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WaterWatt

Improvement of energy efficiency in industrial water circuits by online self-assessment, benchmarking and economic decision support

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1. Executive Publishable Summary

The WaterWatt project is an ambitious project aiming to help companies achieve greater energy efficiency in their industrial water circuits (IWC). From the outset, the WaterWatt project identified (i) low awareness of energy saving potential of industrial water circuits and (ii) uncertainty about positive economic effects as two important barriers to more investment to improve the energy efficiency of water circuits.

The principal route to overcome this twin barrier is to develop an interactive online self-assessment tool, the Energy Efficiency Evaluation or E^3 Platform. The two main capabilities of the planned E^3 Platform are carefully designed to remove the investment barriers. On the one hand, the E^3 Platform will allow industrial users to identify and calculate the unrealised energy saving potential of their water circuits. On the other hand, the E^3 Platform will also be able to assist companies in working out the cost-effectiveness of any investment into water circuits, thereby indicating whether an investment in energy efficiency has positive or negative cost implications.

To develop a useful and usable online tool, the WaterWatt project has relied on both technical and sociological research to gain a deep understanding of industrial water circuits in a variety of sectors and countries. This report summarises the findings of the sociological research on the human and organisational challenges i.e. research on the social, institutional and structural challenges faced by companies wanting to increase the energy efficiency of their industrial water circuits. The report identifies a range of organisational and contextual factors based on the case studies conducted at different plants within a range of sectors (see Deliverable report D3.2 and others for details):

- A steelwork in Germany in June 2016
- A steel plant and a non-ferrous metal plant in Norway in October 2016
- A paper & cardboard and a sugar plant in Portugal in November 2016

2. Introduction

The WaterWatt project is an ambitious project aiming to help companies achieve greater energy efficiency in their industrial water circuits (IWC). From the outset, the WaterWatt project identified (i) low awareness of energy saving potential of industrial water circuits and (ii) uncertainty about positive economic effects as two important barriers to more investment to improve the energy efficiency of water circuits. The principal route to overcome this twin barrier is to develop an interactive online self-assessment tool, the Energy Efficiency Evaluation or E^3 Platform. The two main capabilities of the planned E^3 Platform are carefully designed to remove the investment barriers. On the one hand, the E^3 Platform will allow industrial users to identify and calculate the unrealised energy saving potential of their water circuits. On the other hand, the E^3 Platform will also be able to assist companies in working out the cost-effectiveness of any investment into water circuits, thereby indicating whether an investment in energy efficiency has positive or negative cost implications.

To develop a useful and usable online tool, the WaterWatt project has relied on both technical and sociological research to gain a deep understanding of industrial water circuits in a variety of sectors and countries. This report summarises the findings of the sociological research on human and organisational challenges that has been an integral part of the WaterWatt approach.

The report consists of three main parts:

In the first part, organisational factors are introduced and described. We understand organisational indicators or factors[1] to be the points of intersection between human actions and IWCs. Our research to date indicates that while IWCs fulfil critical functions within industrial settings they are usually a marginal concern from an organisational point of view. Whether or not IWCs are automated or not, they tend to run in a fairly autonomous way i.e. with a minimum of human involvement. As such it is not surprising to find that there is only a limited number of intersections between human actions and industrial water circuits. To date, we have identified three broad areas in which organisational factors are located:

1. Maintenance of IWCs
2. Strategic Planning related to the design of IWCs
3. Processes drawing on the water supplied by IWCs

The first part of the report considers each of these areas in depth and shows how the organisational structures and strategies that intersect with water circuits can contribute to or undermine energy efficiency in industrial water circuits. Thus, understanding organisational factors and their impact on energy efficiency in water circuits can help to overcome the first barrier to investment identified by the WaterWatt project.

The second part of the report introduces and discusses what we call 'contextual factors' as it has become clear during the fieldwork that these factors play a crucial role in assessing the cost-effectiveness of energy efficiency investment in a realistic way. Contextual factors can

[1] In completing the research the language of 'factors' became more appropriate than 'indicators'.

thereby play a crucial role in helping to overcome the second barrier to more energy efficiency investment, which is uncertainty about the positive economic effects of such investment.

By contextual factors, we mean factors that impact in some way on the cost-effectiveness of energy efficiency investments. The WaterWatt proposal suggests that a payback time calculator will be part of the E^3 Platform. The proposed calculator uses the most basic formula to calculate payback time. The advantage of this approach is that the same formula can be applied across countries and sectors. This is achieved by only taking investment costs, energy costs and saved energy costs into account. Our interviews as part of the case studies, however, revealed that such a simplified approach does not yield a realistic picture of the economic benefits. There are a wide range of potential additional costs as well as savings that come with energy efficiency investments into IWCs. For example, such an investment might save water in addition to energy, which increases the positive effects of the investment. Likewise, new IWC equipment might make it necessary to provide maintenance staff with additional training which means that training costs will reduce the positive effects of the investment. While these contextual factors are important, it does not appear to be practical to incorporate them directly in the payback time calculator that is part of the E^3 Platform.

<u>The third part of the report</u> does not directly contribute to overcoming the twin barriers to more energy efficiency investment, but focuses instead on the potential for applying gamification not only to the use of the E^3 Platform but to work processes that affect energy use in IWCs. While there are good reasons to embrace gamification when it comes to using the E^3 Platform, our research found that applying the idea to actual work processes has much less promise. This brief section discusses four reasons as to why gamifying work processes as part of the drive to more energy efficiency in IWCs is unlikely to work.

3. Organisational Factors

3.1 Maintenance of IWCs

As mentioned above IWCs run fairly autonomously. Nonetheless, permanent maintenance is required to keep IWCs running efficiently. Maintenance is required to keep all the equipment that constitutes IWCs, including pumps, pipes, valves, sensors, heat exchangers, filters, cooling towers and so on, running in the most energy efficient way. Any malfunction, break-down or leakage impacts on the efficiency with which an IWC is running. While the actual practices of maintenance – the actual repairs and tending to equipment – performed by engineers and workers is crucial, from an organisational point of view the overall characteristics of the maintenance regime is of greater interest. The case studies have revealed several aspects of maintenance regimes that ultimately will shape the maintenance practices in a plant. In particular, we can distinguish different approaches with regard to the type of maintenance regimes, the organisation of maintenance work, the documentation of maintenance work and the expertise of maintenance workers. Each of those aspects can be associated with a spectrum:

- Type of maintenance regime → *Proactive vs Reactive*
- Organisation of maintenance work → *In-house/ stand-by vs Outsourced/ bought-in*

- Documentation of maintenance work → *Undocumented vs Documented*
- Expertise of maintenance staff → *Generalists vs Specialists*
- Number of maintenance staff

Before the different aspects are considered in detail, it has to be noted that our research only affords limited normative conclusions. For example, while our research suggests that proactive maintenance is preferable if the main goal of a company is to achieve energy efficiency in their water circuits, we cannot advise a company to embrace a proactive maintenance regime without highlighting that we do not know whether such an approach is also cost-effective.

3.1.1 Type of maintenance regime

We have encountered the two extreme ends of the maintenance regime spectrum while conducting case studies. For example, the German steel plant and the Portuguese sugar factory both utilised proactive maintenance regimes. This means that they have scheduled maintenance cycles for IWC equipment (this usually excludes pipes). In the Portuguese sugar factory, for example, each pump would receive attention from a maintenance engineer every two years. According to our interviewees the idea is that the proactive approach will prevent breakdowns of pumps which can have serious impacts on the production, but also on the efficiency of the IWC. The other end of the spectrum – a reactive approach to maintenance – was encountered in the steel plant in Norway and, to some extent, in the paper factory in Portugal. In the Norwegian steel plant, for example, maintenance engineers are mainly working on particular projects and only shift their work towards the maintenance of IWC equipment if a breakdown, leakage or malfunction is encountered.

Of course, neither approach works on its own in practice: a proactive approach to maintenance might minimise the chances of a sudden breakdown of equipment, but will not completely eradicate the possibility. Equipment that suddenly breaks down requires by definition a reactive approach. The reactive approach might also entail proactive elements, for example when maintenance workers encounter equipment that indicates – for example through strange noise or fumes – that a breakdown is soon to be expected.

Thus, while particular plants might associate their maintenance regime with a particular approach, neither approach is pursued in a purist manner. From an energy efficiency point of view, the proactive approach is preferable as it will ensure that emerging faults and breakdowns, which can impact on the energy-efficient running of IWCs are either prevented altogether or at least detected in a timely manner. Whether such an approach is, however, cost-effective is unclear. This is an important caveat that needs to be pointed out to recipients of such a recommendation.

3.1.2 Organisation of Maintenance Work

Regarding the way in which maintenance work is organised, we can again identify two extreme ends of a spectrum. On one end of the spectrum are in-house maintenance workers, which means that maintenance workers are part of the core-workforce of a given plant or factory. In the majority of case studies this was the way in which maintenance work was organised.

On the other end of the spectrum is a completely outsourced maintenance workforce that is only called upon when needed by a company. We have not encountered such an extreme case, although the Portuguese sugar factory relied to a certain degree on sub-contractors who provided maintenance workers. Less familiarity might lead to the non-recognition of emerging problems with equipment but also to slower repair times. Again, this does not mean that in-house maintenance staff is overall more cost-effective than subcontracted staff. While the management of the Portuguese sugar plant appears to be convinced that using agency maintenance workers is cost-effective, the managers in the other visited plants appear to be equally convinced that this is not the case.

3.1.3 Documentation of Maintenance Work

We found significant differences in the way companies document the maintenance work directed towards IWCs. On one extreme end of the spectrum are those who document everything, even the smallest intervention. The German steel plant is an example of the former approach. Specialist software was used to record and log any maintenance intervention in the plant, including anything done in relation to the IWCs.

On the other end of the spectrum are companies who do not keep any historic maintenance records. While we did not encounter such an extreme case, interviewees in the Portuguese paper factory indicated that until recently this was the approach taken there. In recent years, however, major events are electronically recorded and the aim for the future is to increase the documentation further.

From an energy-efficiency point of view, meticulous recording appears to be advantageous. Interviewees in several visited plants described a range of advantages. For example, the interviewees in the German steel plant pointed out that record keeping helps with the identification of reliable as well as unreliable equipment. This can concern a brand of equipment as record-keeping might reveal that the products of a particular equipment manufacturer tend to require disproportionate maintenance efforts compared to equipment supplied by another brand. It can also concern particular items of equipment. Record-keeping can reveal that a particular pump breaks down more often than the same pump that is used elsewhere in the IWC. Thus, record-keeping can feed into strategic decision-making as it can help those who make decisions on the equipment of IWCs to identify and ultimately choose reliable equipment. The better the equipment works, the more energy efficient an IWC can run.

Record keeping can also help to structure proactive maintenance: interviewees in the Portuguese sugar plant suggested that they used two-year maintenance cycles for pumps as their experience informed by utilising specialist maintenance software suggests that pumps work error free for about 2.5 years. While the given examples as well as the opinions of interview partners suggest that meticulous recording promises cost-effectiveness, we do not know whether this is really the case given that ‘recording’ itself takes up staff time and therefore incurs costs.

3.1.4 Expertise of Maintenance Staff

The expertise of maintenance staff can also have an impact on energy efficiency of IWCs: the more maintenance staff knows about water circuit equipment and how water circuits on the whole are supposed to work, the more efficiently staff can deal with breakdowns and problems. Adequately trained staff needs less time to identify problems and to choose the best response. With regard to expertise, we can distinguish between generalists and specialists. In the context of maintenance, specialists are electricians and mechanics while mechatronics can be considered as generalists. We have not encountered anything resembling a spectrum in this regard, rather it is a matter of balancing the overall composition of maintenance collectives in plants. The German steel plant is a good example of a well-balanced maintenance collective: they have an almost equal number of mechanics and electricians while they also employ some with a mechatronic background. The advantages of such a balanced team were described to us as resulting in faster repair times. For example, an electrician might encounter a particular problem, but recognises that the fault is mechanical in which case they can call upon a mechanic to deal with the problem. Even in the night shift, the two-man maintenance team consist of an electrician and a mechanic. In contrast, the Portuguese sugar plant lacks such balance. Their night shift also used to be manned by two workers – one electrician and one mechanic – but is now only manned by one maintenance worker with a background in mechatronics. One interviewee in this particular plant voiced his concerns that this has detrimental effects for the smooth running of the water circuits although he gave no concrete examples to illustrate his worries about the lack of specialist expertise in the night shift.

Parallel to the expertise of maintenance staff is the importance of expertise of mechanical and electrical engineers and technicians more generally. The UK case study highlighted that a lack of sufficient expertise can lead to the (purchase and) fitting of the wrong pumps to IWCs, which is inefficient in two ways: i) the extra cost of running an inefficient pump, and ii) increased costs related to greater frequency of pump breakdown, maintenance and pump purchase.

3.1.5 Number of Maintenance Staff

A sufficient number of adequately trained maintenance staff is also important if optimising the energy efficiency of IWCs is a main goal for companies. While having the right kind of maintenance staff in terms of expertise ensures that they are able to respond to the great variety of potential problems that can be encountered, having the right number of maintenance staff ensures that problems can be dealt with in a timely manner, thus preventing problems from accumulating.

In all case studies, we found that the maintenance of water circuits is just one of many tasks for staff in maintenance sections of companies. Thus, decisions about the size of maintenance teams depend on the overall need for maintenance services in a given plant. It is therefore not possible to make definite judgements about under- or overstaffing of maintenance sections. We have, however, encountered interview partners in different plants who conveyed the perception of not having adequate staff numbers, albeit for different reasons. In the case of the Norwegian steel plant, for example, maintenance problems were mainly linked to the age of the water circuits. The maintenance teams in this plant struggled to cope because most elements of the water circuits were more than 60 years old. This results in frequent leaks and breakdown of pumps. While interviewees did not suggest that the maintenance of the IWCs is neglected, they indicated that continuous problems with the water circuits kept them away from the projects they are mainly working on. In the case of the Portuguese sugar plant, interviewees admitted that the maintenance section had been cut down to a minimum and additional agency workers were temporarily brought in if needed. One interviewee suggested that cutting maintenance staff has had negative effects for the energy efficiency of water circuits as sometimes not enough staff is at hand to ensure that breakdowns in the water circuit are dealt with in a timely manner, which results in the sub-optimal working of the water circuits. Another interviewee, however, appeared to imply that from a cost-effectiveness point of view the sharp reduction of in-house maintenance staff makes sense for the company.

3.2 Strategic Planning and Decision-Making

The WaterWatt proposal has identified certain strategic decisions related to the water circuit as having effects on the efficient use of energy in water circuits. For example, the proposal notes that changes to the layout of a water circuit, such as reducing the distance between components to shorten the overall length of a circuit can have positive effects for energy efficiency. Likewise, replacing old equipment with modern, energy-efficient equipment can lead to the overall reduction of the energy required to operate an IWC. Also, utilising topographic features such as natural elevations in the terrain to create pressure in IWCs can contribute to their energy efficient running.

Overall, we have identified the following aspects of strategic planning related to IWCs that can have effects on energy efficiency of IWCs:

- Dimensioning
- Layout
- Accessibility
- Decisions about Investment in Equipment

'Dimensioning' refers to the matching of the capacity of an IWC – both in terms of flow and pressure – with the needs of the users of water within a plant. Interviewees in all case studies suggested that their respective IWCs were adequately dimensioned and the issue was not pursued in any more depth. From an energy-efficiency point of view, only over-dimensioning appears to be an issue as it suggests that a circuit system pumps more water around and/or produces more pressure than is actually required.

An optimal 'layout' is one that allows an IWC to fulfil its functions within the context of a plant with the shortest possible piping system. The longer the piping system the more energy is required to pump water around. While those interviewees that were asked about the layout suggested that their respective circuits had an adequate layout, it is also noticeable that most interviewees were not able to state the precise length of piping systems. This suggests that there is often no precise knowledge as to whether the layout of an IWC is adequate or not.

Another set of strategic decisions is related to the accessibility of the components that make up a water circuit. We have first been made aware of this issue while visiting the German steel plant. Interviewees there pointed out that the location of, say, pumps can impact on the repair times of equipment. If access to a pump is awkward, even a simple procedure can take a long time. The point was driven home more forcefully, however, during a visit to a British steel plant where an engineer pointed out that parts of some water circuits had to be buried underground to avoid having water pipes traversing train tracks on which liquid iron is transported. He pointed out that this was done in a suboptimal way as the access issue was not considered at the time of burying the pipes. Today, several decades later, access has become an issue because leaks, which have a negative impact on energy efficiency of IWCs, cannot be repaired.

While decisions concerning dimensioning, layout and accessibility are taken very rarely, decisions about particular equipment of IWCs such as pumps, filters or cooling devices are taken more frequently. The latter is exactly the type of decisions that the E^3 Platform is supposed to support. Our case studies have not returned a uniform picture about the state of current decision-making practices in the different plants. In the German steel plant, decision-making with regard to equipment is highly developed. The maintenance section understands their water circuits very well which also means that they understand very well what kind of equipment they need to ensure the optimal working of the circuits. Moreover, decision-makers in the German steel plant consider a wide range of factors such as the ability of maintenance staff to repair equipment, ease of repair, compatibility with existing equipment so that spare parts can be interchanged as well as the reliability track record of particular equipment (this is linked to then meticulous documentation of maintenance work). Thus, a complex cost-benefit calculation precedes any decision to buy particular equipment. In the case of the Portuguese paper plant, in contrast, investment decisions appear to be taken on the basis of instinct and approximation as apparently not even rudimentary cost-benefit analyses are performed. In the Norwegian steel plant, on the other hand, this type of decision-making is virtually non-existent as management prefers to repair existing equipment rather than replace old and inefficient equipment. Some of their pumps and most of their piping have been put in place in the 1950s and no plans are in place to replace them.

While we were able to identify these aspects during the interviews, we do not fully understand how companies approach them. There are three reasons for this: one is that our interactions with staff during the case study work was rather brief and most of our time was used to understand how the circuits worked. Another reason is that our interviewees were often not fully, if at all, involved in strategic decision making and we did not get access to those with these decision-making powers. Making structural changes to a water circuit is expensive as it not only requires high levels of investment but also necessitates temporary production stops. Thus, strategic decisions are often taken at a level within the hierarchy of a company that we were not given access to. A third reason is that strategic planning and decision-making is not an everyday activity. In some cases we encountered, water circuits have not been changed or modernised for decades, which meant that interviewees had no personal experience of making such decisions even if they had decision-making power.

3.3 Processes drawing upon water

Employing the language of economics, everything said so far has concentrated on the ‘supply side’ with regards to water: what effects have organisational configurations on the efficiency of water provision. It has been shown that the organisation of maintenance regimes as well as strategic decisions related to water circuits can have a profound effect on the degree of effectiveness with which water is made available for a range of industrial processes.

In this section, the focus will be on the ‘demand side’ i.e. the processes that draw upon water. The importance of this approach ought to be obvious: the less water is demanded by processes that are external to the water circuit, the less energy is required to operate an IWC as less water leaves the circuit.

The case studies have identified a range of practical measures that individual companies have implemented to reduce the demand for water. In what follows, we provide five examples to illustrate the range of possibilities, but have to note from the outset that apart from the general insight that innovation in and modernisation of processes that draw on water has the potential to reduce the energy use of industrial water circuits no generalisations can be drawn. It is up to the individual companies in the various sectors to explore whether changes to the way processes work can have an energy-reducing effect on their water circuits.

The first example concerns the replacement of existing materials used in rolling mills with material that is more heat resistant, which in practice means that less cooling water is required. Interviewees in the German steel plant suggested that one innovation they are looking at is changing the material of the rolls that allow steel to be moved through the rolling mill. Currently, the rolling equipment requires continuous water cooling to avoid damage from the hot steel as it moves through the mill. Using rolls that are made of more heat resistant material instead would reduce the demand for water as less cooling is required. As this would reduce the demand for water, the energy using IWC equipment such as pumps needs to do less work and therefore reduce the overall energy consumption of the cooling circuit.

The second example concerns the pulp circuit in the Portuguese paper plant. One current step in the paper production entails the pumping of pulp into boxes that are suspended under the roof of the plant. These boxes once fulfilled a critical function in the production of paper as they utilise gravity (the height difference between the boxes and the actual paper machines) to ensure a steady flow of pulp into the paper machine. This is important to guarantee the consistent quality of paper. It was explained to us that these boxes were once required because fluctuations in energy supply meant that pumps were not able to provide a constant flow of pulp into the paper machine – the fluctuating energy supply meant that the flow of pulped through the pump varied accordingly. Interviewees also explained to us that this has been a problem of the past and that energy supply is nowadays steady, which means that pumps could do the same job that the suspended boxes do. As it takes more energy to pump pulp in the suspended boxes than directly into the machine, modifying the production process in a way that does away with the suspended boxes will reduce the energy required to operate the pulp process.

A third example that illustrates how the elimination of redundant processes can lead to energy savings in water circuits stems from visits to steel plants in Germany and Norway. In both cases, the flow of cooling water in the rolling mill can be manually interrupted when the rolling process is interrupted. In both plants, the rolling mill equipment requires constant cooling while hot steel is rolled. While the supply of steel is supposed to be constant, this supply can be interrupted for a range of reasons. In these cases, the operators in the control room of the rolling mill are supposed to stop the flow of cooling water by pressing certain buttons. Stopping the flow of water means that the cooling circuit requires less energy as less water exits the circuits and pumps have to work less. One way of optimising the flow of water cooling that is about to be implemented in the German steel plant is to replace the manual button with a a sensor. In this way, the sensor eliminates the When the supply of steel is interrupted, the sensor automatically shuts down the flow of cooling water, resulting in an optimised use of cooling water. This also means that pumps in the the cooling circuit only have to work when cooling water is really required which increases the efficiency of energy use.

Another way to realise energy efficiencies in water circuits is to try and optimise production processes in such a way that less water is required. Interviewees in the Portuguese paper and cardboard company made us aware of one possible approach: producing card board also involves printing things like symbols, labels or instructions onto the card board. The same machine can print a range of colours, but before a new colour can be printed the printer needs to be cleaned to remove traces of the previously used colour. Interviewees pointed out that the printing schedules had been reviewed and subsequently optimised. In the past, printing was done on a ‘first-come-first-serve’ basis. For example, a first batch of card board might require red ink, the second batch requires blue ink, the third requires red again and the fourth again requires blue ink. Under their old approach, they would have processed all batches in that order, which means that they would have to clean the printing machine after dealing with each batch. They have changed their approach in such a way that cleaning is minimised. In the given example, they would first deal with batch 1 and 3, then clean the printer and proceed with batch 2 and 4. Less cleaning means less water is used which also reduces the energy consumed by the water circuit that provides water for cleaning.

A fifth example how the optimisation of production processes can have energy-saving effects on water circuits stems again from the German steel plant. They have introduced a new automated oven that ensures that steel is heated to the exact required temperature to roll it. Before the introduction of this innovation, steel was routinely heated up more than required and cooling water was then used to ensure that it had the right temperature when entering the rolling mill. This innovation not only saves the company costs by avoiding the excess heating of steel, but also saves energy used by the water circuit because the demand for cooling water is reduced.

The five examples show the great variety of approaches that companies can take to reduce the demand for water provided by IWCs. Whether there is room in a specific plant to reduce the demand for water needs to be assessed case by case. For example, while the paper plant was able to optimise its cleaning schedules, interviewees in the sugar plant suggested that current cleaning schedules were already optimal and no further savings could be made. Moreover, it depends on then individual circumstances of a company whether optimising the demand for water can be achieved in a cost-effective way. A measure that might be cost-effective in one context, might not be cost-effective in another context.

3.4 Interim Conclusions

When energy efficiency is regarded as a technical issue, it is likely to lead to the proposition of 'technical solutions' to fix it. Theorists in Science and Technology Studies, however, have suggested that understanding energy efficiency as a complex sociotechnical problem will also broaden the focus when it comes to looking for imaginative solutions.[2] The WaterWatt project has from the outset embraced such a broader perspective by integrating an analysis of organisational factors that affect the energy efficiency of industrial water circuits.

To identify and describe organisational factors, we have used a case study approach. In practice this meant that we visited companies and interviewed local water circuit experts. In addition, we were occasionally able to observe how water provide by circuits were used in production processes.

We have identified three broad areas in which the way processes including human practices (i.e. work) are organised can impact on the energy efficiency of industrial water circuits: maintenance, strategic planning and decision making and processes that draw on water. The quality of our insights into the three domains varies as the access to relevant actors and their willingness to divulge potentially critical information to outsiders has not been uniform.

The importance of maintenance for energy efficiency in IWCs is the best understood area. This is mainly due to the fact that most of our interview partners were located in maintenance sections. Five distinctive 'organisational factors' have been identified in this area. In contrast, insights into strategic planning and decision making and into the effects of production processes on energy consumption of IWCs are less well developed due to limited access to interview partners that are concerned with these areas. In addition, the division of labour in relatively large industrial enterprises often meant that the staff we interviewed were not directly involved in strategic planning and decision making and had only limited insights into the organisation of production processes. Thus, while we were able to identify a range of critical aspects and examples that are relevant to those two area, the discussion has been necessarily less systematic.

[2] Jasanoff, S. 1999. STS and Public Policy: Getting Beyond Deconstruction. *Science, Technology and Society* 4(1): 59-72.

The insights presented so far can hopefully serve to inform those in pursuit of greater energy efficiency. This could be achieved by publicising the findings both on the project website and as part of the information material delivered through the E^3 Platform. It has, however, become clear that the organisational factors themselves can only contribute to the removal of one of the barriers to greater energy efficiency in IWCs as identified by the WaterWatt project proposal. They can contribute to raising awareness of the energy saving potential of industrial water circuits. Moreover, their identification and description appears to confirm the claim that energy efficiency is better approached as a socio-technical problem and not as a technical problem alone.

While organisational factors are limited to raising awareness about the energy saving potential of IWCs, the insights gained through our case studies can nonetheless also contribute to overcoming the second barrier to energy efficiency, which has been described as uncertainty about the positive economic benefits of investing in IWCs. This contribution takes the form of what we call ‘contextual factors.’ We discuss the latter in the following section.

4. Contextual Factors

4.1 Background

By contextual factors, we mean factors that impact in some way on the cost-effectiveness of energy efficiency investments. One important and widely used way to assess the cost-effectiveness of any kind of investment is the concept of pay-back time. In its most basic form, the pay-back time gives decision-makers an indication within which time-frame an efficiency investment pays for itself. This can be expressed in the following equation:

$$Payback\ time = \frac{Investment\ costs}{Annual\ cost\ savings\ achieved\ through\ investment}$$

One of the promised capabilities of the E^3 Platform is the integration of a payback time calculator as a means to demonstrate to users the positive economic effects of energy efficiency investments. The proposal does not, however, specify the level of sophistication at which the calculation is operating. We can distinguish between universal and contextualized approaches to the calculation of payback times. In both versions, the ‘Investment Costs’ are the same. Where the two versions differ is with regard to the way in which the cost saving part of the equation is calculated. In the universal version of the payback time calculation the cost savings are calculated by simply multiplying the saved energy over a given time period with the local energy prices. Thus, to calculate a payback time of an energy efficiency investment one only needs to know the investment costs, the energy savings and the local energy prices.

The WaterWatt proposal’s approach to payback time calculation can be characterised as universal: the proposal’s calculation relies on the so-called ‘maximal theoretical efficiency’ (MTE). MTE is calculated by analysing the pre-investment energy use in any given IWC over a given time period and then recalculating the energy use over the same time period by assuming that every available energy saving measure that could be implemented is implemented. The maximal theoretical energy savings over a given time period can then be converted into cost savings and fed into a payback time calculation. In a sense, this form of payback time calculation is an interesting way to demonstrate to E^3 Platform users the maximal amount of energy they could save. The advantage of the universal approach is that the same simple payback time calculation can be performed across countries and sectors. Put differently, the advantage of such a decontextualized payback time calculation is that the values that go into the payback time equation are knowable without any deep insights into the specificities of the water circuit for which it is calculated. Such a universal calculation can function as a rough indicator that efficiency gains are realisable through energy efficiency investment, but the disadvantage is that the real economic costs still remain opaque. The problem is therefore that the universal calculation of payback time does not really help in removing the second barrier to energy efficiency investment in IWCs, which has been characterised as the uncertainty about positive economic effects.

The payback time calculation needs to take into account a wide range of factors that can affect the cost savings achieved through energy efficiency investment. This can be illustrated with the help of a hypothetical example: assume that a universal payback time calculation indicates that an energy efficiency investment does not pay for itself over, say, two years. The underlying EE investment might, however, lead to a reduced use of water. Under such circumstances, it would be more prudent to use a more complex formula to calculate payback time: while the investment cost side of the equation stays the same, the cost savings are increased by taking the costs saved on both energy and water into account. This will shorten the calculated payback time and might even bring it below a specific threshold set by a company, say 2 years, that is used to distinguish cost-effective from cost-ineffective investments.

Consider another example: the simple payback time calculation for IWC investment costs in a company in the far North of Norway suggests that such an investment will pay for itself within 12 months. In reality, however, for a payback-time calculation to be meaningful, it needs to take into account a range of additional costs that will diminish the cost savings of the investment further: 1.) the transport costs of getting the energy saving equipment to the plant (they will be low if the equipment comes from Scandinavia but will be high if it comes from the South of Europe); 2.) The actual exchange rate at the point of buying if the equipment has to be imported from a country with a different currency; 3.) Training costs for maintenance staff in case that they are not familiar with the new equipment. And so on: the list of potentially relevant additional factors that might influence the real payback-time of an investment is lengthy.

We call the additional factors that ought to be taken into account to arrive at a more realistic payback time calculation ‘contextual factors’. As the label suggests these factors are context specific, which means that determining as to whether they are relevant in any specific case requires an analysis of the local circumstances and conditions into which IWCs are embedded. For example, water costs are virtually negligible in Norway, which means that saving water in a Norwegian plant as a consequence of energy efficiency investment in water circuit will therefore not have a great influence on a payback time calculations. In contrast, in Portugal, where water costs are relatively high, saving water will impact in a much more significant way on payback time calculations.

The following table (see table 1) sets out all the ‘contextual factors’ that we have been able to identify during our case studies in Germany, Norway and Portugal as well as during a recent visit to a steel plant in the UK. This list is by no means exhaustive. Identification of the factors occurred during site visits that were limited in several respects. We were not able to cover plants in all the proposed sectors which means that it is possible that different factors relevant to uncovered sectors are not included in the list. We also had limited interactions with staff in the field sites and it is possible that interviewing a wider set of employees would have led to the identification of more contextual factors.

Moreover, while we have identified a wide range of factors, we do not in all cases fully understand their potential impact on the cost saving side of the payback time equation. For example, we were told by interviewees that the structure of company internal budgets can determine the size of investments or the timing of investments. What we do not know is why this is the case and how rigidly companies tend to adhere to those structures even if it has limiting effects on the amount of energy that can be saved. For example, the manager of an IWC might have a total annual budget of €1m, which is divided in equal measure into a budget for capital spending and for spending on training. An interviewee told us that such a budget structure cannot be simply changed by the manager, even though it might at times make economic sense to do so. The manager is not able to combine both budgets to make a €1m capital investment even if that were to save far more energy than two smaller investments in capital goods and skills respectively. While the company would still gain from the two smaller investments, they lose out on the extra gains provided by the big project due to their inability to combine two separate budgets to finance the big project. While we know that budget structures can play a role, we do not really understand how this plays out in practice and how relevant this issue is for companies. The impact of other factors such as 'Water Prices' or 'Maintenance Costs' on the payback time calculation is, in contrast, relatively straightforward and thus well understood.

We envisage the table to assist some decision-makers in companies who have to estimate the economic benefits. How exactly is this to be achieved? While we have been able to identify a wide range of contextual factors, we are not well placed to decide whether they are actually relevant in a given specific context or not. Such determinations ought to be made by the users of the E^3 Platform who are familiar with the actual context in which their IWCs are embedded. Thus, the table ought to function as a check-list that can make users aware of factors that they might not have considered. From the limited insights gained during the case studies, we envisage that the table will be useful to some E^3 Platform users while others are already employing elaborate contextualised approaches to payback time calculation. As described further above in this report, decision-making in the German steel plant is highly developed and interviewees suggested that a wide range of contextual factors are taken into account when the cost-effectiveness of a given investment is considered. In contrast, most of the decision-making in the Portuguese paper plant is based on instinct and common sense.

An additional benefit of identifying contextual factors is that they can also be used to inform the WaterWatt consortium's E^3 Platform marketing strategy. The basic assumption is that the more cost-effective a potential energy efficiency investment into IWCs is the more likely it is that it will be realised by companies. Thus, it makes sense to direct marketing efforts towards companies that stand to profit the most from using the E^3 Platform.

The table contains three columns: the first column identifies the contextual factors. In the second column, short descriptions make clear as to why and how the factor is relevant to the calculation of payback times. The third column tries to formulate the marketing lesson for the WaterWatt team.

Table 1: Description of Contextual Factors

Contextual factor	Description of relevance for payback-time calculations	E^3 Platform marketing lessons
Energy prices	The higher prices the higher incentive to increase Energy Efficiency (EE) and the shorter payback-times. In addition, even the expectation that energy prices will rise in the future can stimulate investment decisions.	Concentrate on countries with high energy prices; look for reliable indicators that can help to predict the development of energy prices in countries (e.g. investment levels in energy sector)
Water prices	EE measures in IWCs might affect water use. Water savings can positively affect the payback time calculation. The higher water prices in a given location, the more relevant this becomes to the calculation of payback times.	Concentrate on companies/countries with high water prices
Labour costs	1. EE investment might save costs by replacing labour (automated control infrastructure makes makes regular inspections redundant) 2. EE investment might save costs by reducing labour, e.g. due to less maintenance (save labour costs) The higher labour costs in a given location, the more relevant this might become to the calculation of payback times.	Concentrate on high-wage countries
Training costs	Investing in new technologies (new pumps) might require additional training costs for maintenance staff	Make platform users aware of this
Maintenance costs	Maintenance costs need to be factored into a proper payback time calculation but the actual maintenance costs will only be known within a company. Maintenance costs are practically highly relevant for investment decisions. For example, managers in the German steel plant made the conscious decision to use pumps that are less energy efficient than other available pumps because they use the same pump elsewhere in the plant and therefore have experience in maintaining and repairing the pumps and can make savings on spare parts.	Make platform users users aware of this

Contextual factor	Description of relevance for payback-time calculations	E^3 Platform marketing lessons
Amortisation period threshold (payback time)	Some companies work with set amortisation periods: any investment has to pay for itself within a pre-defined period. Case studies suggest that this period is often relatively short, usually between 2 and 3 years. The length of the amortisation period directly affects the cost-benefit calculations. While the practices vary from company to company, the general rule is that the longer the assumed amortisation period, the greater the chances that an EE investment is cost-beneficial as longer payback times allow even small efficiency savings to become cost-effective.	If the amortisation period assumptions applied by companies are known, target companies with relatively long amortisation periods
Level of competition	High competition usually means that companies need to reduce their costs. The higher the competition in a sector the greater the incentive to implement cost-saving energy efficiency measures	Target companies that operate in highly competitive contexts since even the most marginal gains will improve the company's competitiveness
Type of energy supply contract	Energy flat rates disincentive investments in EE measures as actual use of energy is not reflected in costs.	Target companies that do not have flat-rate energy contracts
Topography	Enables/Disables certain energy efficiency measures. For example, having elevated ground close to a plant might make it possible to utilise differences in elevation to move water instead having to use pumps	Make platform users aware of this
Exchange rates	Exchange Rates might affect equipment prices depending on location where equipment is bought from and where it will be deployed	Make platform users aware of this
Transport costs	Transport costs for EE equipment impact on investment decisions (potentially be significant if deployment location is on margins of Europe)	Make platform users aware of this
Fitting costs	Fitting costs are an important part of investment costs but are not reflected in Equipment Costs. Costs depend on availability of in-house skills or whether external contractor is doing the fitting work.	Make platform users aware of this

Contextual factor	Description of relevance for payback-time calculations	E^3 Platform marketing lessons
Mode of production: in-line vs fragmented	In-line production means that each production step directly depends on the previous production step (sugar: if Portuguese sugar company wants to modernise IWC the whole production process would stop – cost implications!). Fragmented production means that specific production steps can be halted without affecting overall production The Portuguese paper & cardboard company in Portugal is an example: The company could stop the complete paper production and rebuild the water circuits, but still produce cardboard with paper bought elsewhere or paper that has been stored. This has consequences for maintenance (in-line production incentivises attempts to keep production going even if this means energy inefficiencies).	Concentrate on companies that have fragmented production systems?
Participation in Energy Management System (EMS)	EMS offer external incentives in the form of access to some form of subsidies; this has the potential to turn internally cost-ineffective energy efficiency measures into ones that are overall cost-effective.	Point this out to platform users
Length of participation in EMS	The longer a company has been part of an EMS the greater the pressure to make marginal efficiency gains to retain certification. The sugar plant in Portugal is an instructive example, as their interest in the waste water project has been partly justified to us by the fact that they have an EMS since 1980s. The last audit made just 5 recommendations for further improvements as they have already improved all the obvious things in the plant. To achieve the mandatory annual reduction of energy use, they now turn to neglected areas like water circuits and the behaviour of staff (new programme to save energy by encouraging staff to turn of lights, AC units and so on).	Target companies that have participated in EMS for a long time (20 years and more)
Size of company	The bigger a company the greater the chances that they have a well-developed bureaucracy that can undertake complex but standardised cost-effectiveness calculations	n/a
Regulations / the law	The regulatory context might close down or open up particular options with regard to energy efficiency measures The Non-Ferrous Metal plant in Norway is an example: keeping zero-energy cooling circuit was taken away as option by regulator.	Point this out to platform users

Contextual factor	Description of relevance for payback-time calculations	E^3 Platform marketing lessons
Equipment environment	This refers to the environment in which certain IWC equipment (mainly pumps but potentially other things) are expected to function. We could roughly distinguish between clean and dirty environments: operating in dirty environments increases maintenance costs	n/a
Robustness of equipment	IWC usually ‘transport’ water, but in certain sectors (paper and probably food), IWC might also be used to pump around other substances: in the case of paper, parts of the IWC transport pulp (mix of water and cellulose fibres). Interviewees told us that for those purposes, they need pumps that are especially robust. Such equipment is likely to be more expensive.	n/a
Continuity of production	In some companies such as the Non-Ferrous Metal plant in Norway, production runs 24/7 all year long which means any major interventions in the IWCs such as modernisation of equipment requires production stops which are usually costly. Other companies have ‘natural’ production stops over weekends or in holiday periods which allows for interventions in the IWCs without any interruption of production.	Focus on companies with production stops
Accessibility of equipment	In some plants, most if not all the components that belong to a water circuit are easily accessible. In some places, however, pipelines are buried underground or pumps are installed in hard to reach places	
Thread of plant closure	n/a	Focus on economically healthy companies. Companies in economic distress tend to worry about short-term survival and not about the energy efficiency of their water circuits
Invariability of IWC	Invariability of IWC means that a given circuit always runs at the same level: there are no fluctuations in the way it runs, i.e. there are no breaks or slow-downs. The Non-Ferrous Metal plant in Norway is an example: their production runs at the same speed 24/7 all year long which also means the cooling circuit is running at a steady pace. In such a case there is simply no human involvement in the water circuit and thus no scope for any organisational intervention to improve energy efficiency.	Concentrate on technical solutions

Contextual factor	Description of relevance for payback-time calculations	E^3 Platform marketing lessons
Structure of company budgets	Accounting practices in companies have impact on investment decisions as budget structures might not allow for big investments It might, for example, be the case that only big EE investments are cost-efficient, but sections within a company might not be able to do large investments if they cannot combine resources from different budget posts. This is not directly relevant for payback-time calculations. Instead this factor points towards a particular E^3 Platform marketing message: the advantage of the E^3 Platform is that it can calculate the MTE by adding up all the energy saving potential of individual components of IWC. This also allows users of the E^3 Platform to rank the individual interventions in terms of energy reduction potential. The marketing message could therefore be: no matter how big your budget, the E^3 Platform can help to identify energy efficiency potential.	Emphasise ability of E^3 Platform to identify small-scale and large-scale energy efficiency potential (even with a small efficiency budget, E^3 Platform might have something to offer)

4.2 Interim Conclusions

This part of the report has characterised Industrial Water Circuits as being part of a larger context. It has been shown that such a view has consequences for the way in which payback-time is calculated as part of the E^3 Platform. Adopting such a perspective is critical for at least two reasons. First, adopting a contextualised perspective will enhance the usability of the E^3 Platform in practice. This is because relying on a decontextualized approach to payback time calculations can produce misleading decision support for investment decisions. While big companies with a well-established internal bureaucracy will have their own ways of calculating return of investment some of the case studies suggested that smaller companies rely mainly on the instinct of managers as to whether an investment is worthwhile or not. Integrating a contextualised decision-support into the E^3 Platform can therefore address an important knowledge gap in some companies.

A second benefit of a contextualised approach to the calculation of payback times is that recommendations for the marketing of the E^3 Platform can derived, which can help WaterWatt consultants to target companies that could benefit most from using the E^3 Platform.

The big question is, however, how exactly the research on contextual factors can be integrated into the E^3 Platform. One theoretical possibility is to create a complex formula for the calculation of payback times that incorporates all the factors. While feeding in data for the calculation it would then be up to users to provide relevant values for those factors that apply to them and to ignore the irrelevant ones. The practical problem is that such an approach would not be very user friendly as users have to navigate a lengthy list of potential inputs. A more promising route would be to pursue a two-step approach to the calculation of payback times. In a first step, the decontextualized approach based on maximal theoretical efficiency can be pursued to get a rough idea as to whether energy efficiency investment might be cost-effective. The contextual factors can be integrated into a questionnaire which may then be deployed in a second step. WaterWatt consultants can use the questionnaire feedback to calculate a more realistic payback time to help industrial users in their decision-making.

5. A brief note on Gamification of work processes

Due to ambiguities regarding the proposed reach of the gamification idea in the research proposal, our research also pursued the question as to whether gamification could be used to directly modify work practices so that they would contribute to energy efficiency. Put differently, we interpreted some passages in the project proposal to mean that the gamification idea should not only be applied to improve the usage of the E^3 Platform but also to actual water-circuit related practices and behaviour of staff. Thinking about the potential for this, we imagined for example that maintenance staff could approach repairs and other maintenance tasks in the spirit of ‘friendly competition’. For example, maintenance staff could ‘compete’ with regard to response times, i.e. the time it takes between problems are detected and solved. The underlying assumption is that the faster the response time, the earlier a water circuit is working properly again with positive effects on energy efficiency. Faster response times might be rewarded to incentivise rapid response to maintenance issues in water circuits.

So-called ‘gamification’ constitutes a central element of the social approach to increased efficiency in and around industrial water circuits (IWC). In a nutshell, gamification entails the incorporation of game-like elements into non-game environments, such as work places, in order to change human behaviour in particular ways, usually with the goal to improve performance. Gamification as an academic concept, rooted in management studies and computer sciences, is a relative recent idea (Kapp 2012, Burke 2012, Deterding et al. 2011)[3], even though actual practices that are consistent with the current meaning of ‘gamifying work environments’ are much older and pre-date the conceptual or theoretical basis developed recently. For example, the Stakhanovite movement in the USSR in the 1930s or the idea behind the ‘Hennecke Activism’ in the early years of the German Democratic Republic are prominent manifestations of the idea to link particular work achievements to particular and visible rewards – in the East German case this took the form of acquiring the metaphorical ‘badge of honour’ of being a ‘Hennecke Activist’ for those who went over and above the state-set productivity targets. The ability to earn special ‘badges’ as reward for particular achievements is nowadays a widely used element associated with digital games (see the idea of game-transcending ‘trophies’ on the Playstation platform). The idea of ‘bonus’ is another marker of a well-known reward scheme found both in the world of business and the world of games. Again, the idea of the bonus is to reward particular achievements and thereby to incentivise workers or gamers to try harder in order to gain the bonus.

[3] Deterding, S., Dixon, D., Khaled, R. and Nacke, L. 2011. From game design elements to gamefulness: defining ‘gamification’. [Conference Paper]. *MindTrek'11*, September 28-30, 2011, Tampere. https://www.cs.auckland.ac.nz/courses/compsci747s2c/lectures/paul/definition-deterding.pdf

Another game element that can be transposed into work environments (and probably has been already somewhere) is the 'leader board'. Leader boards can serve as a means to provide feedback to workers by measuring and ranking performances of different workers. The idea is that this feedback motivates workers to improve their individual performance because they will want to see their names at the top of the rankings represented on the leader board. Other, more intricate and subtle feedback mechanisms employed in game environments such as sounds or visual stimuli might also be used to improve workers' performance as might help to keep the motivated to perform certain tasks even though they might be perceived to be boring or repetitive. In a sense, the idea behind gamification is to create certain behavioural patterns – or 'behavioural addictions' (Alter 2017) as some might say – that are beneficial in some sense.[4]

Our first site visit in steel plant in Germany yielded a very good example to illustrate the potential efficiency gains that could be realised from pursuing a gamification approach. The case study also illustrates the downsides of such an approach. Despite efforts to automatize the water circuits in their plant, when asked whether there are points where human decision making impacts in some way on an IWC interviewees mentioned that those operators monitoring the rolling mill in the plant had access to a button that allows workers to switch off the supply of cooling water on those occasions when there is an (usually unplanned) interruption of supply of steel to the mill. In theory, the operator should press the button as soon as it becomes clear that there will be a production break. Doing so does not only save water but also energy. Interviewees reported, however, that this is not necessarily what happens in reality. Some workers, for a variety of reasons including scepticism regarding the reliability of the button or forgetfulness or sheer ignorance with regard to efficiency, do not push the button when production is interrupted which means that energy is used to provide cooling water when it is not required. 'Gamifying' the use of the button is, in theory, a promising way to change operators' behaviour to make it more compatible to the goals of water and energy efficiency. The gamification could take a variety of forms: a leader board could be constructed on the basis of the time that passes between an interruption of steel supply and the pressing of the button thereby incentivising operators to press the button as soon as possible to rise to the top of the leader board; or pressing the button might light it up or generate an affirmative sound thereby inducing pleasure through feedback in the form of light or sound. Receiving pleasurable feedback should in theory nudge operator towards using the button at any given opportunity. Gamification has therefore the potential, through a set of incentives taken from game environments, to induce lasting behaviour changes: the operator who distrusts technology or who does not care for water and energy efficiency is given reasons (her position on a leader board or receiving pleasurable feedback) to modify her behaviour.

While this appears to reveal real promise for gamification to contribute to greater energy and water efficiency of water circuits there are a variety of reasons to be cautious.

1. Measuring performance/ monitoring behaviour of staff has pitfalls
2. Technological replacements might be easier and cheaper to implement

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[4] Alter, A. 2017. *Irresistible: The Rise of Addictive Technology and the Business of Keeping Us Hooked*. London: The Bodley Head.

3. Integration into E^3 Platform might be challenging
4. Not many opportunities for social intervention in IWC (it's a marginal opportunity)

Firstly, while gamification appears to operate on the basis of assumptions that appear to be intuitive and sound, there are pitfalls associated with external attempts to boost the performance of workers (Martin 2016, Ariely 2016). One problem is related to different interpretations of interventions: while advocates of gamification (and other performance enhancing interventions) usually regard performance measurements and the pitting of workers against each other as unproblematic means to a well-intended end, the perception within companies – both from workers and managers – might be very different. Indeed, when we mentioned gamification in the form of 'friendly competition' as a possible way to make staff behaviour more energy and water efficient, the uniform reaction across several companies in different sectors was one of rejection and scepticism. Both staff and managers were usually concerned about the corroding effects of company-internal competition. In particular, they were concerned about cases of jealousy and personal resentment. On a higher level, there appears to be a clash between the logic of gamification and assumptions held by managers in the visited companies that underpin internal strategies for the enhancement of staff performance. While the former is based on competition, the latter, at least in the cases we have encountered, is based on cooperation and collaboration. Managers believe that staff works well when they are trusted to do well and they did not feel that measuring and ranking staff performance to be helpful in this respect.

There is also a body of literature that is concerned with the outcomes of various performance strategies. Some of it suggests that strategies work to different degrees depending on context specific factors such as the nature of work (conveyor belt vs cognitive work) (Ariely 2016) and some authors also suggest that some strategies and measures to enhance staff performance can be counter-productive (Martin 2016). During one site visit, a manager and an operator together provided us with an illustration of this. When asked about whether gamification could be used to improve the performance of maintenance teams, they were very sceptical. Their reasoning was that the introduction of targets, performance related pay or any other external incentives to improve performance were might be counter-productive because it might lead maintenance staff to do jobs that are time-consuming less well than they could and should if they have to hit certain targets or benchmarks. They explained that a lot of maintenance work was unpredictable: the same part in two pumps might break but this does not mean that it takes the same time to repair the pumps. One could be in an awkward, hard to reach location or an additional problem might present itself during the repair process which makes it impossible to compare the two interventions adequately even though they seem to be identical at the outset.

Secondly, based on our necessarily limited access to companies that operate water circuits, it emerged that there is only a limited number of intersection between human action and efficiency in industrial water circuits that might be suitable for gamification. The main reason appears to be that even old water circuits are designed to run as autonomous and independent of human intervention as possible. Advances in automation technology further reduce the need for human intervention into IWCs. An interviewee in Germany with overall responsibility for the water circuits in his plant told us that their aim was to 'eliminate human involvement in the way water circuits run completely.'

Thirdly and closely related to the second point, it might also turn out that applying technological solutions are more cost-effective than gamification approaches. The above described example of the button to interrupt water supply in rolling mills when production comes to a halt illustrates this perfectly: one can of course install technology to measure the response time of staff to interruptions in production, i.e. equipment to measure how soon they hit the button, but a much simpler and cheaper solution is to replace the manual button with an electronic valve that can shut water supply down as soon as it receives a signal that production is interrupted. Thus, technological fixes can make gamification redundant.

Fourthly, there might also be a computing challenge for those within the WaterWatt consortium who have to embed gamification options into the E^3 Platform. The problems posed by the social research as part of the WaterWatt project are twofold: on the one hand, the research visits were too short and too limited in scope for us to be able to present detailed descriptions of human behaviour that interacts in some way with water circuits in sufficient detail. As already pointed out, we have not encountered many instances where specific human behaviour has a concrete measurable effect on energy and water use of particular water circuits. This might, however, be a consequence of the generally limited access granted to us by industrial partners. We were only able to cover a handful of companies operating in four different sectors. The chances that certain potentially gamifiable work practices around water circuits have been overlooked are high. On the other hand, links between behaviour and energy efficiency vary in their complexity. The two examples mentioned above, maintenance and temporarily switching off water supply in rolling mills, bring this issue out. The problem for gamification is that behaviour has to be measured in some way to make a variety of individual actions, potentially performed by a variety of people, comparable. This is straightforward in the 'button case', but as described above, is less practical in the case of maintenance work. To return to the example of the two identical pumps that suffer from the same fault: to truly measure the human behaviour involved in the maintenance work, one would need to account for subtle contextual differences such as the ease of access to the pumps or the relative age of the pump.[5]

6. Conclusions

This report summarises the findings of the sociological research on human and organisational challenges that companies wanting to increase the energy efficiency in their industrial water circuits face. The report identifies a range of organisational and contextual factors. Organisational factors describe intersections between water circuits and human activity in industrial plants. The focus on organisational factors is important because the way these factors are configured in practice can have a tangible effect on the degree of energy efficiency of an IWC. The identification of organisational factors can therefore contribute directly to overcome one of the two main barriers to more investment – a lack of awareness of energy efficiency potential – as identified by the WaterWatt project proposal. Perhaps contrary to expectations, our research found that the intersections between human actions and industrial water circuits appear to be fairly limited. The report has identified three broad areas – the maintenance of IWCs, strategic

[5] The latter is relevant as corrosion on older pumps might slow down the repair process.

planning related to the design of IWCs and processes drawing on the water supplied by IWCs – in which organisational factors are salient. The first part thus considers each of these areas in depth and shows how the organisational structures and strategies that intersect with water circuits can contribute to or undermine energy efficiency in industrial water circuits. Thus, understanding organisational factors and their impact on energy efficiency in water circuits can help to overcome the first barrier to investment identified by the WaterWatt project.

The report also introduces and describes so-called 'contextual factors.' Rather than being prescribed as a focus of the sociological research, the importance of contextual factors emerged out of engaging with and talking to partners in the individual industrial plants that have been visited as part of the case studies. It emerged that these factors are critical for the realistic assessment of the cost-effectiveness of energy efficiency investment. This is due to the fact that certain local or national conditions in which companies operate their IWCs can influence the cost-effectiveness of such investments. Recognising these factors and incorporating the findings into the development of the E^3 Platform is important for overcoming the second barrier to more energy efficiency investment in IWCs as identified at the outset of the WaterWatt project. Recognising the importance of contextual factors for calculating the cost-effectiveness investments might also be critical in dealing with potential legal issues that are implicated in offering decision-support as part of the E^3 Platform design. The potential problem is that with offering financial advice comes responsibility. If the decision-support process is flawed, wrong decisions might follow which might also mean that future clients might seek compensation from the WaterWatt consortium.

A third substantial part of the process has considered the potential of gamification to contribute to the energy-efficient running of water circuits in industrial settings. Gamification is an integral part of the WaterWatt approach to ensure continuous use of the E^3 Platform. During the fieldwork we explored whether gamification could also be applied to actual work processes that meaningfully intersect with the water circuits. A range of barriers have led us to conclude that this is not a fruitful and practical approach to pursue. Apart from there not being many clearly identifiable processes that could be gamified, we also encountered a lot of resistance to this idea from our interview partners. Their main concerns centred around the erosion of trust that might follow from introducing competitive elements into intra-workforce relations as well as doubts about the feasibility applying measurements to often idiosyncratic work processes. These concerns are also reflected in the wider literature around gamification and intra-workforce competition. There are some reasons to believe that this critique of gamifying actual IWC-relevant work processes does not necessarily apply to the gamification of the use of the E^3 Platform itself. Users will be mainly in management positions, who are used to work in a competitive environment in which their performance is measured and monitored. Moreover, the 'game' in which they will engage by using the E^3 Platform is situated on a higher level than their actual workplace and can span entire sectors and transcend national boundaries.

We close this report with a reflection on conducting research itself, which ought to have relevance for the future success of the E^3 Platform. Despite having learned a great deal about organisational and contextual factors during the fieldwork, it is very likely that additional site visits will reveal more of these factors. In other words, we cannot be sure that the lists of factors are complete. It needs to be remembered that our research did not cover some potentially interesting sectors and locations. One indicator of incomplete research is the absence of saturation.

Saturation is reached when additional fieldwork does not generate new insights. We can be confident that we have not yet reached that stage as we still discovered new aspects during our last site visit in the UK. In some sense, incompleteness is unavoidable given the brevity of time given for completing this research. The lesson is, however, that those who will be involved long-term with the E^3 Platform need to continue to pay attention to human and organisational aspects and keep on adding to the list of identified organisational and contextual factors.