The sustainable industrial water cycle - a review of the economics and approach

M. Andrews, P. Berardo and D. Foster

ABSTRACT

Studies suggest that only 31% of Europe is thought to have a water supply that is either plentiful or sufficient to meet demands until 2015, and water stress indexes show a number of countries with traditionally wet climates such as Belgium and Bulgaria, under significant water stress. Therefore, there is both a desire and a need to reduce the consumption of water over much of Europe. For industry, often economics determine the viability of water recycling, which does not necessarily fall under the standards currently being set for the major water reuse schemes. While the additional annual recycling capacity in Western Europe is set to increase by 10%, much of the Global market is focussed on major reuse facilities based on the municipal sector. Within the industrial sector there are opportunities to achieve major changes in the water cycle which can have a significant impact on total water consumption. The impact on regional water consumption by industries efforts can be massive, as industry accounts for 50% of the water consumption in Western Europe. When benchmarked data across industry sectors is analysed, we find that industries ranging from paper mills, dairy, beverage, ceramic and electronics have opportunities to reduce their water consumption by around 50%. But what are the mechanisms that drive actions in the industry water cycle, and how great can the impact be? This paper explores industrial water costs across Europe, and the drivers leading to reduced water consumption. As operators of water and wastewater facilities for many industrial customers across Europe, Ondeo Industrial Solutions examine the raw water costs and the viability of recycle schemes. Economics is not the only driver towards the reduction in water consumption on industrial sites. There are political and legislative drivers that can often override the economics such as the European PPC (Pollution Prevention and Control) directive that can often lead to a programme of water consumption reductions.

Key words | industrial water cycle, reducing water costs, sustainable water, water applications, water legislative and incentives, water reuse

EUROPEAN SUSTAINABLE WATER DRIVERS

There is little doubt that climate change is coming and that it will impact on the lives of everyone in Europe one way or another. From this, there does appear to be a focused approach to sustainable water in Europe. As a major source of effluent, much of the reuse activity surrounds municipal effluents i.e. “treated water shall be reused whenever appropriate” (Council of European Union 1991) as quoted in the Urban Wastewater Treatment Directive. The regulatory approach in Europe seems to be structured around existing European legislation such as the EC bathing water directive implemented into Statutory instruments in member states (Matthews et al. 2004). Europe is reported to have a relatively
slow growth (Alcamo et al. 2000) in the total water withdrawals as a whole. This is because efficiency improvements have been driven by consumer awareness, economic incentives and regulation. In addition, large corporations that are profligate with the environment may not achieve the commercial success of companies who strive to lead on environmental issues. Reductions in water use have also been caused by a decline in heavy or high water demand industries, and the conversion of industries from high demanding water to low demanding water technologies. By examining the position in Europe, we find that the general country wide approach belies the local limitations of supply that can cause shortages and restrictions. Europe is bracing itself for the impact of climate change with a number of studies and strategies in place and being applied to accommodate the forthcoming challenges. For the industrial water user the impacts of water availability, cost of water, political pressure on water reuse and restrictions must all be considered as issues that will be part of daily life.

The slow growth in water consumption in Europe is partly driven by regulation and economics. It appears that the intention is for these strategies to carry on being applied and this will, in turn, continue to drive down the relative consumption. In looking at the impact of climate change and how Europe is planning to manage the changes that are ahead, there is a clear drive to put in place mechanisms to enable control of the water resource. These mechanisms are aimed at managing the predicted changes in precipitation, with Northern Europe seeing an increase of 1–2% per decade in precipitation, which will be delivered in the winter months with a summer decline. Southern Europe is expected to see a 5% decrease in summer precipitation (Tank & Albert 2002).

Across Europe, industry should be aware that the restrictions and economic vehicles currently in use will intensify. This trend will clearly continue with over two thirds of EU member states noting that they have either currently planned, or recognise the need for plans, for increase efficiency in use, economic and/or regulatory restrictive instruments (Krinner et al. 1999). Of the remaining third, France and Switzerland have already implemented the required mechanisms, Iceland is in the fortunate position of not needing any, and the others failed to respond to the survey (see Table 1 for details).

The only conclusion anyone can draw is that those mechanisms that require industry to put more emphasis on water conservation and reuse, will increase in strength and intensity. As cited in E-Water 2007 “presently, there are regions in several EU member states where water abstraction is impairing the sustainability of water resources and the environment, and the situation tends to aggravate in the future”

While reuse schemes are developing in Europe, the number quoted range from 200 (Bixio et al. 2006) projects to 700 (De Monte 2007). In Europe there is no clear understanding or consistent approach to water use in industry, or as metrics since some include cooling water and other do not. Even so, the range varies from 10% (excluding cooling) (Krinner et al. 1999) to 59% (Clarke & King 2004) of all freshwater withdrawn, so getting a consistent picture across Europe and the World is not straightforward.

The industrial water reuse metrics are usually only cited when municipal effluent is returned directly to specific companies in large quantities. In fact, there are thousands of internal recycle and reuse schemes operating across Europe driven by the political and economic drivers already in place.

A current example of industry taking action against climate change was seen in March 2008, when the top 21 food and drink companies in the UK demonstrated their commitment to the environment by uniting together and pledging to curb their water use by 20% before 2020 (Environment and Food and Drink Federation 2008).

In addition, sustainable development policy, particularly in large corporations is a key driver. Companies may wish to meet non-compulsory government environmental targets and objectives, with one of the key motivators in such an approach is the impact it has on shareholders, employees, and the way it may influence, even not directly, business development.

**LEGISLATIVE INCENTIVE**

Since the early 1970s, when water protection directors were first introduced by the EU, imposed legislation has become more stringent in order to protect and improve water quality and the surrounding environment across Europe. Many influence industries activities and lead to imposed operational upgrades and changes. Below are some examples of the introduced legislation that has effected industries water operations.
When the Urban Waste Water Treatment Directive (Council of European Union 1991) was introduced in 1991, which includes regulations for the treatment and disposal of industrial waste water, industrial customer had to insure that certain discharges that were controlled by the directive met the treatments levels. Generally, most already met these levels, but those that did not, required process improvements.

In 2000, the revolutionary Water Framework Directive (Council of European Union 2000) (WFD) was introduced, the first policy to protect all of Europe’s waters including surface and ground waters, and states that all waters must achieve ‘good water status’ by 2015. The initial phase, through the River Basin Management plans, was to identify the current water quality and develop plans to improve areas that are below standard. This means industry will have to comply with chemical, biological, thermal and physical standards and this will, in effect, impact on abstraction licenses, trade discharge consents, and trade effluent licenses. In the long term, this is likely to include the reduction of pollutants entering the water environment such as nitrates and phosphates and the reduction in water abstraction, particularly in areas with high water stress.

Since the introduction of the WFD, a daughter directive relating to the prevention and control of groundwater pollutions (Council of European Union 2006) was established in 2006, which provides clear criteria for groundwater makeup, and prevents and limits the indirect discharge of pollutants into groundwater, which can impact industrial user’s activities.

<table>
<thead>
<tr>
<th>Country</th>
<th>Increase efficiency</th>
<th>Economic instruments</th>
<th>Restricted use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Implemented</td>
<td>Planned</td>
<td>Required</td>
</tr>
<tr>
<td>Austria</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Belgium</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Cyprus</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Czeck. Rep.</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Denmark</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Finland</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>France</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Germany</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Hungary</td>
<td>No data</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Iceland</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Ireland</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Italy</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>Lithuania</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>Netherlands</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>Portugal</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>Romania</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Slovakia</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Slovenia</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Spain</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Sweden</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Switzerland</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>England &amp; Wales</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Scotland</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>
EU directives, such as those mentioned above, can have a substantial impact on industrial activities in relation to their water systems. They can often lead to industrial customers having to reassess their current operations to ensure that set criteria from newly imposed directives are met, which can often lead to substantial remediation work to certify compulsory regulations or searching for alternative solutions like re-use water schemes.

We can also see that large industrial users are being driven down the route of water reduction, easy targets under the Integrated Pollution and Prevention and Control Directive (Council of European Union 1996, 1999a, 2008). As implemented across Europe, for example in England and Wales (UK Parliament 1999) and Scotland (Scottish Parliament 2000), this legislation can, and often does, require a facility to have a programme of water consumption reductions. For the England and Wales, the mandatory mechanism imposed by the local regulator, the Environment Agency, is to seek a ‘credible water balance’ to be produce within three years of being awarded a licence, and water consumption reductions under improvement notices for the licence, some of which can lead to major capital investment. In practice, a failure to meet with the required reductions or recycling can result in improvement notices being served, forcing the industrialist to install a recycling plant that otherwise may not have budgeted for or required if alternative water recycling methods had been implemented.

Indirect legislation, like the landfill directive (Council of European Union 1999b), can also impact on industrial water processes and provoke the development of new innovations. For example, developing a sludge treatment that improves the quality of the waste, through reducing Total Organic Carbon (TOC), so it could be re-classify as non-hazardous waste (Ondeo Industrial Solutions 2007) can generate substantial cost savings and environmental benefits.

Funding through various local governments in Europe is also available to give companies an incentive to implement energy or water saving schemes particularly during the current financial crisis. For example, in the Netherlands, the government operates a Green Fund Scheme (SenterNovem 2008), where they offer tax benefits and lower interest rate on a loan to encourage companies to invest in projects that have a positive effect on the environment. A similar scheme is also in place in Germany, through the KfW Environmental Protection Programme (KfW Forderbank 2008). In Denmark the government have introduced an Action Plan (Danish Ministry of the Environment 2007) that invests in eco-efficient technology, and in Austria, through the government owned Austrian Business Agency, they also offer subsidies for projects that work towards protecting the environment.

The European Parliament also provides funding for projects across Europe through programmes such as Life + (European Commission 2007), which supports environmental and nature conservation projects, contributing around €1.35 billion to the protection of the environment. This includes supporting projects in relation to EU water policy, many of which are related to the industrial sector. For example, funding was provided to help aid a new dairy production plant in Holland with the objective of being self-sufficient in water supply and reducing waste water by 50%. Even though the key objectives were not met, which were mainly due to the complexity of the water management and water demand of the new plant, water intake was reduced by 66%, waste water was reduced by 32%, and groundwater intake was reduce to 0. Substantial energy cost savings were also generated.

The Eco-Innovation programme (European Commission 2007) is another centrally funded scheme, which aims to bring eco-friendly products and services that prevent or substantially reduce environmental risk to market. This newly established programme is committed to investing almost €200 m between 2008 and 2013.

**WATER COSTS AND MANAGEMENT IN EUROPE**

There may be a desire for water costs to be implemented in a manner to avoid conflict on competition, but when charging mechanisms implemented across Europe are examined it is clear that the approach varies from country to country. Equally, as water stress from each country and each region (Henrichs & Alcamo 2001; Melin & Wintgens 2006; European Environment Agency 2007) vary vastly, it is inevitable that charges will also differ. There are also other mechanisms which may limit the water availability to the industrial user.

Firstly, looking at the raw water resource for large users, abstraction licences, implemented by local authorities, are issued as part of the ‘command and control’ mechanism.
Such abstraction control is charged in a variety of ways and reasons. In France, for example, the abstraction charge is used to generate government revenue and as an incentive to reduce consumption. In Germany, dependant on the region, the abstraction charges are used to recover the costs of managing the scheme, generate revenues, as a reduction incentive, and/or as a replacement for local taxation. In the Netherlands, the charges are for everything but cost recovery, whereas in England and Wales the abstraction charge only covers the cost of managing the scheme. These assertions are reflected in the abstraction charge rates, with England and Wales having the lowest cost and Germany the highest (Krinner et al. 1999).

When it comes to evaluating the costs of water in Europe the picture is more complex than the direct abstract charges. For example, some parts of Europe provide water supply only, where as in other regions there is a combination of water supply and effluent treatment encompassed in a single charge. For treated water supply, the costs vary significantly, not only between countries, but also within a country, and in some cases there is a complex blend of water supply and effluent charges. These can be split, as in the case of Spain, where they have supply only, effluent only, or combined. In the case of the UK, the split uses a sophisticated charging mechanism of standing charges based on the size of the supply line and volume consumed as well as an effluent carriage charge, and the cost of effluent treatment is based on the load as calculated using the Mogden Formula.

In addition to the actual mechanism complexity, the rising cost of the water itself needs to be considered, with water prices across the world having increased by an average of 8% in 2006/07 (NUS Consulting Group 2008). Figure 1 demonstrates the difference in the average water cost per m³ in Europe as well as Africa, America and Australia.

For Spain, 2009 figures showed regional variations with water costs along ranging from €0.61/m³ to €2.65/m³ with the average of €1.81/m³ (AEAS 2009). Water costs rose 4% between 2006/2007 and 15.5% between 2006 and 2009, mainly because of a planned water provisions programme in southern Spain.

Many Europe countries have seen a substantial increase in their water supply costs over the past 5 years with Belgium showing an increase of 58.6% and Italy 28%, with Demarks prices having increased 9.3% in just one year (NUS Consulting Group 2008). Out of the 11 European countries surveyed, only Finland showed a fall in prices between 2006/07.

For the UK, detailed data is available and enables a full review of the range of costs and installed capacity. It is also possible to calculate effluent charges, although these can be subject to specific tariff negotiations between the supplier and


**Figure 1** Average cost of water per m³ for commercial users across 14 countries in Europe, Africa, America and Australia.
the user, with the large users usually getting the best price. For 2007–08, the cost range for water supply is €0.54 to €1.44, having increased over 38.7% in 5 years, and effluent charges range from €0.55 to €2.58. The combined charges range from €1.09 to €3.68 (OPWAT 2007). These cost figures have been assembled using a range of possible customer connections and a selected effluent load, based on 95% effluent flow. The range encompasses small, medium and large industrial users for all combined service providers (water and sewerage treatment) for England, Wales and Scotland.

The figures presented above for England, Wales and Scotland belie the complexity of water charging mechanisms that should be explored when seeking to reduce costs. For example, in some cases a Maximum Daily Demand (MDD) is used to select the baseline charge per cubic meter of water.

REUSE APPLICATIONS

Water reuse is a hot topic in the water sector, with an impressive array of projects and references (Envirowise 2001a, b, 2002a, 2007). Research is accelerating, driven by the overexploitation of water resources in many areas, with Israel, Russia and Romania leading the better known players such as Australia and the USA when it comes to research citations (Scott et al. 2000). Even though additional annual recycling capacity in Western Europe is set to increase by 10%, much of the focus is on major reuse projects in the municipal sector with predicted growth in Western Europe to be 3,895 million m³ d⁻¹ (Kolodziejski & Gasson 2005). Impressive projects such as the Sulaiabiya Wastewater Reclamation Plant in Kuwait (Water Technology 2006) recover some 375,000 m³ d⁻¹ and their wastewater is treated to a quality suitable for aquifer recharge or direct reuse in agriculture. Legislation and guidelines around the world are also quite focused on municipal reuse projects, and define quality based on health protection (Cranfield University 2001; Environment Agency NZ 1997) with water reused in agriculture or occasionally (in high stressed countries) for direct use such as the Windhoek project in Namidia (Lahnsteiner & Lempert 2007).

While highly stressed countries in the world have standards that allow for specific applications in general, there are gaps in Europe with water industry professionals calling for coherent water reuse policy and standards (Rowlands 2008; Salgol & Huertas 2006), however, this seems to be improving, as seen through previously mentioned examples given by European Commission.

Looking at national statistics does not seem to reflect the localised reuse and recycling that is occurring within individual industries and companies. It is the drivers, indicated above, that have allowed a reduction in water use throughout the industrial sector despite its growth (even when allowing for the demise in some of the heavy water consuming industries in Europe). Reuse is not just a municipal to industrial phenomenon. Reuse within a plant, factory, or production line can be the most cost effective mechanisms, often generated through simple processes, with benchmarked data showing that industries have the opportunity to reduce water consumption by around 50% (Envirowise 2002a, b, 2002a, 2007).

The industrial water demand has been approximated for different sectors a number of times. Typical figures are given in Table 2 below (Judd & Jefferson 2003).

Reuse applications are as varied as industry sectors. Typically, the first opportunity for recycle or reuse is to take a relatively uncontaminated stream and return it to the required standard for direct reuse. This could involve polishing condensate for boiler use, or filtering out waste particulate for direct reuse. Such schemes are generally straightforward to discover and implement. It is also simple to identify the economic viability of a project by calculating the return on investment by determining the cost of replacing the water. This is why condensate recovery is a typical target as the high quality of boiler feed water is an expensive commodity, due to costly pre-treatment, compared with the raw water costs illustrated earlier. Appropriate recycling of condensate can also recover energy, making such projects highly economic.

The next most common application appears to be recycling water through cooling applications. The quality of cooling tower water is often not as stringent as other industrial process applications, as long as appropriate risk assessments have been carried out (e.g. Legionella risk assessment), lending themselves for reuse or second use of effluents for indirect cooling.

Many industries require significant amounts of water for cleaning and washing purposes. Again, relatively relaxed
water quality requirements often apply for these applications, allowing simple technologies to be used for recycling or reuse. Another example is charging fire water systems with effluent, again providing the appropriate risk assessments have been carried out.

A list of some typical reuse applications is given in Table 3 below.

### Table 3 | Typical reuse applications and technologies

<table>
<thead>
<tr>
<th>Industry</th>
<th>Technology</th>
<th>Reuse Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Board Manufacture</td>
<td>Clarification and Filtration</td>
<td>Production</td>
</tr>
<tr>
<td>Coating</td>
<td>Clarification Ozonation and filtration</td>
<td>Production</td>
</tr>
<tr>
<td>Power</td>
<td>MF + R.O.</td>
<td>Cooling</td>
</tr>
<tr>
<td>Power</td>
<td>Clarification MF and Filtration</td>
<td>Cooling</td>
</tr>
<tr>
<td>Paper</td>
<td>Clarification, filtration and UF</td>
<td>Production</td>
</tr>
<tr>
<td>Chemicals</td>
<td>pH correction</td>
<td>Cooling</td>
</tr>
<tr>
<td>Electronics</td>
<td>UF EDI, Demin</td>
<td>Production</td>
</tr>
<tr>
<td>Refinery</td>
<td>Clarification, Filtration</td>
<td>Firewater</td>
</tr>
<tr>
<td>Refinery</td>
<td>AS, DAF, UF + R.O.</td>
<td>Cooling</td>
</tr>
<tr>
<td>Automotive</td>
<td>Clarification, UF</td>
<td>Paint line</td>
</tr>
<tr>
<td>Textile</td>
<td>Clarification + R.O.</td>
<td>Production</td>
</tr>
<tr>
<td>Food</td>
<td>MBR</td>
<td>Boiler, wash and cooling</td>
</tr>
</tbody>
</table>


### REDUCING COSTS WITHOUT CAPITAL EXPENDITURE (CAPEX)

There are many opportunities to reduce water costs without spending large amounts of capital. We must therefore disagree with a competitor statement *“in the industrial sector, reducing demand can be[] complex…,”* large scale water use
reductions are difficult to achieve. Other strategies must be employed” (Veolia Water 2005). Benchmarking for a whole range of industries has been carried out in the UK. This exercise which is fully supported by industry representative organisations, including Envirowise who estimates that commercial sites can achieve savings of around 30% if they have not previously examined their water consumption by implementing simple measures at little or no cost.

In all cases, the first step that companies should adopt is to determine the site’s water balance, and under IPPC legislation, water balances are a mandatory requirement to be complete within a fixed period of being granted a licence. This can highlight unnecessary operational costs which have been accepted as normal. Some examples that we have found which have not required major capital investment include identifying system leakage accounting for around 50% of total water consumption, direct water reuse with water cost savings (including effluent) of 10%, and advised process changes (to prevent water loss) resulting in water savings of 50%.

If any such savings are to be recognised, the following is necessary:

- Identification of all water sources
- Understand in detail the charging mechanisms for water and effluent
- Develop a water balance
- Review and audit water use
- Understand water treatment on site (if any)
- Understand effluent treatment on site (if any)
- Develop and set targets
- Implement measures
- Monitor and control (Envirowise 2002b)

REDUcing COSTS WITH CAPEX

Only when activities without capex have been fully investigated should an industrial water user consider a capital investment approach. The main economic drivers of capital investment schemes include high total water costs (and all arisings), corporate environmental motivations, or regulatory restrictions on water use.

Experience indicates that even if there are suitable economic drivers, industry tend only to invest capital in core business processes that generate the highest Internal Rates of Return (IRR), so often the water reduction schemes are overlooked. This is one reason why some EU member states offer incentive schemes, some of which have been mentioned previously, to improve the IRR on industrial plants (HM Revenue and Customs, UK 2003). Nonetheless, there is good evidence to support cost effective capital schemes as illustrated in Table 4 below:

The applications employed in the schemes given above all involve advanced technologies and demonstrates that such technologies have their vaulted position in the reuse market place. However, more basic technologies are implemented on many sites, such as simple sand filtration (Envirowise 2002a) or other conventional (i.e. not advanced membrane technology) techniques including clarification and sedimentation (Envirowise 2001b).

CASE STUDIES

Ondeo IS undertake water audits to enable customers to develop a ‘credible water balance’ for their site. This non capex approach gives industrial water user a full understanding of the costs that apply to their entire water cycle. Understanding the charging mechanism for one customer was crucial in identifying the potential savings that could be made without significant capital expenditure.

For example, after undertaking a site survey, the major areas of water use were established, as seen in Figure 2, thus

<table>
<thead>
<tr>
<th>Industry</th>
<th>Investment £</th>
<th>Annual Saving £</th>
<th>ROI (%)</th>
<th>Payback (years-months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>929 k</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>2.06 million</td>
<td>392 k</td>
<td>19</td>
<td>5–3</td>
</tr>
<tr>
<td>Power</td>
<td>457 k</td>
<td>146 k</td>
<td>32</td>
<td>3–2</td>
</tr>
<tr>
<td>Paper</td>
<td>–</td>
<td>138 k</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Fibre Board</td>
<td>387 k</td>
<td>234 k</td>
<td>60</td>
<td>1–8</td>
</tr>
<tr>
<td>Textile</td>
<td>274 k</td>
<td>142 k</td>
<td>52</td>
<td>2–0</td>
</tr>
<tr>
<td>Food</td>
<td>–</td>
<td>62 k</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Automotive</td>
<td>179 k</td>
<td>265 k</td>
<td>148</td>
<td>0–8</td>
</tr>
</tbody>
</table>

Adapted from Jefferson & Alvarez-Vazquez 2003
identifying the key areas where the most significant impact could be made.

From this, a more detailed picture was developed focusing on the area with the greatest water use, which in this case was the demineralised water system, can be seen in Figure 3. Using the detailed water audit, an in depth examination of where costs accrued and the reasons for those was undertaken. For example, in the case of a large European industrial water user, raw water consumption was found to be exceptionally erratic, leading to a concerted data search to determine the specific causes of the peak flow events. These turned out to be blow down activities, and could be controlled by operational staff leading to a significant potential reduction in Maximum Daily Demand (MDD), which constituted the larger portion of water costs in this instance.

From a single site survey and without the need for capital investment, significant potential savings were identified. Water costs could be reduced by 17% with the appropriate management to prevent coincidental increases in MDD and its incurring costs, and an additional 8% reduction in water
costs was available by the management of effluent reuse. The most substantial finding came from the management of the condensate blow-down, which could potential generate water savings of over 40%.

Water audits can also identify projects that require capital investment, which can pay for themselves over a set period of time through benefits such as operational cost savings and improved environmental performance. An example of this is a project Ondeo IS identified on a large petrochemical site after a site audit. This involved recycling the effluent produced from two ethanol plants back into the cooling water system. The benefits from this included reducing water usage by 100 m$^3$/hr, which therefore reduces effluent being discharged into the environment by 100 m$^3$/hr, and, due to the high phosphate levels in the recycled water, a corrosion reduction from 7 mpy (mms per year) to 1 mpy. These substantial benefits generated operational savings of over €437.50 k per year, providing economic and environmental advantages.

Another example of a recycling project implemented by Ondeo IS can be seen at an electronic manufacturing plant. Through operational improvements such as optimising chemical usage and minimising waste production, Ondeo IS were able to increasing water recycling by 20% of total usage and generate an overall cost savings of €337.50 k.

**CONCLUSIONS**

Overall, much of the water industry is focused on major municipal wastewater reuse either to agriculture or to industry. Economic, political restrictions, increasing water costs and legislative drivers are forcing industry to look internally to meet the reduced water consumption predicted in the European Environment Agency projections.

Legislation is also currently focussed on the reuse of municipal effluent to agriculture or for irrigation type activities, and there is not yet a consistent approach within Europe for legislation for industrial applications. However, over recent years, it has been seen that the Council of the European Union has increased the legislation upon the European member states to protect, prevent and improve water quality and the surrounding environment. Previous activities have shown that imposed water related legislation is unlikely to ease and are set to become more stringent, which will, in turn, continue to affect the way industry uses and treats water in the future.

With a wide range of water costs and charging mechanisms implemented across Europe, it is difficult to evaluate the effect this has on the industrial water cycle overall. However, there is supporting evidence that this affects the viability of implementing a reuse project, especially for larger users. It is also important to note that any water reductions do not just remove the purchase cost of the raw water, they are also associated with subsequent falls in the cost of the pre-treatment and effluent treatment either on site or by a third party.

Irrespective of the drivers, there is a huge potential for many industries to significantly reduce their costs and their consumption in relation to their water cycle. The first step is to measure and monitor water use and understand their water cycle within the business. By doing this, it is not always necessary to make large capital investments to achieve savings of up to 20% or more. Often large investments have excellent rates of return with payback periods of 5 years or under. In addition, many government-funded schemes available across Europe are contributing to industrial investment in sustainable water projects that otherwise many not have been implemented.

**REFERENCES**


Downloaded from https://iwaponline.com/ws/article-pdf/11/1/67/416408/67.pdf by guest


Environment Agency NZ 1997 ACT Environment and Health Waste-water Reuse Guidelines. NZ.


Envirowise and Food and Drink Federation 2008 Federation House Commitment: Helping the Food and Drink Industry Improve Water Efficiency. UK.


Henrichs, T. & Alcamo, J. 2001 Eurowasser: Europe’s water stress today and in the future, Section 5-1.


Melin, T. & Wintgens, T. 2006 Integrated Concepts for Reuse of Upgraded Wastewater, Aquarec, Report EVK1-CT-2002-00130. RWTH Aachen University Department of Chemical Engineering RWTH-IVT.


Rowlands, C. 2008 Water reuse is a sustainable water supply for UK industry. CIWEM.


Tank, K. & Albert 2002 Changing temperature and precipitation extremes in Europe’s climate change.

