Scheele, U. & S. Malz (2007): Water demand and water use in the domestic and industrial sectors - An overview. In: Lozán, J. L., H. Grassl, P. Hupfer, L.Menzel & C.-D. Schönwiese. Global Change: Enough water for all? Wissenschaftliche Auswertungen, Hamburg. 384 S. Online: www.klima-warnsignale.uni-hamburg.de

2.2 Water demand and water use in the domestic and industrial sectors – An overview

ULRICH SCHEELE & SIMONE MALZ

SUMMARY: *Water is a critical and essential resource. World-wide the provision of new water services is outpacing population growth. Today 1.2 billion people have no access to safe drinking water and in spite of substantial progress, another 2.4 billion people have no access to adequate sanitation. The universally accepted goal to accomplish and to improve sustainable development can only be achieved by an integrated resource management strategy. The main reason for water crisis is population growth, particularly in developing countries. While for most people in Europe and other industrial countries, access to clean water in abundant quantity is taken for granted, in developing countries the growing water demand of the private household sector but espe-cially of the industrial and agricultural sectors leads to severe pressures on water resources. A balanced water supply and water demand management is a precondition for any water policy strategy. It requires a better understanding of those factors which influence the structure and future development of water demand.*
This article focuses on water withdrawals and water use of the private household and the industrial sector. It indicates that the water crisis is not a problem of water availability on a global scale but represents a regional problem.

Problem definition

A missing or insufficient management of water resources is regarded as one of the main constraints of sustainable economic and social development in the long run in many regions of the world.

Water shortage is a common and prevalent issue on the political agenda of different countries. The water related problems will however be intensified by an ongoing pollution and excessive use of the available water resources.

The pressure on the available water resources stems from the demand for drinking water but is also a result of the growing claims on the resources through the industrial and the agricultural sectors. There is the fear, that in the future political and even military conflicts around scarce water resources will increase, since about 60 percent of the water resources world-wide are shared by at least two countries.

While the world population during the last five decades doubled, the water use world-wide has quadrupled. Although two thirds of the Earth's surface consists of water, only a small fraction of these resources is directly utilisable for human purposes.

A world-wide water crisis doesn't necessarily mean an overall water shortage compared to the water demand but the problems arise from an uneven regional distribution of water resources. Especially the developing countries have no or only insufficient financial, institutional, personal and technical resources, necessary to build up a functional water supply and waste water sanitation system.

The figures are alarming: according to the World Water Development Report of the United Nations today about 1.2 billion people have no access to an adequate water supply and about 2.4 billion people world-wide have no access to a sewage and sanitation system at all. In the developing countries, water related diseases count to the most frequent causes of death. It is assumed that in average between 10,000 to 20,000 children per day die as a direct consequence of the insufficient sanitary conditions in their homelands.

Under the prevailing basic conditions the problems will get worse and it will require enormous political and financial efforts in order to reach a trend reversal or at least a stabilisation of the present situation.

The Johannesburg Summit on Sustainable Development describes the development of water supply as the biggest challenge of the 21st century and for the first time determines very ambitious goals: so the number of people having no access to sufficient water and waste water services should be halved till the year 2015 (UNITED NATIONS 2004).

Any serious solution of the world water crisis will not only consist of additional financial resources transferred to the developing countries but in the first place will have to find new ways to balance regional water supply and water demand. In order to implement special water demand management strategies there is a need for sufficient information about the structure of the current water use and the future development of different user categories.

The following chapters give a short overview of the domestic and the industrial water use and it considers the methodology and the results of water demand forecasting approaches.

Definitions and delimitations

Water is a renewable resource, therefore the term »water consumption« has to be defined more closely and analysed in a more differentiated way. First the difference between water withdrawal and water consumption is relevant (*Fig. 2.2-1*). Water withdrawals describe all quantities taken out

Ulrich.Scheele@uni-oldenburg.de

of groundwater and surface water reservoirs for human uses in a wider sense. Those water withdrawals which after the use for domestic, industrial or agricultural purposes are not directly discharged back into the terrestrial hydrological system are marked as water consumption. In other words, consumption is the volume of water that is withdrawn, used, evaporated and not directly available for downstream users. Water quantities which are not consumed are discharged back into the water cycle, however not necessarily at the same point where they have been withdrawn. Comparably small withdrawals of water can lead to serious ecological problems. An example is the desiccation of rivers due to excessive withdrawals. It already suffices, if a minimum discharge can not be secured in order to protect the functioning of an ecological system.

Water withdrawn from the water cycle serves different purposes. There is a distinction between the water use of the industry, the private households and the agricultural sector. For further analyses this sub-structure is still not too specific. Regarding the industrial sector, water use can be again differentiated into drinking water, process water and water for cooling purposes.

Process water is immediately used in the production process for example as a transport medium or a solvent, or water is directly incorporated in the product.

The water demand of the industry is characterised by different water qualities depending on the specific uses. On the other hand, the water demand of the private household sector is concentrated on a specific water quality, fixed by state agencies or by self regulation organisations in the drinking water guidelines or directives.

On an international level, there is the problem of being able to compare the data and figures related to water use due to a lack of compatibility: Figures published in particularly in those countries with a very poor and insufficient water administration are often only based on rough estimations. But also in a lot of industrial nations not all the industrial and agricultural users are connected to the public water supply network but use their own water sources to meet their demand. This water supply is not always included in official water statistics.

The supply of drinking water to the population is in most countries carried out by public water utilities. There are however large differences between the considered water-use categories: published data for drinking water supply often contain water deliveries to private households; in other cases theses figures include also drinking water supplies to small scale services and trade companies and to the public sector (military, schools, hospitals, public administration).

In the meantime, in most Western European countries the connection rates of the private households to public water networks is almost 100%. On the global view however, the majority of private households is still supplied by water out of own water sources. Whereas in Germany for example the water use of private households is captured by a flow measuring, even in some other countries of the European Union there is no water metering in private households.

The allocation of the cost of the water supply to the single dwellings is then based on criteria like the apartment size, number of residents or the rateable value oft the real estate. To conclude, the various organisational structures and institutional arrangements make it difficult to draw international comparisons concerning the structure and the development of drinking water use in the private household sector.

Water use of the private households

Apart from the very small portion of water which is for immediate human consumption the main share of water demand of the private households refers to the production

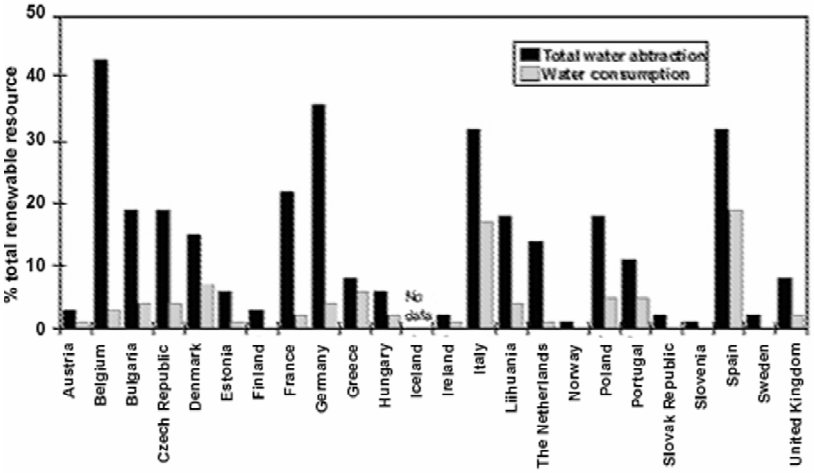

Fig. 2.3-1: Water withdrawal (abstraction) and water consumption as percentage of total renewable freshwater resources in Europe (Source: EEA 1999, p 10) (= European Environment Agency).

of »water services«. Water in households is mainly needed for cleaning and washing, for personal hygiene, and for toilet flushing (*Table 2.2-1*).

To satisfy the basic human needs like drinking, washing and cooking a minimum of about 5 litres water per day and person is estimated (GLEICK 1996). Of course this value varies due to regional climatic conditions and individual psychological features, the deviations in both directions are however comparatively low. The water demand increases, if an adequate quality of life and sanitary conditions shall be achieved. The World Health Organisation (WHO) and the US Agency for International Development published an estimated water requirement of about 20 to 40 litres *per capita* and day and, while the European Environmental Agency estimates a minimum requirement of about 80 litres *per capita* and day.

Taking these minimum requirements into account present studies and reports covering the world-wide water supply show that half of the current world population can not rely on water services which were already standard to the old Romans and Greeks (WOLFF & GLEICK 2002).

Compared to the total amount of water withdrawn from the groundwater and surface water reservoirs, the water use of the private household sector is only of minor importance, but there are large differences between countries and regions. The world-wide water demand of private households grows due to an increase in world population and the ongoing processes of urbanisation in the developing countries. On the other side, in the most developed countries domestic water demand varies strongly but all together the situation is characterised by a stagnant development or in some cases by a real decrease of the water use figures.

The water use of the private households is measured by the volume of water which is withdrawn from the central public water supply network. The specific water use figures per day and capita are then calculated under the consideration of the total population number within the respective regional or local supply area. International comparisons of water use figures have to take into account that in many countries only a part of the population is connected to a public water supply network. Therefore, the statistic figures published may be stated too low in those countries; on the other hand the specific water use rate may be too high in those countries or regions where tourism is of significant importance (WIELAND 2003, p. 3).

Water use in households varies enormously between different regions: while around 20 litres *per capita* and day are used in the rural arid regions in Africa, an US – American has in average a water demand of almost 300 litres per day.

The average *per capita* water use within the member states of the EU is currently around 150 litres per day, but even within this association of developed countries the figures vary between 113 litres *per capita* and day in Belgium and 214 litres in Finland.

The specific water use value in the new accession countries of the EU is 105 litres *per capita* and day on average. This below-average value is mostly a combined effect of a lower standard of living and a higher rate of self sufficiency. In Germany the specific water consumption in 2004 was 127 litres *per capita* and day, about 20 litres lower than the water use in the year 1990, shortly after reunification.

Table 2.2-1 represents the share of the water use categories of the domestic sector in Germany. The data are mainly based on estimations since the water use in households is not differentiated between the individual categories. Hence, international water use studies show comparable results.

Industrial water use

About 20 per cent of the world-wide water withdrawn is used in the commercial and industrial sector. The differences between different countries are considerable; the share of the industrial sector at the total water use is almost 60% in the developed countries whereby the role of the agricultural sector as water consumer plays a comparatively minor role in these countries.

According to different scenarios, an increase of the industrial water demand up to 1,170 km^3 per annum till the year 2025 is expected on the global level, this would correspond to a share of this sector at the total water use of about 24 per cent. The largest part of this projected increase in industrial water use will be realised in those developing countries with high economic growth rates, and especially by those which heavily rely on resource – intensive industries. Water demand projections show a rise in water use for electricity generation especially in the African, Asian and Latin American countries.

In the European countries water use in the industry is currently around 10% in average, not taking into account the water withdrawn for cooling purposes in the electricity generation process. If the water quantities needed for cooling purposes or used in hydroelectric power stations are included, then the share of the industrial sector at the total water withdrawals is up to 32% (see *Table 2.2-2*).

During the 1980s and the 1990s, the industrial water use considerably decreased in the most developed countries. This development is to a great extent caused by new production technologies with lower water input and in a broader sense a decoupling of economic growth and resource consumption. This can impressively be illustrated by the following examples: Before World War II the water quantity needed for the production of one ton of steel was

about 60 to 100 tons, today with improved technologies the water use has been reduced to less than 6 tons of water per one ton of steel. A further reduction of water use in this branch is due to a substitution of steel through aluminium for example in the automobile production (WOLF & GLEICK 2002, p 23; EUROPEAN ENVIRONMENTAL AGENCY 1999).

This development is expressed in the literature by different ratios. The concept of »water productivity« is for example a useful instrument to describe changes in the industrial water use. This indicator relates the quantity of goods and services to the quantity of water necessary to produce these goods. The quantity of produced industrial goods and services can be measured in physical units (number of the products, weight etc.) or in monetary units (gross domestic product, gross added value).

Table 2.2-1: Percentage composition of the private consumption (department of the environusement 2001, p. 34)

Boiling and drinking	3
Personal hygiene	6
Baden and showers	30
Toilet flush	32
Cleaning	3
Washing the dishes	6
Wäschewaschen	14
Garden sprinkle	4
Car laundry	2
Total	100

Table 2.2-2: Share of the industry in the complete water withdrawal (EUROPEAN ENVIRONMENT AGENCY 1999).

Country	**Industrial water consumption (without cooling water)**		**Cooling water for power stations and water power**	
	($\times 10^6$ m^3)	**(%)**	**($\times 10^6$ m^3)**	**(%)**
Belgium	210	3.0	5,149	73.4
Denmark	82	9.0	0	0.0
Germany	6,475	11.0	16,952	28.8
Finland	1,111	33.2	1,690	50.5
France	3,942	9.7	25,835	63.5
Greece	136	2.7	91	1.8
Großbritanien	848	7.0	1,721	14.2
Ireland	250	20.6	277	22.8
Italy	7,980	14.2	7,025	12.5
Luxe castle	14	24.5	0	0.0
Netherlands	507	4.0	11,028	87.0
Austria	489	20.7	885	37.5
Portugal	241	3.3	2,682	36.8
Sweden	1,479	54.6	70	2.6
Spain	1,647	4.6	4,915	13.9
Total	**25,411**	**10.4**	**111,612**	**31.8**
	Average value		Average value	

* water can be used repeatedly

Source: EEA, Environmental assessment report of No 1: Sustainable water use in Europe, share 1: Sectoral Use of Water

The term »water use efficiency« describes another concept and considers the potential of water savings in the industrial sector. Efficiency is the ratio between the minimum of water needed for a certain kind of production process and the quantity of water currently used in this process. Every reduction in the current water use leads to an improvement of the efficiency measure in direction of 1.0 (i.e. 100 per cent efficiency).

Although there is an improvement in the world-wide water productivity during the last decades, there are of course some considerable differences between the countries. This is a result of a very uneven access to new technologies, the various degrees of economic structural changes and the different emphasis of water – intensive branches. But also dissimilar water costs as well as specific environmental policies may be of importance in this context.

Water demand projections

Prerequisite for a long term sustainable management of water resources is a reliable estimation of future water supply and water demand in a region or in any country. Since the 1960s there has been numerous global water demand projections, mainly based on the analysis and the extrapolation of historical water use figures.

GLEICK (2000) evaluates altogether 26 global water demand projections published since 1967 which deal with projection periods between 20 years and half a century.

The results of his study are clear : The older studies are very simple trend extrapolations of water use and operate with ratios in the form of water use per person or per acre in the case of irrigation. More current studies use a larger number of demand categories and distinguish between domestic, industrial and agricultural water demand and the water needed to maintain ecological functions. Some studies also take into account water losses in the supply network as well as the potential effects of climate changes on water resources and water demand. The quality of the projections is improving since more developed projection methods are applied, and a broader data base and expanded information processing capacities are available.

Today water demand projections are based on the scenario method. This is not a forecast or projection in the narrower sense but a method to show possible future developments taking into account different circumstances and assumptions about the development of the main factors influencing water demand. Depending on those different conditions and sets of relevant factors, several future outlines can be distinguished.

The World Water Commission for example describes three scenarios to assess world-wide water supply and water demand till the year 2025. The »Business as usual«

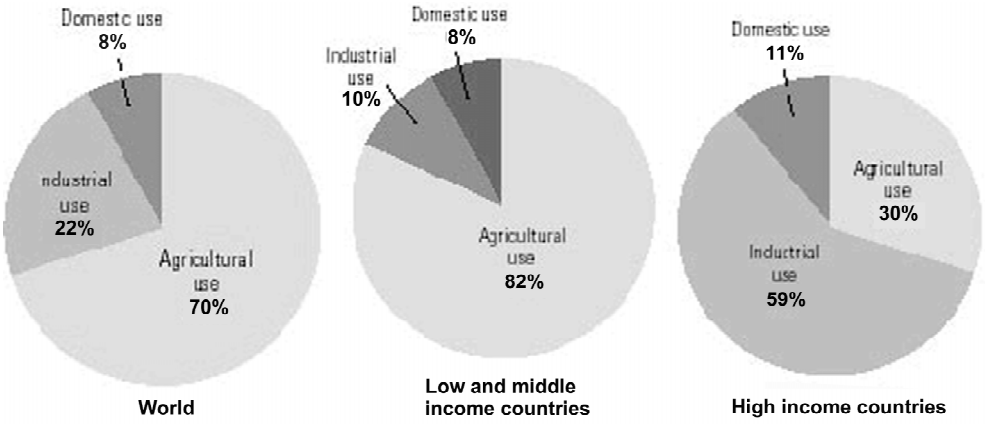

Fig. 2.2-2: Water use by states (UNITED NATIONS 2003, p.19).

scenarios describes the future water demand assuming that there is no change in the economic, social or political framework and relies therefore on the extrapolation of recent trends. The second scenario focuses on future water demand under the assumption that there is a decisive improvement in water use efficiency due to new technologies. The third scenario deals more with changing life styles, values and consumer behaviour and describes a picture of a more sustainable society.

A comparison of the predicted results with the actual results turned out the deficits of most forecast methods. The former projections have overestimated the current water use since they simply extrapolated historical trends without taking into account the changing economic conditions and the effects of new social, institutional or political frameworks. The lower growth of the water use resulted from considerable but maybe not predictable improvements in the water use efficiency. Of course water demand is also influenced by the very unfavourable economic developments in a lot of countries.

In the midst 1990s the actual water withdrawals were world-wide only half of those quantities predicted in the demand forecasts 30 years ago. SHIKLOMANOV (2000) assumes that in the year 2025 there will be less global water use than he himself has calculated 1974 in a demand forecast for the year 2000.

From this point of view it appears to become obvious that at least on the global scale there will probably be no problems with the availability of water resources in a foreseeable future. To illustrate this assessment: even if according to recent projections the world population should increase to about 9.4 billion people in 2050 and if one assumes an average *per capita* water use on the current (high) US level, a *per capita* water volume of 4,600 m³/year would still be available (SCHMANDT 2003).

Despite these good news at the global level there are however regional imbalances between water supply and water demand all over the world and there are clear signs that these problems will increase in the future.

For the implementation of an effective water management, regional water demand projections should be available which take into account all relevant factors and conditions influencing future water demand.

In the context of the UNESCO International Hydrological Programme IV a total of 26 regional water demand projections for so called »natural economic regions« were drawn up; these large scale regions are characterised by comparable economic and natural conditions. Such regional studies are useful to determine those areas which in future will be confronted with serious water problems due to an increase in water demand and/or a reduction of available water resources. The distinction between »water stress« and »water scarcity« regions is of relevance for policy implementation. »Water stress« means that in certain regions only between 1,000 and 1,600 m³ of water are available *per capita* and year, in a water scarce region the water availability is limited to only 1,000 m³ or less *per capita* and year.

Western European countries are altogether classified as water stress regions but according to recent demand studies this situation would not deteriorate however. Modern sewage treatment methods and water reuse techniques will probably reduce the future water demand in the developed countries. Nonetheless, under »business as usual« assumptions, the number of people living in water stressed regions will globally rise to about 3.4 billion world-wide until the year 2025, compared to 1995 this would be almost a doubling ♦