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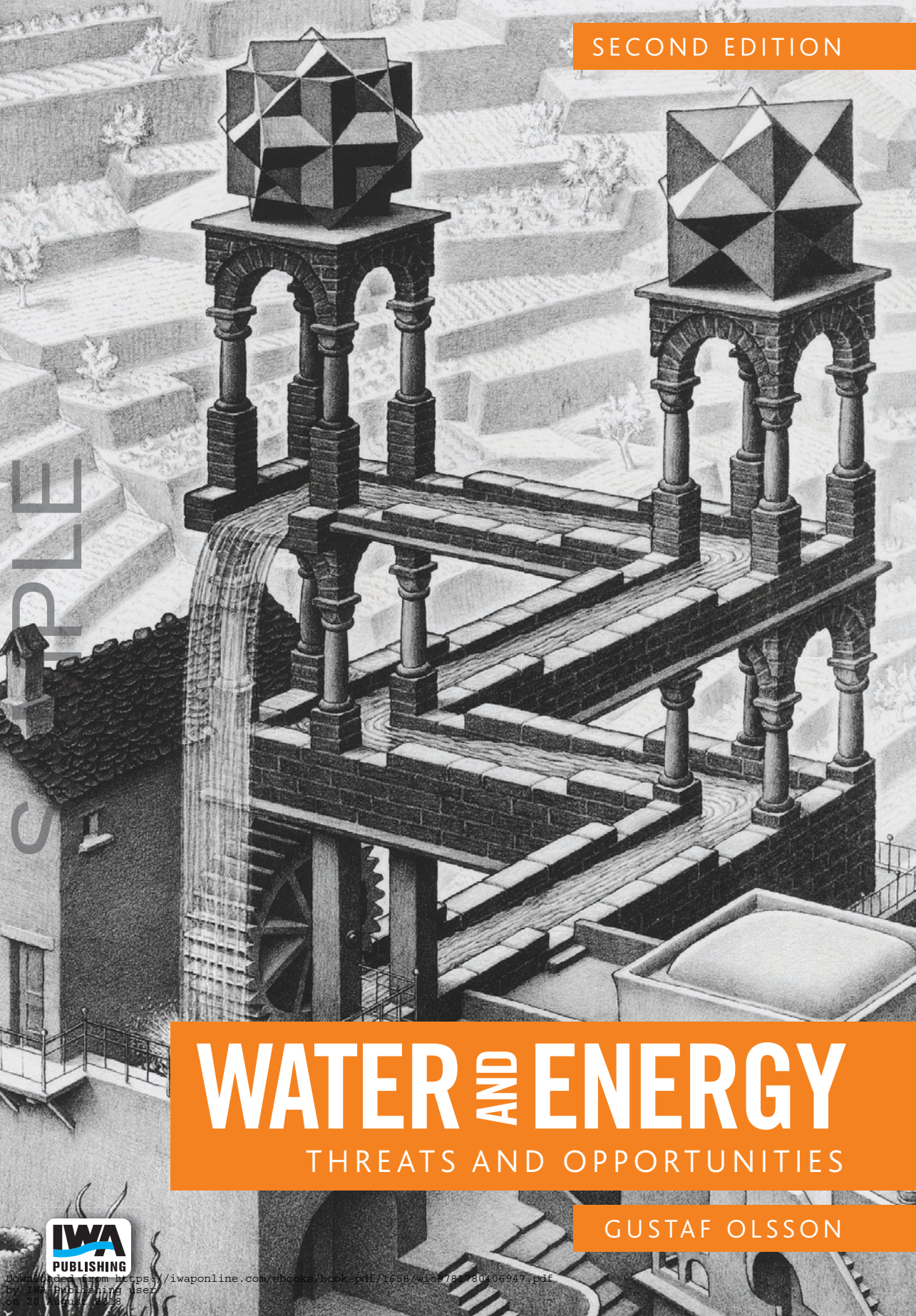

WATER AND ENERGY

THREATS AND OPPORTUNITIES

GUSTAF OLSSON

IWA PUBLISHING

PART I

Introduction

The water and energy interdependence

Water is essential for all life. There are no substitutes. Water is not renewable, so we have to take care of the same amount of fresh water that was available for the dinosaurs. So the water is reused. The problem is that a growing population, climate change, increasing standard of living, food production and industrialization will put a lot of pressure on water resources. Pollution and contamination of available fresh water sources will further decrease available water. Still we witness so much misuse of water. Too often it is considered to be ubiquitous and taken for granted and the water is not given its true value. Water is not just an environmental issue. It is a fundamental issue at the very heart of justice, development, economics and human rights.

As stated by the UN Committee on Economic, Cultural and Social Rights (2002):

> '. . . Water is fundamental to life and health. The human right to water is indispensable for leading a healthy life in human dignity. It is a pre-requisite to the realization of all other human rights.'

Water is certainly needed for life. Still it is a great killer. Floodings and contaminations kill millions of people every year. Most often we can do something about this. Water has been and still is a source of conflict between people, between regions and nations. Water can be considered synonymous with human power and influence. During the history the most powerful nations and kingdoms were established around fresh water sources – rivers or lakes. Civilizations have collapsed as a result of sustained droughts, exemplified by the Tang (907 AD) and Yuan dynasties in China, the Maya empire (900 AD) in Meso America and the Khmer Empire in Cambodia that peaked in the 13th century.

Energy is a fundamental condition for a decent life. Energy is needed to extract, treat and distribute drinking water as well as to collect and treat the wastewater. It is less apparent that energy depends so much on water. Water is needed to extract primary energy, to refine the fuel, and to generate electric power. Energy production also has a large impact on water quality.

The fundamental difference between water and energy is that energy can be renewable while water resources are not.

Water and energy are inextricably linked and as a consequence both have to be addressed together. This is the **water-energy nexus** (a nexus is a connection or series of connections within a particular situation or system). Too often energy planners have assumed that they have the water they need and water planners have assumed that they have the energy they need. In Sweden and in many other countries energy and water issues are managed in separate government ministries. In Malaysia the water and energy issues are handled together in the Ministry of Energy, Green Technology and Water.

Water and energy are fundamental for **food production**. Even if this book primarily addresses the water-energy nexus the links to the food challenge must not be overlooked. Therefore we will shortly address the couplings between food, land use, water and energy.

Neither water nor energy is just one sector of engineering or science. They are fundamental to many sectors. Therefore we have to cooperate between disciplines to solve many of the problems related to water and energy.

Both water and energy infrastructures are expensive. In an industrialized country like my own Sweden roughly 55 billion Euros (€) have been invested over the years in power generation, transmission and distribution and about the same amount of money for water and wastewater systems. This means around € 6000 per capita for electric power and the same amount for water.

The water and energy nexus will be described in Chapter 1. The strong couplings between water and energy are also causing conflicts, and some examples are described in Chapter 2. As a result it is crucial to search for holistic solutions and integrate the various factors. This means that the water community and the energy community have to understand each other and cannot act independently of each other. This is discussed in Chapter 3.

1 The water and energy nexus

Water quality and water supply requires integrated action in the development, management and water usage.
Agenda 21, UN Conf. on Environment and Development (UNCED), 1992

Over the years I have worked with different aspects of control of water and wastewater systems as well as control of electric power systems. However, the starting point for me to realize the importance of the water-energy nexus came from a couple of papers from 2004 by Allan Hoffman, US Department of Energy. He subsequently generously offered me more information on the topic. The interdependence between water and energy has been more widely recognized during the last few years. Allan Hoffman (2004a) wrote on the topic:

> 'The energy security of the United States is closely linked to the state of its water resources. No longer can water resources be taken for granted if the U.S. is to achieve energy security in the years and decades ahead. At the same time, U.S. water security cannot be guaranteed without careful attention to related energy issues. The two issues are inextricably linked'.

He has later presented a lot of new findings (Hoffman, 2004b, 2006, 2008, 2010a, 2010b). This statement is valid for a large number of countries. In the USA the Energy-Water Nexus initiative was initiated in 2004 as an informal DOE (Department of Energy) National Laboratory project to develop a better understanding of the link between the nation's energy and water supplies. The laboratories conducted preliminary assessments that indicated that the interdependence between energy and water supplies were much broader and much deeper than initially thought.

1.1 THE WATER AND ENERGY INTERRELATIONSHIP

The energy sector may be the largest water consumer among all industrial sectors. As long as there is a surplus of both water and energy we do not realize the close relationship between them. When any of them gets limited it becomes obvious that it is necessary to consider their interdependence. Most of us realize intuitively that water operations will require energy, Figure 1.1. It is less obvious that all energy production and generation also require a lot of water; for the extraction, refining, and electric power generation. As a consequence, water and energy systems and operations have to be planned together. Already there have been many negative consequences of water or energy systems being planned separated from each other.

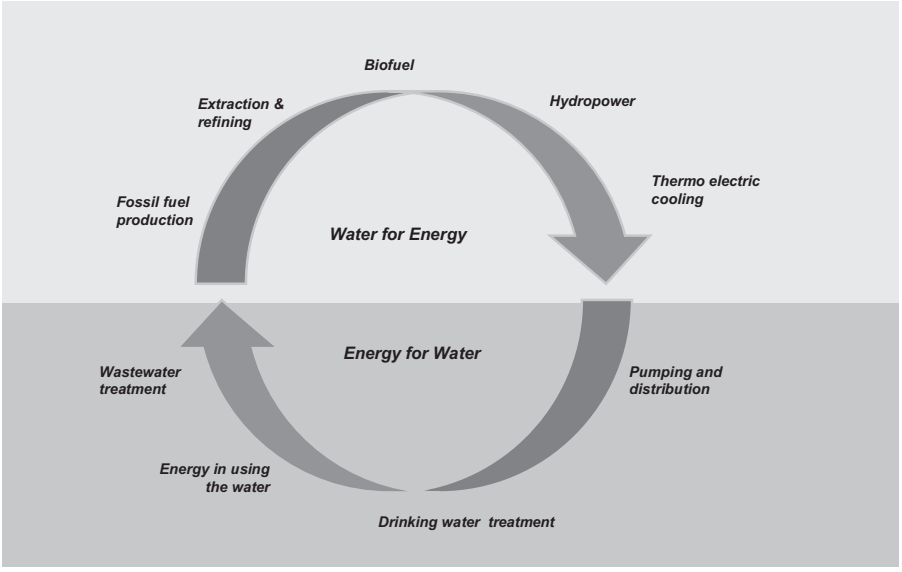

Figure 1.1 Water for energy – energy for water. Adopted from WEC (2010a). Water, Energy and Climate Change, WBCSD (2009a,b).

Population growth, climate change, urbanisation, increasing living standards and food consumption will require an integrated approach. The design of our cities, suburbs, homes and appliances has enormous implication for water and energy consumption. Also our attitudes and our life-style have a crucial impact on the water and energy resources. The water and energy consumption is more than an engineering challenge. Many non-technical issues have to be carefully studied. Some examples of the water and energy interdependence can be mentioned:

- Between 1% and 18% of the *electrical energy* in urban areas is used to treat and transport water and wastewater. The energy related to water use – mostly heating the water in households and industries – requires about ten times more energy compared to the energy needed to deliver the clean and cold water and to treat the wastewater.
- To *treat water* to drinking standards requires energy. As the raw water source becomes more contaminated traditional methods are no longer sufficient. More energy will be required to treat the water to drinking standards, using for example membrane technology.
- *Hydropower* generation obviously depends on water. The dam itself often serves as a gigantic sedimentation basin, and the silt brought by the river flow and that earlier served as fertilizer downstream now is trapped in the dam. Obviously the water flow downstream is affected. Increasing water shortage in combination with increased water use in many regions are now causing lack of water in the dams. With lower water levels the generation of electricity is decreasing.
- *Energy exploration and production* require a lot of water and consequently will generate a lot of wastewater. Oil, gas and coal exploration not only use a lot of water, but it also gets highly polluted and too seldom properly treated.

- Thermal power plants require huge amounts of *cooling water*. For example, around 40% of all freshwater withdrawals in the USA are used for thermoelectric energy production. This is roughly the same amount of water as for irrigation. Most of the cooling water is returned but around 3% is actually consumed, mostly by evaporation. The demand for cooling water competes with agriculture and municipal demands. As a result of the climate change many rivers are running drier and/or warmer in the summer. This will put a lot of constraint on energy production.

There are also indirect links between water and energy. Energy production and use often lead to contamination of underground and surface water supplies. The waterways for transport of goods may be limited if there are competing uses of the water. The interdependencies between water and energy should force us to conduct planning and operation in such a way that both the water and energy flows are tracked. Integrated systems analysis, integrated planning and inter-disciplinary cooperation will become increasingly important.

1.2 THE SUPPLY OF WATER

It is apparent that there has to be a balance between supply and demand of water resources. As a consequence, water scarcity not only appears in very dry countries but also in relatively wet countries. For example, we mostly think about England as a wet country. Still South-Eastern England suffers from water scarcity due to insufficient water transmission systems and to the region's huge ecological footprint. Water scarcity is fundamentally dynamic and intensifies with increasing demand and with decreasing quantity and quality of the supply. It can also decrease when the adequate response actions are taken. Water scarcity can be either *physical* scarcity or *economic* scarcity:

- *Physical* scarcity is related to availability of fresh water of acceptable quality with respect to the demand. Physical water shortage is the obvious example.
- *Economic* scarcity means that there may be water resources available, but there is not sufficient capacity to treat and distribute the water to the users. So, there is scarcity in access to water services. There can also be scarcity due to inadequate infrastructure, irrespective of the level of water resources, due to financial constraints.

Water scarcity can also appear in a 'wet' country when demand is much bigger than supply.

Economic development contributes to the rapid increase of water use.

The water use has been growing globally at more than twice the rate of population increase in the last century. The world water demand has more than tripled over the past half century.

According to FAO AQUASTAT (2015), global water use in 2000 is estimated to have been about 30% of the world's total accessible fresh water supply. That fraction may reach 70% by 2025. The water use of the industry and households increased a factor of four during the second half of the 20th century. This increase is twice as high compared to the farming water use increase. At global level, the water withdrawals are 70% agricultural, 11% municipal and

19% industrial. These numbers, however, are biased strongly by the few countries which have very high water withdrawals. Averaging the ratios of each individual country, we find that 'for any given country' these ratios are 59%, 23% and 18% respectively. The ratios also vary much between regions. In South Asia the ratios are 91% for agriculture 7% for municipal and only 2% for industrial water withdrawals while in Western Europe the ratios are 8, 16 and 77% respectively.

> During the last 60 years the area under irrigation has doubled and the amount of water drawn for agriculture has tripled.

Obviously, the agriculture need varies significantly between regions. In a country with temperate climate and regular rainfall the water need may not be apparent. For example, in the UK agriculture requires around 3% of all water withdrawals. In the USA the corresponding figure is 41%, in China almost 70% and in India close to 90%, most of it for irrigation. The water need for food production will be discussed in Chapter 6.

Less than ten countries hold 60% of Earth's available freshwater: Brazil, Russia, China, Canada, Indonesia, the United States, India, Columbia, and the Democratic Republic of Congo. Other countries, all over the world, face water scarcity or water stress. China and India, with more than one third of the world population, have less than 10% of the world's freshwater. There are huge differences between different parts of these large countries. The average annual rainfall in the south-east of China is 110 times that in the western desert regions. Also within India there are similar large differences between wet and dry areas.

While **water scarcity** considers the natural allocation in relation to the number of users, **water stress** considers the fact that more people live in places characterised by either too much, too little, or the wrong quality of water. Australia, for example, faces the most acute water scarcity of any developed country. In regard to developing countries, India's chronic water scarcity problems will become an even bigger challenge over the next few years, as will the Middle East's and Africa's. Most countries in the world outside the Arctic zone, developed and undeveloped, and even a small developed country like New Zealand, face scarcity challenges in different parts of their geographies. A new high-tech city, Dubai, has been built in a desert and already has the world's highest per capita rate of water consumption.

1.2.1 Water and poverty

An increasing number of regions are reaching the limit at which water service can be sustainably delivered. The combination of demographic growth and economic development are putting an enormous pressure on renewable but finite water resources, especially in arid regions. According to UNEP (2010) available freshwater resources are declining.

> By 2050, 1.8 billion people will live in countries with 'absolute' water scarcity (<500 m^3 per year per capita), and water withdrawals will have risen by 50% in developing countries and 18% in developed countries. Two-thirds of the world population could be under 'stress' conditions (500–1000 m^3 per year per capita).

Human activities will also cause water quality to decline, polluted by microbial pathogens and excessive nutrients. There is also a rising concern about the impact of personal care products and pharmaceuticals.

The situation will be exacerbated as rapidly growing urban areas place heavy pressure on neighboring water resources. Further, the lack of access to clean water has major health implications.

> Globally, contaminated water remains the greatest single cause of human disease and death.

Some indications of the seriousness, according to WHO, UNICEF and WaterAid (www.wateraid.org), are:

- Globally 884 million people (one in eight) live without safe drinking water and 2.5 billion (two in five) do not have adequate sanitation. The lack of these basic services adversely affects people's health, education, dignity and livelihoods.
- Every day 4,000 children die needlessly from diarrhea, and countless others are too sick to go to school.
- Millions of hours are wasted as women and children walk each day to collect filthy water.
- With nowhere safe and clean to go to the toilet people are exposed to disease, lack of privacy, and indignity; problems which are particularly acute in overcrowded urban settlements.
- In schools without private sanitation facilities girls often drop out as they reach puberty.

> 440 million school days are lost because of water-and sanitation-related diseases.

> 4000 children dying every day would correspond to around ten jumbo jet crashes per day, and the majority of the passengers are children.

- Nearly 4 billion cases of diarrhea occur each year;
- 200 million people in 74 countries are infected with the parasitic disease Schistosomiasis;
- Intestinal worms infect about 10% of the population in the developing world. Intestinal parasitic infections can lead to malnutrition, anaemia and stunted growth;
- It is estimated that 6 million people are blind from trachoma, and that the population at risk is 500 million.

Poverty is closely related to lack of access to clean water.

Lack of access to water is one of the defining criteria of poverty and consequently access to clean water is now recognized as the key to poverty reduction.

1.2.2 The millennium development goals

The Millennium Development Goals (MDGs), a series of targets for reducing social and economic ills, were articulated in 2000 by the UN. In 2015 the MDG should improve the existence of many and save the lives of those threatened by decease and hunger. In the UN report for 2014 important progress was reported UN MDG (2014) and many goals had

actually been met. One of the targets was halving the proportion of people who lack access to improved sources of water.

Access to an improved drinking water source became a reality for 2.3 billion people between 1990 and 2012. In 2012, 89% of the world's population had improved water available. This means that still some 800 million people lack clean water, even if UN claims that the MDG target has been met.

UN declares that over a quarter of the world's population has gained access to improved sanitation since 1990, yet a billion people still resorted to open defecation. Between 1990 and 2012, almost 2 billion people gained access to an improved sanitation facility. However, in 2012, 2.5 billion people did not use an improved sanitation facility and 1 billion people still resorted to open defecation, which poses a huge risk to communities that are often poor and vulnerable already. Much greater effort and investment will be needed to redress inadequate sanitation in the coming years.

Global emissions of carbon dioxide (CO_2) continued their upward trend and those in 2011 were almost 50% above their 1990 level. Millions of hectares of forest are lost every year, many species are being driven closer to extinction and renewable water resources are becoming scarcer.

The UN Human Rights Council passed a resolution 7/23 on March 21, 2008. The Council was concerned that climate change poses an immediate and far-reaching threat to people and communities around the world and has implications for the full enjoyment of human rights. It also recognized that climate change is a global problem and that it requires a global solution. Viewing at the IPCC findings through a human rights lens, it was clear that climate-change related effects threaten the effective enjoyment of a range of human rights:

- The right to safe and adequate water and food;
- The right to health and adequate housing.

The Council also emphasized that the human rights perspective brings into focus that climate change is set to hit the poorest countries and communities the hardest.

According to UNSD (2015) and UN MDG (2014) nearly 80% of the unserved population is concentrated in three regions: sub-Saharan Africa, Eastern Asia and Southern Asia. Coverage is above 78% in all regions except sub-Saharan Africa and Oceania where it amounts to 56% and 50%, respectively. While 80% of the developing world population have access to some type of improved drinking water source, only 44% have access through a household connection from a piped system. Although access to improved drinking water is currently above 80% in Southern Asia and South-eastern Asia, levels of coverage through household connections are only 20% and 28%, respectively, not much above the level of 16% in sub-Saharan Africa.

In September 2011, the Human Rights Council adopted its 3rd resolution on 'human rights and climate change', resolution 18/22. The resolution was tabled by the Philippines and Bangladesh and supported by 43 other countries, among them the Maldives. The resolution affirmed the human rights obligations. The results were presented at a seminar in February 2012 in Paris and the report was available for the COP18 meeting in Doha, Qatar, in December 2012. More on the COP meetings is presented in Chapter 4.

So, what is meant by 'human right' to water? According to UNDP and WHO it includes:

- Between 50 and 100 liters of water per person per day to ensure most basic needs;
- The water source has to be within 1 km from home;

- Collection time should not exceed 30 minutes;
- Water cost should not exceed 3% of household income.

1.2.3 Energy supply for water

Part of the effort must be spent on the energy that is required to provide safe drinking water and some adequate sanitation, especially in the urban areas. Obviously, institutional and economic actions are needed, and the technical solutions have to consider the particular needs for the poor people. As stated by the WHO and Unicef (www.unicef.org), the distance to the drinking water tap has several implications: '*An important aspect must be considered in this analysis: the type of access to improved drinking water. … The availability of drinking water within the household through a household connection provides a better level of service. For example, it allows the use of drinking water in quantities that would normally fulfil the health and hygiene requirements of the householders. Where a drinking water source is not available within the property it is likely that they will not use more than the very basic quantities required for hygiene, drinking and cooking (20 liters per capita per day).*'

Energy is a pre-requisite for water availability.

The climate change threatens to make the situation worse. Fossil water – water in aquifers that is not replaced – is disappearing with an alarming rate. Glaciers are melting and many rivers never reach the sea.

1.3 EXPEDIENTS FOR WATER

Action expresses priorities.

Mohandas Gandhi

1.3.1 The value of water

Adam Smith (1723–1790) in *Wealth of Nations*, published in 1776, once posed an intriguing question: 'Why is water, which is essential for life, so cheap while diamonds which are nothing more than pretty stones so expensive?' It took a long time to find a proper explanation, and this has to do with the difference between 'total' value and 'marginal' or 'incremental' value, in other words the value of the next unit being used.

Consider a fixed amount of water to be used for the next month. We would first set aside the water for survival. After that we may use the water for personal hygiene. After that maybe for washing the dishes, and then cleaning the house. For each new use the additional value of water becomes less. The least prioritized use may be water for watering the lawn or washing the car. If the total amount of available water would decrease we will most probably not make an equal proportional reduction in water for survival and water for the lawn sprinklers. We would reduce the least valuable water use and keep the water for survival. The *marginal* value for water is very low if it is not for survival. However, the *total* value of the water is high, since it includes the water for survival. The marginal value may be the reason why we are not willing to pay the adequate price for water, as long as we have plenty of water.

The value of water has to be reconsidered.

Diamonds are not essential for life and have a low total value. However, because we do not have plenty of them their *marginal* value is high. The next diamond we buy is a marginal purchase and is valued very high. So diamonds have a high marginal value but a low total value and it is the marginal value that determines the price. This is the explanation of the paradox stated by Adam Smith. We know that we would trade our diamonds for water if we would need the water to survive the next hours or days.

When water supplies are abundant their value is low. It may seem that we have an infinite supply and there is no need to worry. However, as we approach depletion, even small perturbations due to unforeseen climatic events, sharp increases in demand or technical malfunction result in disproportionate changes in their values and prices, if the market is allowed to work. As a result the total value (price · quantity) rapidly increases as total quantity declines. This is true for any resource that is essential and non-substitutable. As there is less water or energy available, their price quickly increases. This can create havoc in markets and stress the whole economic system. Diminished water supplies may lead to direct conflict and violence. This is further discussed in Chapter 2.

1.3.2 Economic and energy resources for water

Considering the importance of the topic it is interesting to examine how much resources have been spent on water research. The situation in the United States is interesting and may illustrate the more general situation. Since 1973, the population of the US has increased by 26%, the GDP and federal budget outlays have more than doubled, and federal funding for all research and development has almost doubled, while funding for water resources research has remained stagnant. Funding for water supply augmentation and conservation, water quality management and protection, and water resources planning have severely declined since the mid 1970s. Still, the pressure on water resources increases with population and economic growth.

There is an increase in the number of conflicts over water, so there are strong incentives to focus much more on the water and energy issues, both in many parts of the industrialized world and in the developing world.

When the energy supply of non-renewable fossil fuels is depleted we are looking for renewable sources. Similarly, we are over-utilizing fresh water resources in many places. This is compensated by increasing the energy use to import water from other basins by pumping long distances, desalinate sea water or reuse wastewater. Furthermore, nonrenewable water is depleted by over-pumping from fossil aquifers. These practices are not sustainable and will leave our children with fewer options. We need to think much more in terms of increased efficiency and conservation.

In Europe a long term strategy for a European sector has been developed by the Water Supply and Sanitation Technology Platform (WssTP). The outputs in terms of Strategic Research Agendas are aiming to mobilize public and private bodies of all sizes to develop the water sectors and to create synergies between existing water organizations.

In July 2010 the United Nations General Assembly declared that access to clean water and sanitation is a human right essential to the full enjoyment of life and all other human rights. The 192-member Assembly also called on UN Member States and international organizations

to offer funding, technology and other resources to help poorer countries scale up their efforts to provide clean, accessible and affordable drinking water and sanitation for everyone. The Assembly resolution received 122 votes in favour and zero votes against, while 41 countries abstained from voting, among them my own nation Sweden as well as the US, UK and Australia. On that day I was embarrassed and upset.

The text of the resolution expresses deep concern about all the people that lack access to safe drinking water and basic sanitation. The various users of water (people, agriculture, industry and nature) have to make sustainable use of the water resources without disturbing the balance, by not using more water than is needed or using water of a higher quality than needed quality.

1.4 QUANTITY AND QUALITY

For both energy and water both quantity and quality matter.

Water quality is measured by the concentration of impurities, constituents dissolved or suspended in the water, as well as by its physical characteristics, such as colour and temperature.

Water quality can be significantly affected by energy-related projects. For example, water used for cooling purposes in power stations is returned to the river with a higher temperature, which may prove detrimental to some fisheries (Chapter 13). Hydropower that requires dams can also significantly affect physical and chemical parameters of water (Chapter 10). Mining may destroy whole landscapes, including streams (Chapter 11).

We use one kind of energy to produce other forms of energy of higher quality. Low density solar energy is abundant but hard to use. In photosynthesis solar energy is accumulated in woody biomass that can be then be used as a source of energy of higher quality. With photovoltaics (solar PV) we can convert solar energy directly into electricity, which is of higher quality energy than biomass. If we need to use energy to produce a different type of energy of the same quality, we lose efficiency. The higher the quality, and the more efficient a water or energy supply is, the more reliable and the easier it is to provide to end users. This is further discussed in Chapter 15.

Quality of energy can be expressed as efficiency, reliability, and continuity of supply.

As demand for water grows, there will be more competition with regard to water needed for energy production. If water becomes as limiting as energy, there will be more pressure on water-intensive energy producers to seek alternative supplies.

The links between water and energy are also becoming apparent by the frequent inefficiency and wastage in the way that both resources are used. There are serious inefficiencies in many parts of the world in electricity generation, transmission, distribution and usage. Likewise, there are inefficiencies and leaks in water distribution systems. It follows that substantial efficiency gains in water use will reduce electric power requirements, which in turn will lead to more savings of water that otherwise would be used in power generation.

A simultaneous analysis of water and energy use at the planning stage can enable significant increase in productivity in the use of both resources. Water conservation can lead to large energy savings and energy efficiency approaches will have an impact on water.

1.5 CHAPTER SUMMARY

- All water operations require energy.
- Energy production and generation require water; for the extraction, refining, and electric power generation.
- Water and energy systems and operations have to be planned together.
- Water scarcity is a reality for too many people, not only in dry countries but also wherever demand is much higher than supply.
- The value of water is often not appreciated and is often not reflected in the price or in the resources devoted to water research.
- The contamination of water resources further reduces available water supplies.

1.6 MORE TO READ

The books Diamond (2005, new edition 2011) and Pearce (2006) were real eye-openers for me. Diamond analyzes the reasons for the collapse of human civilizations in history, which relates directly to the issues of water, energy and food. Pearce gives a horrifying account of the damage caused by mankind to its rivers. Still, the books give some hope, but this would require that the world begins to think differently about water.

The water-energy nexus is described by Cohen (2007) and in some articles in a special issue of Southwest Hydrology (2007). Pate *et al*. (2007) provide an early overview and the textbook Gautier (2008) is an excellent introduction into this extremely complex topic of water, climate and energy interactions. The paper by Webber (2008) is an excellent introduction into the water-energy nexus. In recent years the water-energy nexus has been topic for an increasing attention, such as the UN report UN WWDR (2014), the BP supported work Williams-Simmons (2013), the World Bank report World Bank (2013) as well as the World Energy Outlooks, presented every year by IEA, the International Energy Agency (IEA, 2012, 2013a, 2014c). Naturally the IPCC Assessment Reports contain a lot of information on the water-energy nexus. This is further discussed in Chapter 4.

The books by Solomon (2010) and Fagan (2008) give fascinating descriptions of the importance of water within history. The books by de Villiers (2001), Bell (2010) and Fishman (2011) are recommended reading to get an appreciation of the water scarcity problem in the world today. The book by Chellaney (2011) is an insightful analysis of the water situation in Asia.

The US Department of Energy provides important sources of information for US water and energy uses (see DOE reports in the Bibliography). FAO, the UN Food and Agriculture Organization, (FAO AQUASTAT, 2015) provides a wealth of information on population, energy, water on the global scale. The increasing scarcity of water has been given much attention at the World Water Forums (from, 1997 and every 3 year). Special workshops and conferences with the water/energy theme have been arranged, such as IWA (2008, 2009, 2010).

Some water data are obtained from WBCSD (2009), CIA (2011), and the most recent Global Environment Outlook (GEO4) from UNEP (2010). The water-energy nexus is formulated in an appeal to the world's decision makers in IWA (2010).

Webb-Johnson (2009) and Voinov-Cardwell (2009) discuss water and economy, with special attention to the US. Farley-Gaddis (2007) describe price elasticity or the opposite for water. The European Water Supply and Sanitation Technology Platform (WssTP), where the author was part of one of the committees, is documented in WssTP (2006). WssTP (2011a) has a special emphasis on the research needs for water and energy.

The online newsletter Water 21 Global News Digest (IWA Publishing) regularly informs about water and energy related issues.

1.6.1 Journals

IWA publishes several journals relevant for the water and energy nexus, see www.iwaponline.com. In particular Journal of Water & Climate and Water 21 but also Water Science and Technology, and Water Science and Technology – Water Supply regularly contain articles on our water supply and relations to energy. IEEE journals like IEEE Spectrum, Control Systems Magazine, Instrumentation and Measurement, Sensors Journal should be of interest for water professionals. More journals are listed at www.ieee.org.

1.6.2 Visual media

Among all films and videos on the environmental theme I wish to recommend one film, called Home. It is freely available on YouTube. It is a magnificent documentary of life on Earth and shows the apparent couplings between food and the use and misuse of water and energy. Access www.youtube.com/movie?v=jqxENMKaeCU (latest access 15 Jan. 2015). Looking at the 1.5 hour video is well spent time.

WATER AND ENERGY

THREATS AND OPPORTUNITIES - SECOND EDITION

'Professor Olsson's book, Water and Energy Threats and Opportunities, the result of a meticulous multi-year effort, meets an important and growing need: to define and illuminate the critical linkage between water and energy. He explores the water-energy nexus in detail, and carefully discusses its many implications, including for food production and its connection to global climate change. He properly and repeatedly emphasizes the important message that water and energy issues must be addressed together if society is to make wise and efficient use of these critical resources. Given its comprehensive scope and careful scholarship, the book will serve as a valuable addition to the libraries of students, researchers, practitioners, and government officials at all levels. In its expanded and updated second edition it adds a clear and comprehensive discussion of the important subject of fracking which has recently emerged as a major public issue.' Dr. Allan R. Hoffman, Senior Analyst, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, Washington, DC

'This second edition of the book is much more than a revision of data, style and contents. It extends significantly some key topics, and adds new information about current issues in the nexus of water and energy, such as water footprint, fracking, oil exploitation in the Arctic Sea, and many others. One of the most brilliant aspects of Gustaf's writing is his ability to pay attention and question unobtrusively our role as citizens, to face the complexity of these environmental aspects and their implications. Gustaf argues the situation with authority, summoning up examples and illustrations that are helpful in challenging our knowledge, but also our thinking, feeling and behaving.' Professors Manel Poch, Joaquim Comas and Ignasi Rodriguez-Roda, Catalan Institute for Water Research and LEQUiA - University of Girona, Catalonia.

'Prof Olsson has pioneered into a new knowledge territory by combining water and energy into a subject by its own. In reality, water and energy should not be separated in terms of academic discipline, sector administration, policy framework or business portfolio. Wherever we need water, energy is to be coupled as common utilities for residential, commercial or industrial development. Prof Olsson has demonstrated his mastery of water-energy nexus in this book.' Professor Zaini Ujang, President and Vice-Chancellor Emeritus, Universiti Teknologi Malaysia

'Gustaf Olsson illustrates the inextricable linkage between water and energy, and demonstrates that an integrated and holistic approach as well as a change of attitude is necessary to solve the complex water and energy challenges we are facing. This book is full of enlightenment.' Jining Chen, President and Professor, Tsinghua University, Beijing

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