Integrated Concepts for Reuse of Upgraded Wastewater

AQUAREC

Reclamation and reuse of municipal wastewater in Europe – current status and future perspectives analysed by the AQUAREC research project

Policy Brief

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1. THE AQUAREC PROJECT

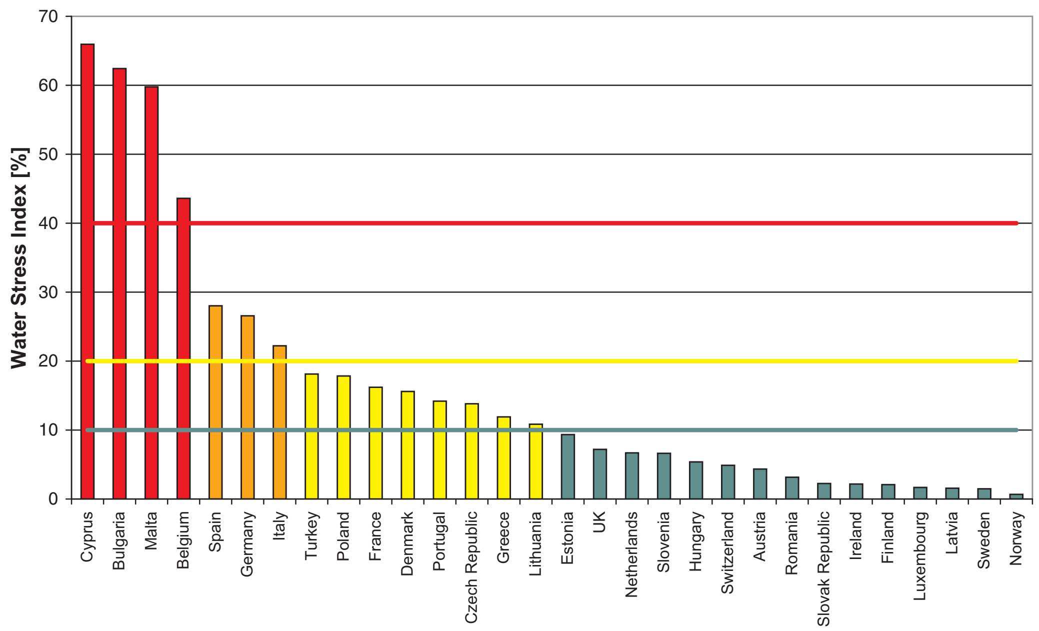
The AQUAREC project on "Integrated Concepts for Reuse of Upgraded Wastewater" is funded by the European Commission within the 5th Framework Programme as well as in Australia by the Commonwealth Department of Education, Science and Training. The project is coordinated by RWTH Aachen University. The general objective of the AQUAREC project is to provide knowledge to support rational strategies for municipal wastewater reclamation and reuse as a major component of sustainable water management practices. The approach is interdisciplinary and broad, addressing issues of strategy, management and technology. The project aims to define criteria to assess the appropriateness of wastewater reuse concepts in particular cases and to identify the potential role of wastewater reuse in the context of European water resources management. The project will provide guidance for end-users facing decisions in the planning, implementation and operation of wastewater reuse schemes as well as for public institutions at various levels. The project commenced in March 2003 and was completed in February 2006.

2. DRIVERS FOR WASTEWATER REUSE IN EUROPE

Europe has extensive water resources compared to other regions of the world, and water has long been considered as an inexhaustible public commodity. This position has however been challenged in the last decades by growing water stress, both in terms of water scarcity and water quality deterioration.

A survey conducted as part of the AQUAREC project revealed that approximately half of all European countries, representing almost 70% of the population, are facing water stress [5]. Figure 1 ranks European countries according to their water stress index. The water stress index – the ratio of a country's total water withdrawals to its total renewable freshwater resources – serves as a rough indicator of the pressure exerted on water resources (note however that different water uses have variable influences on water stress). Water Stress Index values of less than 10% are considered to be low. A ratio in the range of 10 % to 20 % indicates that water availability is becoming a constraint on development and that significant investments are needed to provide adequate supplies. A water stress index above 20 % necessitates comprehensive management efforts to balance supply and demand, and actions to resolve conflicts among competing uses [17]. These data are on a country-level and do not reflect the fact that water stress often appears at the regional scale. Uneven spatial distribution and seasonal variations in water resource availability and demand make the semi-arid coastal areas as well as highly urbanised areas particularly susceptible to water stress. Changing global weather patterns are supposed to aggravate the situation, in particular for those Southern European countries which are prone to drought conditions [6][23].

Figure 1 Water Stress Index for the European countries;
annual abstractions for the year 2000 (or latest available data) are divided by the long term annual average (ltaa) availability (Data sources: ltaa availability data from EUROSTAT; water abstraction mainly from EUROSTAT and national Environmental Reports) [5]

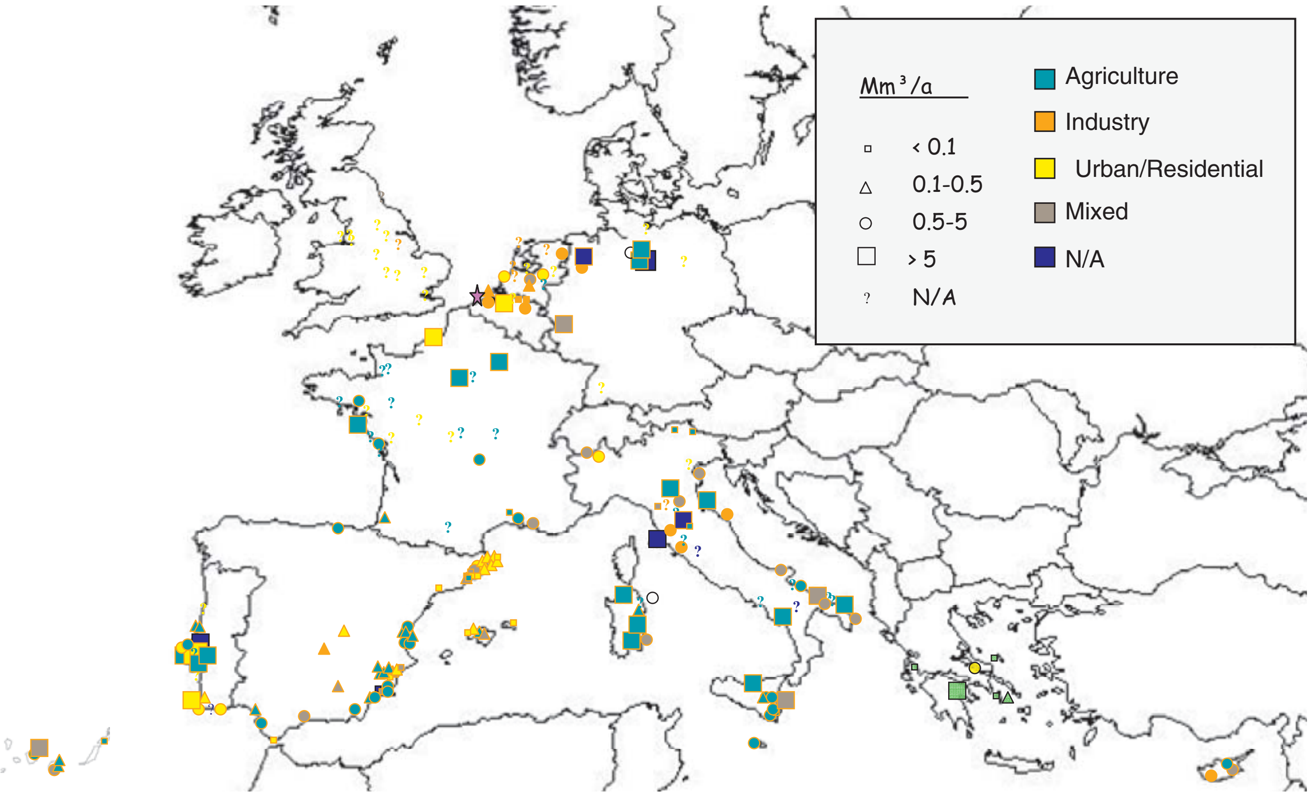


Increasing uncertainty of water availability places many municipalities in a precarious position, especially in the face of increasing water demand, increasing water supply costs and increasing competition (e.g. between industry, agriculture, tourism, etc.) for good quality fresh water resources.
Forthcoming legislative constraints exert institutional pressure to conserve water resources and identify sustainable management practices. In 2000, as an acknowledgement of deteriorated water resources and fragmented water related legislation, the European Union adopted the Water Framework Directive establishing a framework for the Community action in the field of water policy (WFD) [11]. It is expected that the promotion of an integrated approach to water resources management as spelled out in the WFD will favour wider application of municipal wastewater reclamation and reuse projects , for both augmenting water supply and decreasing the impact of human activities on the environment. Note that in 1991, the Urban Wastewater Treatment Directive (91/271/EEC – UWWTD) already urged member states to reuse treated wastewater "whenever appropriate" [10]. But a legal definition of the legally undefined term "appropriateness" is still pending.

3. RECLAMATION AND REUSE OF MUNICIPAL WASTEWATER IN EUROPE - CURRENT STATUS

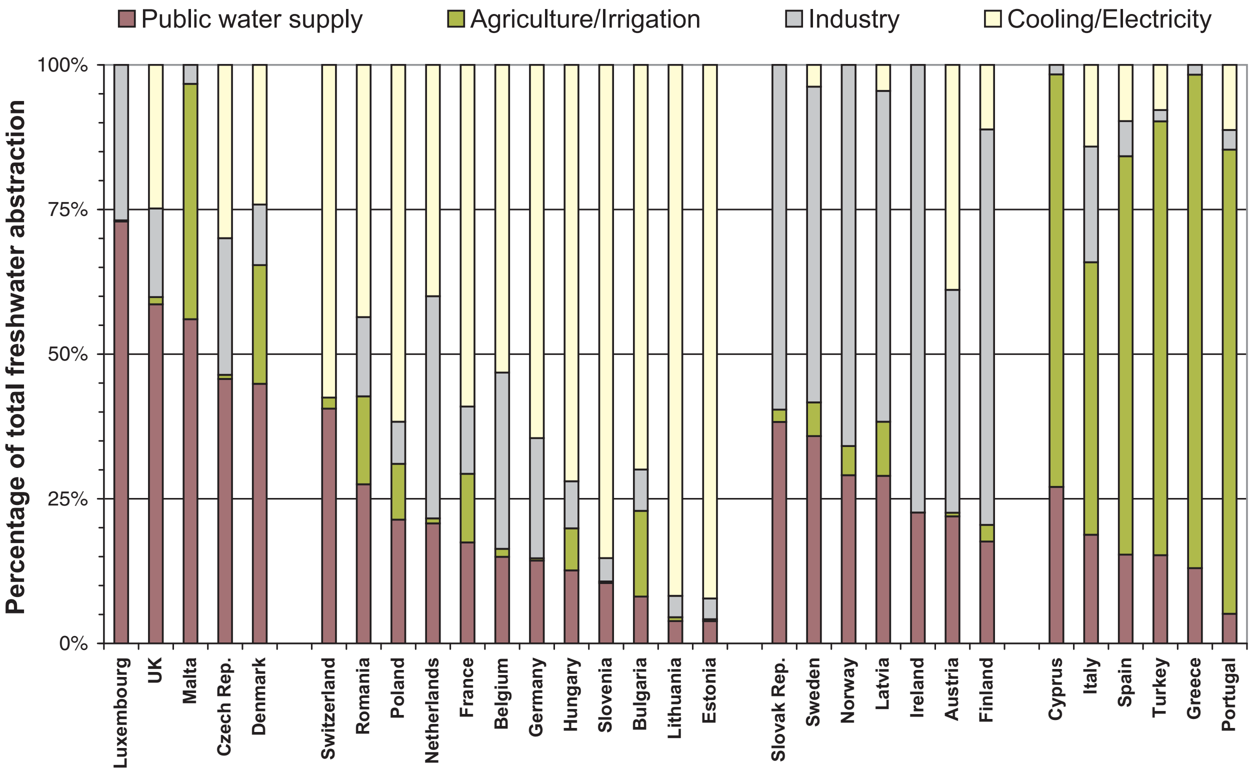
A mapping study within the AQUAREC project revealed that more than 200 water reuse projects exist in Europe and many others are in an advanced planning phase [8]. This is a particularly large figure considering that in the early nineteen nineties municipal water reuse was limited to just a few cases, mostly incidental, i.e. related to the proximity of the wastewater treatment plant to the point of use.
Figure 2 shows the geographic distribution of water reuse projects identified and collated by the AQUAREC project, including their size and details of the water's intended end use. The types of reuse application are divided into four categories: 1) agriculture; 2) industry; 3) urban, recreational and environmental uses, including aquifer recharge and 4) combinations of the above (mixed uses). The scale of the projects is also split into four classes: very small (<0.1 Mm^3/a), small (0.1-0.5 Mm^3/a), medium (0.5-5 Mm^3/a) and large (>5 Mm^3/a).

Figure 2 Identifiable water reuse projects in Europe, incl. their size and intended use (N/A stands for Not Available) [8]



Much of the recent expansion in the number of reuse schemes has occurred along coastlines, on islands of the semi-arid Southern regions, and in the highly urbanised areas of Northern and Central Europe. Figure 2 shows that the use of reclaimed water is quite different in those two regions: in Southern Europe, reclaimed wastewater is reused predominantly for agricultural irrigation (44% of the projects) and for urban or environmental applications (37% of the projects); in Northern and Central Europe, mainly for urban or environmental applications (51% of the projects) or industrial (33% of the projects) uses.
The distribution of application types reflects quite well the sectoral water use of the different countries (Figure 3), with the exception of France. This exception can be explained by the fact that France has published recycled water quality guidelines only for agricultural irrigation so far.

Figure 3 Sectoral water use in Europe [5]



4. A MODEL BASED APPRAISAL OF WATER REUSE POTENTIAL IN EUROPE

Despite the fact that water reuse is already becoming an essential and reliable water supply option for many municipalities, there is still significant potential for increased utilisation of reclaimed wastewater [15],[20],[13].
The wastewater reuse potential estimates that are available, however, tend to cover particular regions or countries and are typically presented without any reference to the quantification method applied to derive the appraisal. More often, future projections only refer to potentially irrigable areas without giving discrete figures on volumes [2],[3] or assessing reuse options for a specific application type [1] [22],[3].
The AQUAREC project developed a model-based approach which is able to quantitatively assess the potential for wastewater reuse using effluents from wastewater treatment plants (WWTPs) which can be applied to either a whole country, a region or river basin. The approach was applied to quantify the European water reuse potential and compared well to existing estimates.
The methodology is based on a mass balance approach describing the volumetric flow of reused wastewater Q in a particular spatial or temporal context at an equilibrium point of supply and use of reclaimed wastewater. The amount of WWTP effluent reclaimed is assumed to equal the amount reused while covering a particular fraction of total demand. If wastewater is reused in different sectors like agriculture, domestic uses or industry, these segments can be regarded separately. The basic model equation for the assumption of reuse in different sectors is structured as follows:

$$E \cdot \eta = U \cdot \phi = \sum U_i \cdot \phi_i = Q \quad \Rightarrow Q = \frac{1}{2} \cdot \left(E \cdot \eta + \sum U_i \cdot \phi_i\right) \quad \text{(Equation 1)}$$

Where;
E : Effluent of WWTPs [Mm^3/a]
U : Total water demand [Mm^3/a]
U_i : Use of water in a specific sector i [Mm^3/a]
Q : Volumetric flow of reused wastewater [Mm^3/a]
η : Fraction of wastewater reclaimed, hereafter reclamation-factor [-]
ϕ : Fraction of total demand covered by reclaimed water, hereafter reuse-factor [-]
ϕ_i : Fraction of demand covered by reclaimed water in a sector i

To calculate a change in the total wastewater reuse volume during a time interval, the current wastewater treatment capacity, the fraction reclaimed and reused and the sectoral water demand have to be known. For the purposes of demonstration, these data were extracted from the EUROSTAT database, the FAO AQUASTAT database and various national statistics. Information on wastewater reclamation and reuse is based on a literature survey and on the results of a mapping study [4].
For the computation of a first estimate of the water reuse potential in European countries Equation 1 is used with the corresponding data for time-discrete points (t(0)=2000; t(1)=2025) and with parameters calculated according to the derived correlations [19]. Figure 4 depicts the calculated wastewater reuse potential for most European countries.

Figure 4: Model output for wastewater reuse potential of European countries; projection horizon 2025

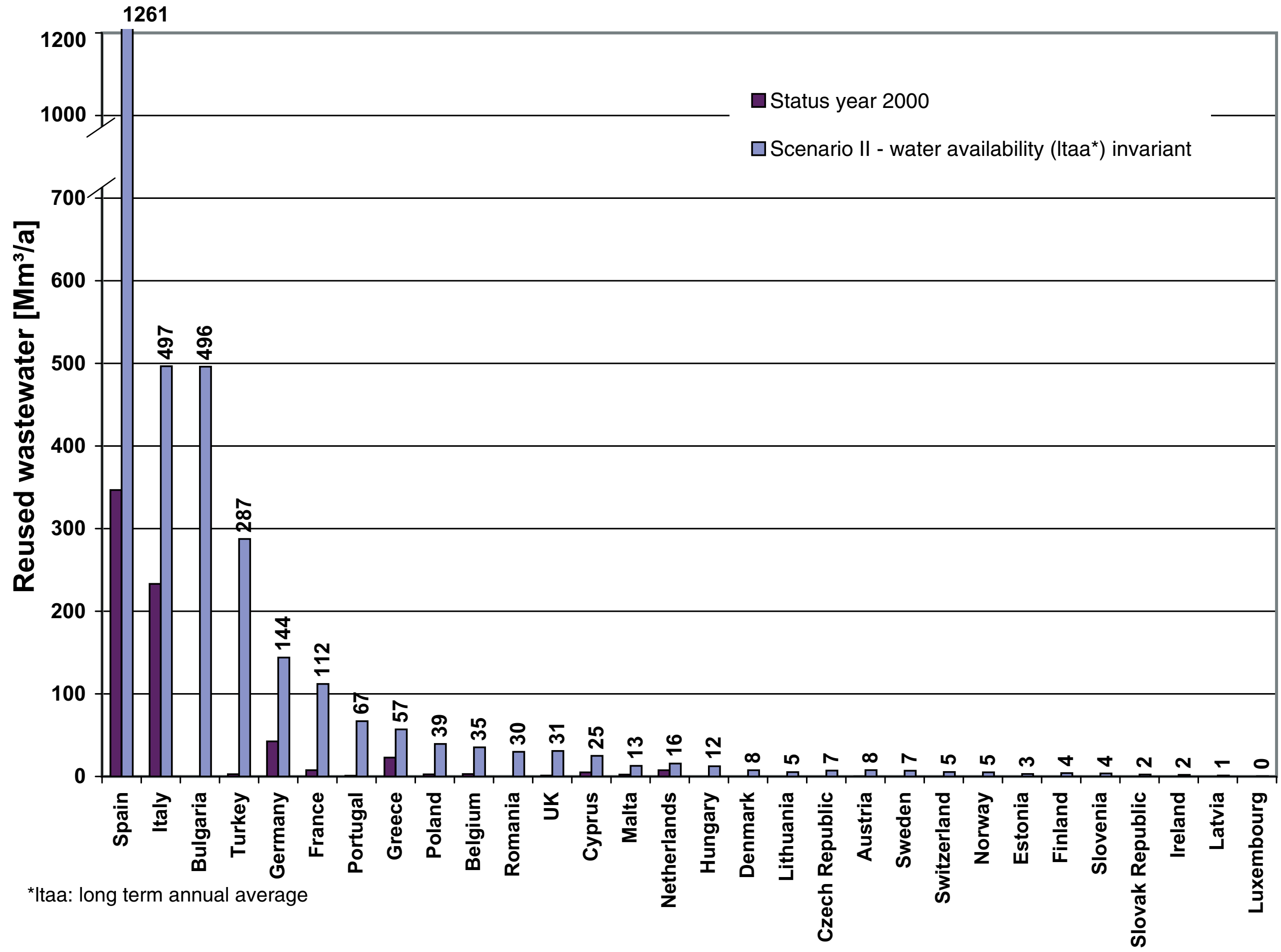


Figure 4 illustrates that Spain shows by far the highest reuse potential, the calculations suggesting a value of over 1,200 Mm^3/a. Italy and Bulgaria both exhibit estimated reuse potentials of appr. 500 Mm^3/a. Wastewater reuse appraisals for Turkey amount to 287 Mm^3/a, whereas Germany and France are supposed to reuse 144 and 112 Mm^3/a respectively. Portugal and Greece account for reuse potentials of less than 100 Mm^3/a (67 and

57 Mm³/a). Overall, the estimates suggest a wastewater reuse potential of 3,222 Mm³/a. As expected, for most Nordic or small countries, the estimated reuse potential is low in both absolute volumes reused (≤ 7 Mm³/a) and relative to the country's total water demand. On a European level, the reused wastewater volume would save 0.9% of the total water abstraction in the year 2025. While for most countries the substitution potential is less than 0.5%, Malta, Cyprus and Spain could replace 26%, 7.6%, and 3% of their future water abstractions respectively.
This model is obviously only a first step towards a mathematical representation of drivers and barriers for wastewater reuse, basically neglecting or just summarizing some of them in a black-box type of fashion. All the data presented above relate to a country-level and, as noted above, do not reflect the fact that water scarcity often appears at a regional scale. Even though the presented model outcome disregards such natural variability within a country and socio-economic objections to the implementation of wastewater reuse, it provides a first quantitative estimate of reuse potential.

5. RECLAMATION AND REUSE OF MUNICIPAL WASTEWATER – IDENTIFIED CHALLENGES

If the water reuse potential of Europe is to be tapped to its fullest potential, a variety of deployment or implementation issues will have to be tackled. A preliminary evaluation of the large number of European water reuse projects that have been screened by the AQUAREC project [4] indicate that several common issues exist. Some of these issues are briefly described in the following paragraphs.

5.1 Re-orientation of the water governance towards integrated water management

Although the practice of Integrated Water Resources Management (IWRM) is still in its infancy in several Member States, the implementation of the Water Framework Directive is progressing and will provide a basis for further steps in IWRM at catchment scale [7]. The WFD is a soft legal document, i.e. it sets forth the principles to achieve sustainable water governance, but not the means. In developing appropriate mechanisms to achieve IWRM both disciplinary expertise and interdisciplinary understanding needs to be nurtured. Too often water reuse options are excluded from IWRM scenarios, regardless of whether such opportunities are financially or technologically realistic. The challenge here is to better inform all the important stakeholders about viable options which bridge the tight but somewhat artificial isolation (in management terms) of water supply and wastewater treatment systems. This lack of an integrated perspective often produces a considerable time lag between feasibility studies related to reuse options and their realisation in practice, especially (but not only) for those regions where water and sanitation services are run by different entities.

5.2 Need to strengthen cooperation among stakeholders

There has been extensive debate on how water reuse projects should be managed, in particular who should take the initiative in project planning, and how responsibilities/liabilities should be divided. This issue has been investigated by the AQUAREC project through an international survey that covered four types of ownership structures:

1) where water and sewerage management is the responsibility of a single corporate entity,
2) where either water or the wastewater company managed the water reclamation project, or
3) where ad hoc project-related structures were set up.

The survey indicates that the ownership structures are influenced by local circumstances, political will, legislation, institutional structure and regulation [4]. An analysis of successful case studies suggests that the details of ownership is not a significant issue, but does influence access to financing and cost allocation. A case in point is the Tilburg water reuse project in the Netherlands where the water supply and the wastewater services joined together to set up an ad hoc water reuse company under an administrative and legal framework that has tax advantages while at the same time having the ability to allocate funds at the lowest interest rate.
Another preliminary conclusion of the survey is that communication and collaboration between the water and the wastewater sector is always desirable. The Tilburg project for instance benefited from the technical capacities of the two companies, namely: the wastewater treatment company for the management of the water reclamation scheme and the drinking water company for the distribution system and for the customer relations. This is a clear case where the whole is more than the sum of the parts.

5.3 Establishment of guidelines or criteria for wastewater reclamation and reuse

Once the case for water reuse has been successfully made, project development is dependent on the existence of credible and legitimate standards. However, it is not always easy to obtain a permit for the reuse of reclaimed water despite encouragement from the European Union to reuse treated effluent. One of the major problems in Europe is the lack of clear criteria to support decisions on when reuse is desirable and on quality standards for different reuse purposes.

A lack of water reuse criteria forces public administration bodies to adopt conservative assumptions. This, in turn, has led to various types of misunderstanding and misjudgment. An extreme example is an agricultural reuse project where the wastewater treatment plant effluent complied with the strict standards for unrestricted agricultural irrigation, but the public administration released a permit basically referring to the WHO's recommendations on irrigation with raw wastewater. Although this is an extreme case, it illustrates quite well how urgent the need is for the establishment of water reuse guidelines.

Despite the fact that no legally binding guidelines or regulation yet exist at European Union level, several countries and federal regions have published their own standards or regulations (Table 1).

Table 1: Existing country/regional water reuse criteria within the European Union

Country/Region	Type of criteria	Comment
Belgium: Flemish Regional Authority	Aquafin Proposal to the Regional Government (2003)	Based on Australian EPA guidelines
Cyprus	Provisional standards, 1997	Quality criteria for irrigation stricter than WHO standards but less than Californian Title 22 (TC < 50/100 mL in 80% of the cases on a monthly basis and < 100/100 mL always)
France	Art. 24 décret 94/469 3 juin 1994 Circulaire DGS/SD1. D./91/n°51	Both refer to water reuse for agricultural purposes; Essentially follow the WHO standards, with the addition of restrictions for irrigation techniques and set back distances between irrigation sites and residential areas and roadways
Italy Regional authorities: Sicily, Emilia Romagna and Puglia	Decree of Environmental Ministry 185/2003	Quality requirements are defined for the three water reuse categories: agriculture, non-potable urban uses and industrial uses; Possibility for the Regional Authorities to change some parameters or implement stricter regional norms
	Guidelines	The proposed microbiological standards are similar to those of the Title 22 regulation for Puglia and Emilia Romagna and to WHO standards for Sicily
Spain Regional authorities: Andalucia, Balearic Is. and Catalonia	Law 29/1985, BOE n.189, 08/08/85 Royal Decree 2473/1985	In 1985 the Government indicated water reuse as a possibility, but no specific regulation followed. A draft legislation has been issued in 1999, with a set of standard for 14 possible applications of treated water. The proposed microbiological standards range is similar to those of the Title 22 regulations in terms of defined use categories but not as to the standards set for each category.
	Guidelines from the Regional Health Authorities	Developed their own guidelines concerning wastewater recycling, in particular in the field of the irrigation, based on the WHO guidelines of 1989

The AQUAREC project is making an effort to provide a basis for future harmonisation of the various approaches at European level.

5.4 Targeted use of economic instruments

Financing is perhaps the single most significant barrier to wider use of reclaimed wastewater. In the EU, financing of up-front costs is often provided by (local) government grants while revenue programmes were financed by the end users i.e. on a commercial basis. Recent trends are that only a portion of the up-front cost is paid through grants (generally up to 50% of the approved cost) and that the water reuse project has to provide the balance.

In order to better match project costs with acceptable volume unit cost, targeted, time-bound subsidies are important and necessary. The subsidy is generally aimed at allowing the project to operate on a commercial basis while achieving certain public programme objectives. Often water supply benefits alone cannot cover the project costs. One of the reasons is that there still exist distortions of the water supply market. Since the Dublin conference in 1992, the full cost recovery principle is becoming more widespread in the provision of water supply [18]. However, even when the cost recovery principle is applied, externalities such as, for instance, the scarcity of water and the marginal cost of new sustainable sources of water, e.g., where existing sources are at - or beyond - their sustainable limit, are rarely accounted for. Similarly the financial, social and environmental burdens of effluent disposal to the environment are rarely considered in the economic analysis.

Subsidies cover a number of areas, predominantly: planning, technical assistance and research (pilot studies, etc.), construction costs, actions contributing to regional objectives which are not locally cost-effective and pay-for-performance incentives. Subsidies do not cover (or are unlikely to cover) operation and maintenance costs.

Water reclamation projects have also benefited from several types of specific financial incentives. Examples include a recent regulation allowing exemption from the user tax for reclaimed water in Costa Brava, Spain [16]. The EU does not have specific subsidies to encourage water reuse but EU financial institutions can play a key role in favouring water reuse schemes. On a case-by-case basis several schemes have benefited from EU subsidies. The predominant programme objective is typically the creation of a framework that supports innovation and competition.

The current transitional phase of European water management practices represents a unique opportunity to correct market distortions while providing, together with water reclamation, a cheaper alternative to applications not requiring drinking water quality. EU Member States will have to promote cost recovery policies ensuring adequate incentives for users to exploit water resources efficiently by 2010 [11].

Cost-benefit comparisons should be made that compare total cost for integrated water resources management alternatives, rather than considering simply cost before and after the project. Moreover, as the costs and benefits of a project are shared among different groups, there is a need for clearer institutional arrangements for the distribution of the effects of the projects. It is not ethically and economically possible that the water reuse consumers have to bear all the costs for the benefits generated by the project.

5.5 Building trust, credibility and confidence

Whilst the development of suitable technologies which provide opportunities for water recycling has moved on apace over the past decade, their practical application will not depend solely on effective and reliable engineering performance. Successful employment of preferred strategies and technologies will require an understanding of the social environment in which they are to be applied. The drivers which promote involvement in recycling may vary between households and cultures, and will certainly be different for domestic, commercial and industrial users.

In exploring opportunities and developing options for water recycling, policy makers, planners and system designers face a number of problems which do not have simple technological or legislative remedies. For example, the use of treated and recycled wastewater in agricultural, municipal, or domestic applications is quite properly a source of concern for a variety of consumer groups. Irrespective of what conclusions the scientific evidence leads to, the impressions and attitudes which the public hold can speedily and effectively bring a halt to any reuse scheme. Consequently, strategic level decisions on the introduction of water recycling schemes need to be informed by knowledge of public attitudes and behaviour towards the technologies and processes involved.

Public and institutional acceptance of water recycling is a social process with a high emotive content. In many existing urbanized catchments the water cycles actually include indirect, unplanned and uncontrolled reuse of

- sometimes even untreated - wastewater. However, facts and figures might inflame rather than convince. In some cases the involvement of local NGO's and environmental associations has proven to be a critical success factor, as the case of the Empuriabrava project in Spain clearly demonstrated [12].
As a basis for building the trust between stakeholders there is a need to convey simple, clear and reliable information. A best management practice framework is needed to provide a basis for structure and transparency in the management and companies, the community and the consumers alike. Otherwise even basic sustainability principles may be disregarded as examples from the AQUAREC survey in Europe indicate. Take the cost recovery rule imposed by the WFD: in a water scarce area for instance, the regional environmental ministry now imposes a water tariff in accordance to the cost recovery principle while the agricultural ministry supports farmers in the form of subsidy to compensate increased water cost. This approach maintains the situation with water resources management in the region - including the attractiveness of water reuse - practically unchanged. A sub-optimally managed project may result in adverse health, environmental or financial outcomes that may quickly reduce enthusiasm for water reclamation, hindering its development in the region. In case of failure one might not get a second chance! For example in the Netherlands dual reticulation systems are banned altogether because of one negative experience of cross-connections with the drinking water supply. This need for a best management practice framework is well acknowledged within the European Union according to a recent survey undertaken by the EUREAU Water Reuse Group. The AQUAREC project seeks to firmly anchor a best management practice framework to reality [9]. Plenty of information on water reclamation and reuse practices is now available, but is often fragmented and open to misinterpretation.
Of particular importance are the management practices to reduce and communicate the risk of human exposure. Management practices relating to quality control and failure management vary considerably from region to region and even from project to project. A common trend in process operation and risk management amongst the surveyed projects was the adoption of extensive quality control practices and in particular the widespread use of instrumentation, control and automation. On the other hand, despite the fact that procedures such as Hazard Analysis and Critical Control Points (HACCP) are increasingly used to direct efforts in process control and monitoring to guarantee hygienically safe reclaimed water [21][14], very few surveyed projects have used them. Another interesting point is that very few projects seem concerned about emerging pollutants such as trace organics.

6. CONCLUSIONS

In Europe, the last decade has witnessed slow but growing acceptance of water reuse practices, and there are now more than 200 municipal water reuse projects in existence. The scenario analysis presented in this paper reveals however that only a limited fraction of the water reuse potential is actually exploited. It becomes also obvious from the analysis that Spain is by far the country with biggest potential in water reuse applications. The current environmental policy supports the further development through the A.G.U.A. master plan which foresees to increase the total volume of reclaimed wastewater to 1,200 Mm^3/year until the year 2018. This has also been emphasised by the Federal Environmental Minister of Spain Cristina Narbona, attending an AQUAREC Workshop held in September 2005 in Valencia [24].
Despite the great water reuse perspective the AQUAREC findings leave open the question of how to realise this massive potential from a regulatory point of view and how to shape an appropriate framework of incentives and implementation support measures on a harmonised European level. However, we would note that implemented schemes are often characterised by a coalition of institutional and private stakeholders who emphasise benefits over barriers and solutions over problems. We would also comment that if utilisation of reclaimed wastewater is not to contradict the "whenever appropriate" guidance of the Urban Wastewater Treatment Directive, a definition of appropriateness is needed.
These aspects will be of paramount importance for the realisation of wastewater reuse potential in applications that could absorb huge volumes of water but are at the same time sensitive to health objections. In other cases, switching from conventional water resources to reclaimed wastewater is primarily hindered by cost arguments. This would demand the establishment of water prices that reflect the full-cost recovery principle on the one hand, and the monetarisation of the potential environmental benefits of wastewater reuse, on the other.
Finally, we would emphasise the importance of best management practice frameworks and increasing public awareness of the water cycle as two key aspects of water reuse project promotion.

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