of the Jiu plant is 76 million Yuan while the initial investment of the Qing plant is only 2.9 million Yuan (Table 12). That is to say, the expenditure on constructing one centralized plant (capacity: 60,000 m^3 per day) can be used for the construction of around 25 decentralized plants (capacity: 400 m^3 per day).

Some findings are obtained through the comparison on initial investment and O&M cost. The initial investment of the centralized systems is an extremely high because of the necessary pipe construction. The cost of demolition and relocation and the interest paid for the loan, are the main cost of pipe construction in the centralized systems, but they are seldom occurs in the decentralized systems. Moreover, for both centralized and decentralized wastewater reuse systems, the energy cost is the largest expense in the O&M cost. But the item of the second largest expense in the O&M cost is different between two kinds of systems. The second largest expense in centralized systems is the maintenance cost while it is the personnel cost in decentralized systems.

The difference between the unit O&M cost and the rate of reclaimed water leads to different implication on cost recovery. In centralized wastewater reuse systems, the unit O&M cost is lower than the rate of reclaimed water. But in decentralized systems, the unit O&M cost is higher that the rate of reclaimed water. Hence the rates of O&M cost recovery of centralized systems are much higher than the rate of cost recovery of decentralized systems. The current rate of reclaimed water is not suitable for the cost recovery of decentralized systems.

2.5. What have they contributed to a better insight in the issue?

Are decentralized water treatment systems a good alternative to centralized system? Our comparative analysis between the centralized and decentralized wastewater reuse systems in Beijing focuses on the financial and economic feasibility, including environmental and social effects. Scale plays a role just like the current financing practices in China. Subsidies for small scale decentralized WWT systems are usually limited to the initial period of the project and the price of alternative sources of water tends to be lower than the cost of treating the grey water. The analysis indicates that decentralized wastewater reuse systems are economically feasible. It means the systems have positive effects on society. Thus, from the point of view of government or society, the decentralized wastewater reuse systems are worth to be promoted.

However, the decentralized wastewater reuse systems are not financially feasible. The low rate charged for reclaimed water is the key reason for the systems not being financially feasible. From the project manager's perspective, the decentralized systems may not continue to operate in the long term if the financial problems are not solved. Thus solving the financial problems of decentralized wastewater reuse systems should be on the political agenda in the future (Angelakis et al., 2003). It would require subsidies unless realistic pricing policies for water are introduced.

The results show that the centralized wastewater reuse systems are not only financially feasible but also economically feasible. It implies the centralized wastewater reuse systems in Beijing have positive effects on society and these systems could operate in a long term. From the perspective of financial feasibility, the centralized wastewater reuse systems are more competitive than the decentralized systems.

3 The financial analysis of rainwater harvesting systems

3.1. What was the issue?

The increasing population, continual drought in the north of China, and depletion of groundwater stocks are big challenges for Beijing. 70% of total water supply of the city is sourced from groundwater. However, the overexploitation of groundwater due to the increasing water demand and less groundwater recharge due to the decreasing precipitation are both causing the depletion of underground water stocks. The main issue is how to finance the investments and recover the cost of RWH while a cheaper alternative (ground water) is also available. Again the issue of scale turned up. Rainwater harvesting is a cheap and easy way to obtain more water for agricultural irrigation. Using rainwater helps to save water resources and to solve the problem of environmental degradation (Li et al., 2000). Rainwater harvesting systems have been constructed since 2006, mostly in the rural area of Beijing (Wang et al., 2007).

3.2. Where has it been studied?

RWH has been studied not only in Beijing, but also in Switch cities like Belo Horizonte and Tel Aviv. Beijing is used as a case study because Beijing is a typical case of urban water scarcity.

3.3. What are the technological options?

A rainwater harvesting system in China consists of a rainwater collection part and a water reuse part. The rainwater collection part includes plastic covers for green houses, storage tanks and collective ditches, and the water reuse part is made of pumps and irrigation facilities. There is a plastic film covering the green house, rainwater goes through the plastic film down to the ditch in front of the house. Rainwater moves from the shallow ditch to the big underground pipe and then to the sediment tank. There is a filter installed in the tank. After depositing the solids, cleaned water enters the storage tank. Then the water is transferred from the storage tank to the green house by pump.

Large and small scale RWH systems are available. They tend to be relatively simple systems which depend on the size of the house of the owner or the size of his other buildings. Usually the purpose of collecting rain water is agricultural irrigation.

3.4. Which economic tools have been used? Financial analysis

Decisions to invest in and run a RWH system has to be taken by the farmers, based on incentives. These could come via subsidies on the investments and also on the O&M cost, or through a tax on the use of ground water. The methodology used for this study is financial analysis of the rainwater harvesting system from the user's point of view. The costs are the necessary investments and the expenditure for operation and maintenance. The benefits are the increased revenues of farmers using rain water harvesting. The financial analysis contains the evaluations of the financial cost and financial benefits. The financial cost includes initial investment (defined as U_I), operation and maintenance (O&M) cost (defined as $U_{O\&M}$). All components contributing U_I and $U_{O\&M}$ are shown in the following equations respectively:

$$U_I = U_C + U_D + U_P + U_R + U_O$$

$$U_{O\&M} = \sum_{t=1}^{m} \frac{U_t}{(1+r)^t}$$

where U_C, U_D , U_P, U_R, and U_O are the initial costs of construction, demolition and relocation, preparation, interest and others, respectively. U_t is the O&M cost occurring in year t; r is the discounting rate; n is the evaluation period (number of years). The ratio of financial benefits to cost is the criterion to determine the financial feasibility of the plant. If the ratio is larger than 1, the plant is financially feasible.

Three options of using different water resources for agricultural irrigation are specified:

Option 1: using underground water for agricultural irrigation without charge. As there is no rainwater harvesting system, the irrigation water is all pumped from the well.

Option 2: using underground water for agricultural irrigation while paying a water charge. As there is no rainwater harvesting system, the irrigation water is all pumped from the well. The underground water is supposed to be charged by the government with 2 Yuan/m3.

Table 13 List of financial cost and benefits of different sizes of systems

	Option 1	Option 2	Option 3
Small size systems			
Financial cost			
Initial investment (Yuan)	0	0	27000
O&M Cost (Yuan/year)	156	2556	60
Financial benefits			
Subsidies (Yuan)	0	0	9000
Incomes from crops (Yuan/year)	5000	5000	5000
Medium size systems			
Financial cost			
Initial investment (Yuan)	0	0	300000
O&M Cost (Yuan/year)	2080	34080	800
Financial benefits			
Subsidies (Yuan)	0	0	150000
Incomes from crops (Yuan/year)	98000	98000	98000
Large size systems			
Financial cost			
Initial investment (Yuan)	0	0	450000
O&M Cost (Yuan/year)	3120	51120	1200
Financial benefits			
Subsidies (Yuan)	0	4137000	137000
Incomes from crops (Yuan/year)	137000		

Option 3: using rainwater for agricultural irrigation. All irrigation water comes from rainwater due to the rainwater harvesting systems. The rainwater harvesting tank is subsidized by the government, but the remaining cost should be paid by the project manager.

3.5. What have they contributed to a better insight in the issue?

The current price mechanism is not enough to increase rainwater consumption. Increasing the groundwater price provides farmers' an incentive to use rainwater, but it could lead to a decrease in the farmers' income. It is important to reach the balance of effectively increasing rainwater demand while keeping an eye on farmer's benefits.

It is more convenient for the farmers to access groundwater. Pumping it up is cheap and no tax or regulation withholds them. Hence there is a need for financial incentives to change their behaviour. As the cost of using groundwater is too low, farmers have few incentives to use rainwater. In order to motivate the consumption of rainwater, the Beijing Water Authority is expected to raise the cost of using groundwater through collecting a charge of groundwater. Higher cost of groundwater can effectively increase the consumption of rainwater, but it can also have a negative impact on farmers' incomes. Subsequently research on the transition form ground water to using rain water was undertaken.

4. Financial incentives for transitioning to rainwater harvesting in Beijing

4.1. The issue at stake

Hundreds of rainwater harvesting systems have been constructed in the last decade to relieve water scarcity in Beijing. However, the operation of around 70% of the rainwater harvesting systems is a failure. Ten important factors including the technological and non-technological factors were chosen for the study to find out which ones explain the high rate of failure. The issue is that there is an alternative technology available, which under the current conditions is financially not viable. Through a number of related steps a transition to a more sustainable situation may be possible.

4.2. Where studied

Liang and Van Dijk (2011) studied the reasons for failure to design financial incentives for transitioning to rainwater harvesting in Beijing. The results show that farmers have doubts about the rainwater quality and cheap groundwater is available. The research indicates that if farmers have doubts about the rainwater quality or if groundwater sources are available, the rainwater harvesting systems are not in use, while if there is a shortage of groundwater sources the rainwater harvesting systems tend to operate continuously and successfully. These two decisive factors are non-technological factors At the moment there is no systematic information proving whether rainwater in Beijing is suitable or not, hence other solutions need to be looked for.

4.3. A description of the technological options

Given the non technical nature of the problem possible solutions were explored and we basically identified three, which will now be discussed. They are: an increase of the price of municipal piped and recovered water, a tax on ground water and a bigger subsidy on the investment and maintenance of rainwater harvesting systems.

4.4. Economic tools: bigger subsidies on investments and O&M of RWH systems

We would like to substitute one way of using water (pumping up ground water) by a different option (RWH). The economic theory of substitution states that an increase in the price of one good will lead to an increase in demand for its substitute. It means that an increase of the cost of groundwater can raise the consumption of rainwater. If the cost of using groundwater is higher than using rainwater, farmers would prefer to reduce the consumption of groundwater while increasing the consumption of rainwater. Enforcing a levy on groundwater could be one method to increase the cost and restrict the consumption of groundwater.

The analysis provides the elasticity threshold for a groundwater charge. If the groundwater cost is lower than the threshold, farmers would have few incentives to change their water source from groundwater to rainwater. If the groundwater cost is higher than the threshold, the consumption of rainwater increases. The analysis also shows that the elasticity threshold of groundwater move following changes of the characteristics of RWH systems. The linear programming illustrates that increasing subsidies and enlarging the size of RWH systems can decrease the elasticity threshold of groundwater. Decreasing elasticity threshold of groundwater implies that the cost of groundwater enabling the increase of rainwater consumption becomes lower. Hence a realistic groundwater charge has been determined by taking into account different sizes of RWH systems and the level of subsidy on the initial investments for the rainwater systems.

Subsidies for initial investment can effectively help to lessen the farmers' expenditures. For larger systems initial investments are higher. For example, for the small size of rainwater harvesting systems with the capacity of 50 m^3, the initial investment is around 27,000 Yuan (or 2700 US dollar) including the construction and equipment. The capacity of 50m^3 is only suitable for supplementing the needs of a household. The total income of a small household of farming in Beijing is averagely around 10,000 Yuan per year, meaning the initial investment is almost three times their income. If there are no subsidies, it is very difficult for farmers to afford such an initial investment. Hence most rainwater harvesting systems are provided with subsidies of around 50 to 100 percent of the initial investment although some systems are subsidized by less than 50 percent of initial investment. Some state-owned facilities receive already subsidies for the expenses related to the operation and maintenance of the rainwater harvesting equipment. However, similar subsidies are not available for private operators. Government subsidies may be a beginning, but are not sufficient to promote rainwater harvesting in Beijing, in a sustainable way. The confidence in rain water also needs to increase to get successful rainwater harvesting systems in Beijing. Increasing the barriers to obtaining groundwater is another important step. All kinds of measures such as pricing ground water, prohibiting building new wells, and limiting the quantity of ground water pumping may be required.

4.5. The insights: transitioning to the solution

China is convinced it has to make better use of scarce resources such as ground water, because per capita water consumption is more than water availability and the population of the Chinese capital keeps growing. Given the urgency a choice will have to be made to either impose stricter regulation for ground water use, or to discourage its use by imposing a ground water tax. However, the low current rate charged for treated and reused water is a crucial factor why these systems are not financially feasible. The reused water rate is lower than the actual O&M cost of rainwater systems and hence needs to be increased. Transitioning should take a three pronged approach. After finding the optimal level of subsidies on RWH, a tax on ground water needs to be introduced, which does not discourage farming. It will also be necessary to impose more strict regulations on the use of ground water and then finally only in combination with an increase of the price of recovered water we can expect the desired effect, a larger uptake of rainwater harvesting systems.

Liang van Van Dijk (2011) found that the optimal ground water charge may not be high enough to discourage the use of ground water all together. For that reason other policies are necessary as well, in particular stricter regulation. The price for reclaimed water is 1 Yuan/m^3 in Beijing while the price of drinking water is 3.7 Yuan/m^3. The rate of 1 Yuan/m^3 for reused water does not reflect the real cost. Therefore, rain water harvesting systems cannot be financially feasible as long as these cheap alternatives are available.

5 Sustainable urban drains

5.1. What was the issue?

Climate change will lead to more or less water ain cities and to greater volatility. This is a challenge for drainage systems. The question is how to introduce sustainable urban storm water management. Where are Sustainable urban drains (SUDs) needed, what size of drains and which necessary additional options are required? How to deal with road runoff in a sustainable way and yet provide the level of services (and road security) required? The issue is to how to determine what extent different types of SUDs are appropriate for different road types in different cities.

5.2. Where has it been studied?

Considering the use of SUDs has happened in different Switch cities. The case of Edinburgh in Scotland has been documented by the Transition manual (Duffy and Jefferies, 2010). In this case the project went for recommending permeable block paving, porous asphalt and the use of bio-retention areas, sand filters and modular storage systems.

5.3. What are the technological options?

Road designers want to provide effective sustainable drainage and ensure safe traffic. There are several options and the life cycle costing tool, embedded in a decision model has been proposed to make the choice between these options. The decision support tool comprises of a road SUDs selection flowchart and matrices to help making the right choice. Three matrices are used for a hierarchy of roads found in the case of Scotland and different options, levels of performance and maintenance are considered.

5.4. Which economic tools have been used?

A decision tool was developed, for the selection of SUDs components for road drainage. It is based on the life cycle costing tool, for which the project even developed its own (open) software (Software for urban drainage systems; Sieker, 2009). Life cycle costing (or whole life cycle cost and whole life maintenance cost calculation) and in particular life cycle cost analysis method is a systematic analytical process for evaluating various designs or alternative courses of actions with the objective of choosing the best way to employ scarce resources (Durairaj et al., 2002). It lies not only in the determination of a total cost of a project alternative, but also in the ability to compare the cost of project alternatives and to determine which alternative provides the best value per euro spent. The decision criterion for life cycle costing is relatively straight forward, but in the case of the decision model is more difficult, because different stakeholders may have different interests and give different weights to the decision factors. However, the system helps scoring alternative options, makes the decision more transparent and helps choosing the most appropriate option. Costs are expressed as whole life cycle cost (capital, maintenance, operation and rehabilitation costs) and whole life maintenance cost from the point of view of the maintaining organisation. The decision model goes from scoping to evaluation to final selection, where technical drivers, social and political drivers and O&M drivers are taken into consideration for the preliminary design. In the final selection the life cycle cost and whole life cycle maintenance and other factors affecting the cost are playing a role.

5.5. What have they contributed to a better insight in the issue?

Drainage systems are a long term investment, and it is very difficult to estimate the benefits of a sustainable system, hence a cost benefit analysis would not have helped much in this case. The relatively simple decision support system allowed combining stakeholder involvement, with using objective criteria to come to a decision based on the economic tool of life cycle costing.

6 Drinking water options for the poor

6.1. What was the issue?

Urban water service providers may be classified as formal or informal. The formal service provider is the official urban water utility provider. All other service providers constitute the informal service providers who provide services to consumers not served or under-served by the formal utility provider. It is recommended to include cost recovery systems from the beginning.

6.2. Where has it been studied?

This research has taken place in Accra, the capital of Ghana by UNESCO IHE staff and students (Herry Rachman, 2010 and Raymond Luwita, 2010). Van Dijk (2009 and 2010) reported and presented the research in learning alliance meetings in Accra in 2009 and 2010.

Table 14 Piped drinking water options: institutional arrangement, source of finance and cost recovery system

Drinking water option	Institutional arrangements	Source of finance	Cost recovery
1. Individual house connections	Public, private or Public Private Partnership (PPP)	Government budget, but connection fee: could use micro finance	Tariff
2. Standpipes, to promote social inclusion	Contract with community or a person indicated by the community	Donors (Water for life for ex.)	GWCL is paid directly, consumers pay vendors
3. Water tanks in community with water supplied by GWCL using a private tanker	Water storage with private vendor, one case so far, water from filling point GWCL. Selling bulk	AVRL direct, Evaluated by Trend, selling price of water may increase, but too expensive	Maximum was 5 pesewas per bucket (18 litres), vendor rents tanker and can increase price
4. Distribution line providing water in bulk to a community	Manage their own network, not yet, there is just a pilot somewhere & may be tried in Accra	Bulk meter bill to be paid by community	Community paid by vendors or households
5. Using pre paid meters	Exists for some industries & SMEs	High investment cost for equipment	Assured, unless people turn against the system
6. Private operators using tankers with GWCL water	They often use the filling points of GWCL. This allows quality control	Limited investments, NGO support	Depending on the deal with the local community
7. Allowing private connections to sell	GWCL gives 20% reduction for reselling	Private, but limited	Price should not be too different from GWCL price

Source Van Dijk (2010).
GWCL = Ghana Water Company Limited
AVRL = Aqua Vitens Rand Limited.

6.3. What are the technological options?

A large number of drinking water supply options exist and in table 14 seven options, the corresponding institutional arrangement, and the possible source of finance and system to recover the cost are listed.

6.4. Which economic tools have been used?

The tools promoted in this study were preparing good business plans to qualify for loans or other sources of private finance. Not only alternative sources of finance should be part of it, but also solid cost recovery systems. This means at least a financial analysis of the investment and the O&M cost of the proposed option and an estimation of the revenues.

6.5. What has the research contributed to a better insight in the issue?

To link the idea of tapping alternative sources of finance to the idea that cost recovery is essential if a sustainable system would have to be launched. The report did not limit itself to look at piped water solutions, but also studied a number of non-piped options (wells, desalination plant and surface water). An integrated approach has been advocated covering the development of all relevant options simultaneously. However, it was stressed that access to extern and new sources of finance would depend on a business plan with a solid financial analysis showing that the cost recovery system is such that it promises a sufficient cash flow to serve the debt. Blending of aid (grant) money with more expensive commercial funds was advocated, but good cost recovery systems will contribute to the sustainability of the solution chosen.

7. Conclusions

We have listed a number of issues in water management and indicated that different economic tools may help to better understand these issues. In the Switch project different tools have been used for different issues to be solved with different degrees of success. However, later work will always build on the work of earlier research and there is no doubt that an analysis of economic, financial and institutional aspects of certain innovations in the water sector has added to our understanding of the issues

From the examples analyzed a number of conclusions can be drawn. In the first place that often a combination of different economic and financial tools is necessary to analyze an issue and to come up with appropriate solutions. It is very common that a number of economic and financial methods are combined, for example to analyze cross cutting issues, such as the issue of scale, which turned up several times. In that sense Box 1 is a simplification when it tries to link the relevant issues to the most important tools from economics, management and finance.

Box 1 Most important tools from economics for relevant issues in IUWM

Relevant economic issues in IUWM	Most important tools from economics, management and finance
Developing a strategic vision of the city of the future	**Action and strategic planning, integrated water resource planning, scenario exercise**
Allocation problems	**Allocation models**
Making choices between different options	**Decision support systems, for example for WDM or SUDs**
Estimating future demand	**Demand curves, scenarios and other planning tools**
Comparing future cost and benefits	**CBA, financial analysis, but also** **Cost effectiveness analysis, LCC &**
Convincing actors to undertake certain actions	**Incentives, subsidies, taxes on unattractive alternatives**
Transitioning to a new situation	**A combination of planning and incentives**
Obtaining access to other sources of finance	**Develop a business plan and do a solid financial analysis, including cost recovery options**

Other conclusions

1. A limited number of issues

Box 1 shows that the real number of relevant issues is limited, just like the number of economic tools. It is important that technicians have a feel which combination of economic tools to use to analyze an issue.

2. Models can be used

The Switch project has generated a number of useful models. However, in the context of developing countries models may quickly be too complicated. The data may not be available or no local expertise is available to update and run the model.

3. Defining costs and benefits

It is important to be very precise about all possible costs and benefits of a certain scheme. It is not always easy to quantify these cost or benefits, but they should be listed. Sometimes alternatives for the CBA are available such as cost effectiveness methods and Life long costing, in particular when it is difficult to estimate all the future benefits.

4. Sometimes the CBA and the financial analysis provide almost the same results

If the number of factors taken into account is limited and the deviation between the market price and the shadow price is small the results of a cost benefit and a financial analysis come very close. This was the case of calculating the benefits of rainwater harvesting, while in the case of wastewater reuse the number of external effects of centralized systems was very high and hence the difference with the outcome of the financial analysis can be substantial.

5 The importance of the social, institutional and regulatory context in which IUWM is promoted

IUWM takes place in a certain context and that context needs to be taken into account. It was argued that institutional economics can help to analyze the functioning of this context and can show how institutional arrangements influence the allocation process.

6. A distinction can be made between the following stages in preparing alternative options in IUWM

a. Research to identify the issue

b. Identifying different options

c. Study the options and compare the data

d. Select one that seems to score best on a number of criteria

e. Implement it

f. Monitor and evaluate to correct the course of action and to provide feedback to the researchers, technicians and social scientists.

References in the text

Angelakis, A N, Bontoux, L and Lazarova, V. (2003), Challenges and prospective for water recycling and reuse in eu countries. Water Science and Technology, 3, 59-68.

Dijk, M.P. van and M. Schouten (2010), European water liberalization scenarios in: Journal of Water Policy 12, pp. 248-259.

Dijk, M.P.van (2010), Financial and institutional analysis of Strategic options concerning water and sanitation for the Strategic plan for Accra. Delft: UNECSO IHE.

Dijk, M.P. van (2009) Turning Accra (Ghana) into an ecological city. In: M. Schouten and E. Hes (eds, 2009): Innovative practices of African water and sanitation providers. Johannesburg: Sun Media, pp. 99-114.

Dijk, M.P. van (2008), Sanitation in developing countries: incorporating informality, the role of Small-scale independent providers. Contribution to A Workshop to prepare a Policy note for DGIS on Urban Sanitation, 26 November 2008 Delft: UNESCO-IHE.

Dijk, M.P. van (2006) Managing cities in developing countries, more urban management. Cheltenhem: Edward Elgar.

Durairaj, S.K. and Ong, S.K., Nee,A.Y. and Tan, R.B., 2002, *Evaluation of Life Cycle Cost Analysis Methodologies*, Corporate Environmental Strategy, Vol.9. No.1
Duffy, A.and C. Jefferies (2010), Switch Transition manaual. Delft: Switch project.
Green, C.H. (2003) Water economics, Principles and practice. Chichester: Wiley.
Green, C.H. and D. Newsome (1992), Ethics and the calculi of choice. Stockholm: Stockholm Vatten.
Li, F., Cook, S., Geballe, G. T. and Burch, W. R. (2000), Rainwater harvesting agriculture: An integrated system for water management on rain fed land in china's semiarid areas. Ambio, 29.
Liang, X. and M.P. van Dijk (2010), Financial and economic feasibility of decentralized waste water reuse systems in Beijing. In: Water science and technology, 61(8) pp. 1965-1974.
Liang, Xiao and M. P. van Dijk (2011), Optimal level of subsidy and groundwater charge to promote rainwater harvesting for irrigation in rural Beijing, submitted to Water, an open access journal.
Luwita, R. (2010), On-site grey water reuse in Valley View University: towards a sustainable city development. Delft: UNECSO IHE Master thesis.
Mill, J.S. (1848), Principles of political economy. Harmondsworth: Penguin.
Robbins, L. (1935), An essay on the nature and significance of economic science> London: MacMillan.
Rachman, H. (2010), The poor and water in Accra. Delft: UNECSO IHE Master thesis.
Russel B (1954) Human society in ethics and politics, London: Allen and Unwin.
Samuelson, P. A. (1970), Economics, New York: McGraw-Hill.
Scott, R. (1995) Institutions and organisations. London: Sage.
Sieker, (2009), switch website.
Wang, K., Li, C. and Wang, Z. (2007), Demonstration of rainwater harvesting and reuse in Beijing. Beijing Municipal Bureau of Agriculture.

Text books in economics and finance:

1. Brealy, R.A. and S.C. Myers (1996) Principles of corporate finance. New York: McGraw-Hill.
2. Carlton, D. and J. Perloff (1994) Industrial organization. New York: HarperCollins
3. Dornbusch, R., S. Fischer and R. Startz (1998) Macro economics. New York: McGraw-Hill.
4. Gittinger J. (1982) Economic analysis of agricultural projects. Baltimore: John Hopkins.
5. Green C. (2003) Water economics, Principles and practice. Chichester: Wiley.
6. Koutsoyiannis, A. (1979) Modern microeconomics. London: MacMillan.
7. Little, I.M.D. and J.A. Mirrlees (1974) Project appraisal and planning for developing countries. London: Heinemann.
8. Mishan, E.J. (1990) Cost benefit analysis London: Unwin.
9. Ray D. (1998) Development economics. New Delhi: Oxford.
10. Salvatore, D. (1991) Microeconomics. New York: HarperCollins.
11. Todaro, M.P. (1992) Economics for a developing world. Essex: Longman.

12. Truett, L.J.and D.B. Truett (1998) Managerial economics, Analysis, problems and cases. South Western College.