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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

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The aim of conducting the case studies as part of WaterWatt Project is to understand how industrial water circuits work in practice and in particular contexts. For our technical colleagues, the case study approach has been important to help them in their efforts to incorporate the modelling of water circuits into the E^3 Platform. From our sociological perspective, the case study approach has proved to be an excellent method to develop our understanding of the organizational dimensions of achieving greater energy efficiency. The case studies have helped us to formulate organizational factors, as well as produce a list of relevant contextual factors, which essentially represent the conclusions of this work (see D3.3). The following sets of case studies have been conducted

- 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
- A steel plant in the United Kingdom in May 2017

2. Introduction

Our understanding of the organizational aspects of achieving increased energy efficiency in Industrial Water Circuits (IWC) over the course of the WaterWatt project has benefitted from two parallel processes. On the one hand, conducting case studies in a variety of countries and sectors has helped to identify and to distinguish what might be referred to as 'universal' and 'local' factors that influence the degree of energy efficiency in IWC. An example of a universal factor is the requirement for energy efficiency measures to be cost-effective for the company. An example of a local factor are energy prices, since they vary widely from location to location: the lower the energy prices, the smaller the cost-saving gains from investment into energy efficiency measures which means that investment into energy efficiency measures becomes harder to justify.

On the other hand, discussions within the WaterWatt consortium, partly informed by insights established during the case study research, about the direction and focus of the organizational aspects of the project have moved forward. This has led to a re-evaluation of priorities and focus points. For example, our original understanding of the project proposal suggested that the modification of work processes with the aim to increase energy efficiency through 'gamification' might be a promising route. Feedback from participants in the case studies as well as clarifications within the WaterWatt project have led to a shift in focus away from gamification towards a more thorough understanding of contextual features that can influence decision-making in companies that in turn impacts on the degree of energy efficiency of IWC (see D3.3).

The shift in focus regarding the organizational aspects of the WaterWatt project is reflected in the shifting attention paid to particular issues during the fieldwork underpinning the case studies. In other words, the chronological sequence of the case studies reflects the shifting attention paid to different issues.

The first fieldwork was conducted in a steelwork in Germany in June 2016. Specific attention has been paid to opportunities to 'gamify' certain work processes in order to achieve behaviour change that leads to greater energy efficiency. Despite our focus on gamification, the interviews revealed that a number of contextual features influence those decision processes that can have an impact on energy efficiency in IWC. For example, companies that are part of an Environmental Management Scheme have a greater incentive to look at energy efficiency in IWC due to the link between EMS and access to state subsidies. This introduces an element into the companies cost-benefit calculation accompanying investment decisions that is absent in a company that is not participating in an EMS. Thus, an energy efficiency investment that is not cost-effective for the latter company, might turn out to be cost-effective for the former company due to the access to subsidies.

The second set of case studies involved a steel plant and a non-ferrous metal plant in Norway in October 2016. The focus remained on gamification as a main element in the WaterWatt approach to increasing energy efficiency by organizational means, but brought different considerations to the fore. Norway is a unique place in Europe because of the extremely low prices for renewable energy and for water. Here, the good intentions of the WaterWatt project are strongly tested. While it is difficult enough to encourage companies to look into the efficiency of their IWC due to the relative marginality of IWC as energy users, this becomes even more challenging in a context in which any reduction in energy use only leads, if at all, to very small cost saving.

The third set of case studies, conducted in a paper and a sugar plant in Portugal just after the second joint project meeting, has shifted away from focussing on gamification. Instead, as much attention as possible has been directed towards understanding as many contextual features that either influence decision-making around energy efficiency or influence the way in which a company will use or interact with the proposed E^3 Platform. With regard to the former, for example, we established that priorities concerning the maintenance of IWC are influenced by the way in which production is organized. In companies with 'in-line production' where every production step relies on the previous step, the goal of maintenance is to keep the whole of production running with consequences for the way maintenance is done. For example, instead of replacing faulty parts, there is a preference for patching them up even though this might mean lower energy efficiency. With regard to the latter, we have asked participants directly whether they actually know the technical parameters needed to self-assess their IWC using the E^3 Platform and if not, what kind of barriers they are facing to obtain them.

The diversity of context found in Germany, Norway and Portugal encouraged us to add a fourth set of case studies. Two steelworks in the UK were approached in early 2017 to negotiate access. These negotiations eventually resulted in one additional case study in one of the steelworks as we were unable to gain access to the other plant despite promising preliminary talks – the plant management decided the project was not of interest. The interviews in the UK steelwork were conducted in a different sequence compared to other case studies. In other case studies, our technical colleagues usually visited the companies before us and already focused on specific sections and water circuits, which then structured the sociological interest. In the UK case study, the sociologists gained access first, with technical colleagues following us. Without specific water circuits or parts of the plant to focus on, we conducted interviews with maintenance managers and a technical engineer on general issues, such as economic environment, current strategy and particular efficiency programmes affecting IWCs in the plant. The interviews provided further new insights into how particular contextual factors can shape companies' approaches to energy efficiency. Operating in an extremely challenging and pressurized economic environment provided us with new and unexpected insights into decision-making concerning investments, including investments into a more energy-efficient infrastructure.

Table 1 summarizes the sets of case studies within the Waterwatt project.

In what follows we present the case study data – it is from this data that we draw conclusions on 'organizational indicators' (now discussed in terms of contextual factors – see D3.3), which are the subject of project deliverable D3.3 and the 'human and organizational' data for informing the E^3 Platform[1].

[1] All data that might lead to the possible identification of the case study sites has been removed.

Table 1: WaterWatt case study research by country, sector, company and interviewee

Set	Country	Company	Sector	Interviews	Length of Visit
1	Germany	Steel Co. DE	Steel	• Maintenance Manager • Senior Technician (Electrical) • Senior Technician (Mechanical) • Environmental Manager	2 days
2	Norway	Manganese Co.	Non-Ferrous Metals	• HR Manager • Environmental Manager • Senior Technician	0.5 days
		Steel Co. NK	Steel	• HR Manager • Senior Technician • Operator	0.5 days
3	Portugal	Cardboard Co.	Pulp and Pa-per	• HR Manager • Environmental Manager • Maintenance Manager • Senior Technician	2 days
		Sugar Co.	Food and Beverage	• HR Manager • Maintenance Manager • Senior Technician	1 day
4	United Kingdom	Steel Co. UK 1	Steel	• 3 Maintenance Managers • Technical Manager	1 day

3. Case studies

3.1 Case study in Germany: steel plant

3.1.1 Sources

2 day site-visit; total of 4 recorded interviews lasting between 1 and 2.5 hours respectively; Interviewees: Head of Maintenance, Team Leader Mechanical Maintenance, Team Leader Electrical Maintenance, Environmental Manager; 1.5 hour detailed tour of the main water circuit

3.1.2 Introduction

Can gamification be helpful in reducing the energy use of Industrial Water Circuits (IWCs)? Gamification is an organizational intervention: certain human activities are structured in a way to incentivize particular behaviours with the goal to achieve pre-defined outcomes (higher productivity, more energy efficiency etc.). In our case, the aim is to evaluate whether there are any activities performed by employees of the plant that can be structured in such a way that they contribute to reducing energy use in IWCs. Another potential area that might benefit from the introduction of gamification elements is related to support and/ or to improve the collection of data in a given company, which then feeds back into the E^3 Platform.

Energy use in IWCs can be reduced in two ways: use the IWCs less or use the IWCs more efficiently. There are two related context-specific questions to be answered:

1. Is there, in theory, any scope for gamification in the German steel plant?
2. Do these options, in practice, make any sense?

3.1.3 Production-independent factors influencing energy use in IWCs

3.1.3.1 Energy using equipment

To our knowledge there are two main energy consumers within the IWCs of the plant: firstly a range of pumps needed to move water around and secondly electric fans that are part of the cooling towers.

With regard to pumps, they fulfil a variety of different functions in IWCs. First, there are extraction pumps that get water out of a local river and into the water circuits. Second, there are the main circuit pumps that create the required pressure within the circuit and help to move the water along. Third, there are cooling tower pumps that, when required, pump the warm/hot circuit water into the cooling tower to maintain the desired temperature of the circuit water.

The cooling tower pumps and fans are only switched on if water temperature in the main circuit rises above a 25 °C threshold to provide cooling. The threshold of 25 °C was explained with reference to the prevention of Legionnaires' disease.

Another, probably very minor energy user that is part of IWCs is the digital control infrastructure – monitors and switch boards – that allows operators to monitor the IWCs in numerous locations within the plant. Another minor amount of energy is presumably used for lighting up areas in which important parts of the IWCs are housed. The lighting at the whole plant has been recently replaced with energy efficient LED.

3.1.3.2 IWC internal activities that impact on energy use

In the studied plant, the IWCs have benefited from a recent modernization drive that has focused on technological solutions to minimize energy use as far as possible. The use of numerous sensors constantly measuring pressure and temperature of the water as part of a digitalized control infrastructure in conjunction with frequency-regulated pumps has led to an increased optimization of energy use in the main IWC. According to our interview partners, there is currently not much room for further improvement of energy efficiency within the IWCs themselves. They mentioned the need for a few more sensors and a more complete control infrastructure that allows for more fine grained measurements of energy use at the level of individual energy-using components of the circuits.

Interview partners emphasized that the exclusive reliance on technology to improve energy efficiency has been deliberate. Within the context of IWCs themselves there is only very limited room for human actions to influence the way energy is used. This relates to the continuous maintenance of IWCs as insufficient maintenance can increase energy use: leaking pipes require more energy as pressure has to be kept up, blocked pipes and blocked valves increase the energy use in the circuits as pumps have to work harder than normal, worn or defect pumps need more energy and so on. As maintenance work is the only type of human behaviour we were able to identify that impacts on energy use in IWC it is, in theory at least, the only area that offers some potential for behaviour changes through gamification. In the practical context of the German plant, however, this potential is very limited. Staff directly responsible for the maintenance of IWCs operates on three different levels: a section manager (interviewed), two foreman (both interviewed) that lead their own sections (electrics and mechanics) and operators that either work in the mechanical section (28 staff) or in the electrical section (18 staff). According to the section manager and the two section foremen, there is neither need nor desire to introduce gamification to reduce energy use at the foremen and operator level. Several reasons have been given:

1. Energy use in IWCs is production-driven, thus IWC operators cannot control the energy use of IWCs
2. Competitive elements might undermine existing trust relationship between workers, foremen and manager
3. Non-awareness of concrete energy reduction targets by operators
4. Non-comparability of individual tasks (2 workers can repair the same problem in the same type of pump and one might need 1 hour and the other might need 3 hours – this can be due to complications that are beyond the influence of the individual)
5. Difficulties in measuring potential energy savings of individual workers' action

It can be argued that despite the actual energy use of IWCs depending on production, production-independent measurements such as the actual energy efficiency of the circuit (expressed, for example, in measurements like ‘energy use per cubic metre’) could still be used to capture the influence of maintenance as such since ‘bad maintenance’ should lead to a lower degree of energy efficiency compared to ‘good maintenance’. The other reasons listed above, however, make the introduction of a gamification approach practically impossible at IWC operator level in the German plant. Other companies might be more open in this regard.

Some of the reasons against the introduction of gamification at foremen and operator level do not apply at manager level. First, the maintenance manager is fully aware of specific annual energy reduction targets that are issued by general management. Second, the maintenance manager is responsible for IWC related budgets and therefore in a position that allows him to make meaningful investment and organizational decisions that can affect energy use of water circuits. Third, while the specific energy use of individual parts of IWCs, such as pumps or fans, could not be measured at the steel plant before 2017[2] global energy use of IWCs is constantly measured and currently informs year-on-year comparisons. Fourth, as part of management, the maintenance manager is, like other all other staff at management level, exposed to a metrics culture that evaluates and rewards performance with the help of Key Performance Indicators (KPIs), of which one is related to specific energy reduction targets. While issues of comparability would still have to be resolved[3], the interviewed manager expressed interest in benchmarking and other potential comparison with peers in other companies who are also responsible for IWCs.

3.1.4 Production-related factors influencing energy use in IWCs

Industrial Water Circuits serve clearly defined purposes within specific industrial settings; their existence is therefore always auxiliary to or in support of other processes within a plant. In the plant, the main purpose of the IWCs is to provide water for various uses – such as cooling or cleaning – in a variety of production processes. It is therefore not surprising that specific production processes shape the energy use of IWCs. The production processes that are supported by IWCs shape the water circuits’ energy needs in two principal ways:

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[2] The individual measurement has been installed in January 2017.

[3] One problem is that energy use itself is dependent on production processes and therefore beyond the direct control of the maintenance manager. This is resolvable if instead of energy use a metric that reflects the degree of energy efficiency can be constructed. Another problem is that while the maintenance manager has responsibility for IWC related budgets (two separate budgets: one to cover maintenance work and to cover energy costs) the size of each budget is beyond his control and can make comparisons even within company that owns the particular steel plant difficult. Within the company special budgets attached to environmental goals are occasionally allocated to managers that allow them to do things that their normal budgets would not allow them to do. Such budgets, unless evenly distributed, can distort the measurement of managers’ performances. Of course, budget sizes could be taken into account in constructing a metric that affords comparability.

1. Structurally (i.e. independent of actual instances of production): in the sense that the dimensions of IWCs (as manifested by power of pumps, diameters of pipes, size of cooling towers etc.) are driven by the requirements as defined by production processes. Interview partners, for example, stressed the fact that the IWCs have to maintain a certain level of water pressure as required by production processes and to generate this water pressure, the pumps need to be of a certain size which impacts on energy use. For efficiency this means: efficiency gains through correct dimensioning of circuit and permanent modernization of equipment, especially pumps.
2. Immediately: in the sense that the actual energy use of IWCs depends on the momentary water demand of the production. This does only apply if IWCs can be regulated and have an adequate control infrastructure [organizationally (operators switching things off) or technologically (through pressure or temperature sensors and frequency converters)]

3.1.4.1 Structural factors

With regard to structural determinants of energy use in IWCs, interviewees stated that the specific water circuits in the plant were efficiently dimensioned. Interviewees insisted that fulfilling its function in the plant, the crucial parts defining energy use within IWCs – pumps, fans, pipe diameter and length of piping system and so on – were all of sizes and/or power that were deemed necessary and appropriate. For example, the pumps have to be of a particular size and power to generate the required pressure within the system. The cooling towers and their fans have to be of a certain size and capacity to be able to achieve the required level of cooling. Gravel filters also require some space and their actual position within the IWC might be a necessity and may not be ideal from an energy efficiency point of view (i.e. positioning might lead to longer pipes and greater loss of energy).

Not all changes to production processes will have structural consequences for IWCs. For example, increasing or decreasing the staff numbers involved in a particular step of the production process is unlikely to affect the structural demands of IWCs. Nonetheless, when production processes are re-organized in such a way that they permanently (or structurally) affect the demand for water in one way or another (increase or decrease), they become relevant for our purposes. An example mentioned by an interviewee concerned the use of more heat resistant materials in the rolling mills, thereby reducing the cooling needs as steel can be rolled at a higher temperature without damaging the rolling mill. Another measure, which has already been implemented, is to heat raw steel in such a way that it has the exact required temperature thereby reducing the need for water cooling before the steel is rolled.

It appears that changes to production processes that bring about structural changes to the energy consumption within IWCs usually require significant capital investment and cannot be achieved through behaviour modification at operator/staff level. Instead, the behaviour of managers with decision-making powers regarding capital investments is crucial. Thus, introducing gamification elements at managerial level might encourage behaviour in the sense that managers are steered towards decisions that reduce the energy use and/or increase energy efficiency of IWCs. It is, however, important to note that reducing energy use and improving energy efficiency are not goals in and of themselves for the management of the maintenance section in the German steel plant: for example, one interviewee mentioned that the pump that controls the water flow into the cooling towers is not the optimal pump in terms of efficiency. A slightly less powerful pump would reach a better degree of efficiency, but other considerations (uniform use of same pump type throughout the plant IWCs to provide cheaper maintenance and greater reliability) swayed the decision of managers. It seems that overall cost effectiveness is the main concern for decision-making managers. It is therefore important to note that the worth of incentives/rewards/benefits introduced by gamification is relative to the specific cost context. In the above example, managers were happy to accept slightly higher energy costs in the hope they would save costs on maintenance. The exact calculation that underpins that decision is unclear, but in case that maintenance costs trump energy efficiency gains by margin X, rewards associated with gamification elements would have to be larger than X (the maintenance cost savings) to influence the manager's behaviour in the desired way (i.e. steering them towards higher energy efficiency).

3.1.4.2 Immediate factors

The situation is different with regard to 'immediate production-related organizational factors' that influence energy use in IWCs as there is potentially scope for the introduction of gamification elements at operator level. As pointed out, 'immediate factors' refer to specific events or processes in production that impact directly upon energy use in IWCs. In the context of the studied plant, a concrete example was given by an interview partner: when there is a pause in the actual rolling of steel, operators can manually switch of the supply of cooling water for the particular rolling mill that is idle. By doing so, not only is the energy use of an IWC reduced but it also increases energy efficiency of IWCs when measured as energy expended in IWCs per produced ton of steel products. This operator-behaviour dependent element of the production process will soon be replaced by an automated process in which sensors regulate the water supply. Despite this not being a practical option in the plant, the introduction of gamification elements to steer operators towards behaviour that saves energy, i.e. encourages them to press a stop button as soon as the production process stops, and might be an option in other plants. In fact, gamification might help overcome difficulties in adapting energy saving behaviour on the part of operators. One interviewee reported that despite operators having the option to switch water off when there is a pause in production, some operators do not do this. One reason reported was scepticism about the reliability of technology – in this case the reliability of the switch – as operators were apparently doubtful as to whether the water supply would really be re-established when required. Introducing gamification (with its associated rewards) might help operators to overcome their scepticism regarding the reliability of technical elements such as buttons and switches or to develop back-up solutions.

Gamification elements related to immediate factors that shape the energy use of IWCs appear suitable for introduction at management level to steer managers' decision-making behaviour towards energy saving and increased energy efficiency. The advantage of gamification elements at management level compared to operator level is that it can be implemented regardless whether the actual energy saving or efficiency measures are of technical or organizational nature because at that level decision-making with regard to investments is targeted.

3.1.5 The wider context

Whether the reduction of energy use in IWCs is treated as a goal in its own right by a company and whether gamification is considered to be a useful tool in reaching this goal depends to some degree on features that go well beyond IWCs and their function within production processes. We can distinguish at least five contextual areas:

- Regulatory (EMS, national, European)
    - Makes continuous energy reduction a necessity (due to link between EMS certificate and access to state subsidies)
    - Economic (energy market, competitiveness in sector): current structure of energy markets and high competitiveness in sector create economic incentives for energy reduction as it contributes to cost-savings
- Cultural (paternalism, hierarchies of responsibility & high trust relationships)
    - Cultural environment in the studied plant, while facilitating the reduction of energy use through consensual modernization, acts also as a barrier to the introduction of gamification as this requires some form of performance control and measurement, which is perceived to be counter-productive by maintenance management/foremen
- Organizational (training/education/bottom-up innovation scheme/costs v control);
    - Availability of in-house and external training schemes should mean that potential skill/know-how related barriers to the implementation of gamification elements can be overcome
    - Internal bottom up innovation scheme already uses gamification (cash rewards) to contribute to reduction of energy use
- 'Material context': complexity of controlling and optimizing IWCs

It has to be noted that these contextual features are just that: contextual. In and of themselves, they do nothing to reduce or increase the use of energy. The wider context can, however, be analyzed with regard as to whether it constitutes a barrier or whether it is conducive to energy reduction efforts. In the following discussion, a range of contextual features is analyzed by considering how they benefit or inhibit energy reduction efforts in general and, where appropriate, energy reduction efforts that involve gamification in particular.

3.1.5.1 Legislation/regulation

The studied plant is subject to several layers of legislation given its simultaneous location in European, national, federal and municipal jurisdictions. The interviews with staff at the steel plant brought up two different regulatory frameworks that appear to be relevant for energy use and energy efficiency. First, the plant is subject of the Federal Anti-Pollution Laws (Bundes-Imissionsschutzgesetz), which also reflects European regulations, but, according to one interviewee, at times goes beyond European norms. This environmental protection law regulates what and how much an industrial plant can emit (pollutants, noise, and other disturbances) into the environment, i.e. into the air and water. One interviewee, while stressing the importance of the anti-pollution law for the proper running of the plant, emphasized that the water circuits are not really affected. Of course, this might change in the future in case emission thresholds written into the anti-pollution law are tightened or if the company fundamentally changes its attitude towards the law from 'mere compliance' to 'actively going beyond' legal pollution thresholds.

Also part of the regulatory framework, although seemingly voluntary, are Energy Management Systems (EMS), which have a profound impact on energy use and efficiency within the plant as a whole, which includes IWCs. By utilizing an EMS, companies open themselves up to audits and certification through compliance with prescribed standards and norms. Obtaining the certificate then brings additional financial rewards in the form of access to state subsidies. The most significant aspect of EMS appears to be the built-in year-on-year energy reduction targets that apply at plant level. This means to remain EMS certified, a company needs to reduce its energy use by a set target every year. According to interviewees, the company joined an EMS two or three years ago. Environmental concerns do not seem to play an overtly important role for the company. All interviewees agreed that it is good to do something for the environment but that economic considerations – access to subsidies and the chance to stay competitive – played a bigger role. It is not clear how much the relatively recent modernization of IWCs in the studied plant can be attributed to the EMS, but it is clear that being part of such a scheme puts continuous pressure on the company to reduce energy use and to find efficiency gains. While the IWCs are relatively small energy user in the context of the plant, the continuous pressure to reduce energy use mean that management cannot afford to overlook the IWCs when searching for opportunities to comply with the EMS targets. Membership in the EMS appears to nudge management into making investment decisions that have energy reducing effects. For example, when it comes to replacing or modernizing equipment, energy use becomes a relevant criterion in the decision-making process as management is keen to retain access to subsidies that come with meeting the EMS targets. Such decision-making process is aided by another feature of EMS. The system makes it obligatory for members to monitor and measure the energy use of the various pieces of equipment within the company. While such a detailed monitoring system has not yet been fully implemented in the IWCs of the German steel plant (monitoring stops at transformer level), plans for rolling the system out in such a way that the energy use of every piece of equipment is measured are in place.

In sum, the regulatory context in which the studied plant operates, especially the participation in an EMS, emphasizes the importance of reducing energy use in the plant in general and its IWCs in particular.

3.1.5.2 Economic environment

Another contextual feature impacting company-level decision-making regarding the reduction of energy use in IWCs is the wider economic environment in which the plant operates. In particular, two important features have emerged:

1. Competitiveness
2. Energy-markets

All interviewees mentioned – mostly implicitly – the need for the company to stay competitive. While we have not explicitly explored the competiveness of the market environment in which the company in general and the studied plant in particular operate, it seems obvious that the more competitive the environment in which any given company operates the higher the pressure to be as efficient – and that includes being energy efficient – as possible as this reduces production costs. As such, market-driven competitiveness represents a 'natural' form of gamification – in this case, 'survival' is the main goal of the 'game'.

The other notable development in the economic context has been the transformation of the energy markets over recent years. One interviewee explained that until a few years ago, the company bought energy in bulk for a whole year from a supplier, which effectively resulted in a flat rate for energy costs: the price for energy would always stay the same throughout a whole year as long as the company did not exceed a certain level of use – interviewees referred to this as 'the line'. Going over 'the line' would result in a penalty. While such an arrangement nudges management into ensuring that energy use does not exceed a certain level at any point in time, it does not reward continuous reduction of energy use like membership in the EMS does. The penalties for going over the 'line' also nudge buyers into buying more rather than less energy than is needed, thus further reducing the pressure to save energy. The creation of energy spot markets has changed the practice of buying energy for the company completely. Instead of agreeing to buy in bulk for a year, part of its energy needs are satisfied through buying on daily spot markets (although this is only a supplementary form of energy buying, they still seem to have a particular supplier to cover some of their needs). This can have profound effects as this opens up the possibility to adjust production to the fluctuations of the prices that come with energy being traded on energy exchanges. Interviewees intimated that this is something that is being explored by the management of the company. Apparently, furnaces in other plants are equipped with monitors that feeds live prices from the energy market to the operators of furnaces so that they can start production processes when energy prices are low etc.

Our limited information on the economic context in which the company operates suggests that it does not seem to create a barrier for active and continued energy reduction measures. As such, the economic context does not per se prevent the introduction of gamification elements.

3.1.5.3 Organizational culture

The same cannot be said about the organizational culture within the studied plant, which might act as a barrier to the introduction of competitive gamification elements. In this regard, the conducted interviews in conjunction with observations during a plant tour suggest two elements of the company culture that might create difficulties for the introduction of gamification:

1. high trust work relationships
2. paternalistic management

The studied plant is very small in terms of employees: about 400 people work there. From observations during a tour of the plant and from responses by our interviewees, it appears that a lot of employees know each other personally and, according to interviewees, these personal relationships go beyond the work place. The close personal relationships between staff allow for high-trust work relationships that minimize elements of control. Interviewees pointed out that workers at all levels, while being expected to do their best, seem to enjoy a great deal of autonomy. Introducing competition – however playful – between workers by measuring their performance for gamification purposes does not appear to be welcomed by managers and foremen. They seem to value the benefits of a satisfied workforce that gets on with each other higher than possible cost-savings through the introduction of competition. High trust work relationships should save the company a lot of money as control measures, i.e. performance measurements, are not needed.

The other cultural element in the company that might act as a barrier to the introduction of gamification for the purpose of energy reduction is the paternalism displayed by management. In the case of the studied plant, management seems to limit the information it transfers down the hierarchy. With regard to energy reduction, for example, specific reduction targets are communicated only to the lowest level of management in the company (e.g. the maintenance manager) but not beyond. This means that ordinary workers and operators might be generally aware that the company needs to save energy, but they do not know how much exactly and whether they or they section have to find specific savings or not. One interviewee referred to the practice of limiting information to low level staff as ‘filtering’. He offered two different rationales for this:

1. Responsibility: ensuring compliance with energy reduction targets as demanded by membership in the EMS is regarded as the responsibility of the management. As workers/ operators are not responsible they do not need to know details.
2. Overburdening: another rationale appears to be that management does not want to overburden ordinary staff with too much information. Management worries about two forms of overburdening
    a. Staff receives limited information to protect them from worrying about meeting specific targets (protecting staff from stress)
    b. Staff receives limited information because management seems to assume that they cannot process and make sense of this information (related to epistemic capacity)

As this is based on the account of a single person, we do not know how accurate this information is. If correct, it might be difficult to convince management to support the introduction of gamification elements to encourage energy saving behaviour at worker/operator level as management might not see energy reduction as the responsibility of workers or feel that this overwhelms the burdens low-level staff with regard to their epistemic capacities.

In sum, the high-trust work relationships appear to represent a bigger challenge to the introduction of gamification elements in the context of the studied plant than the paternalistic management style because gamification would add an unwanted layer of competition and control to work relationships that has the potential to destroy trust within the company (which might lead to higher costs in the long-run as trust has to be replaced with control mechanisms). Reservations against the introduction of gamification due to paternalistic management style appear to be surmountable as long as management can be persuaded that gamification does not require more information to be given to workers and does not overburden workers.

3.1.5.4 Organizational features

The interviews have also contributed to the identification of two organizational features that might play an important and facilitating role in the potential introduction of gamification at worker/ operator level.

1. Bottom-up innovation scheme
2. Extensive training opportunities, both internal and external

One is a bottom-up innovation scheme that already exemplifies certain gamification aspects. Every member of staff in the studied plant can – and is seemingly encouraged – to make suggestions that lead to improvements within the plant. According to interviewees, any member of staff in the plant can complete a basic form on which they can outline their innovation. While the majority of the roughly 200 proposals submitted by staff every year deal with improvements related to health and safety or the ergonomics of certain processes, an unspecified number are proposals to save energy. With regard to the latter, the interviewees made clear that such proposals do usually concern improvements that are immediately visible to staff, such as more energy efficient lighting of particular work areas or improving certain production processes so that less energy is used[4].

The suggestions submitted by members of staff which concern energy savings are passed on to a committee that checks each proposal for its economic value. The projected savings per year are translated into points (the exact basis for this calculation has not been explained to us) and the points are then translated into Euros[5]: 1 point equals € X and a suggestion is accepted and will be implemented if it reaches 8 points. This also means the minimum bonus a member receives for a suggestion is €X. In addition to the bonus payments, an interviewee reported that management would create additional incentives to increase the number of bottom-up suggestions in the form of prize draws or one-off extra bonuses. There was some ambiguity about the level of publicity that successful innovation proposals receive. In general, successful proposals are not publicly announced. The reason given is that publicizing individual achievements might increase jealousy among staff. Especially successful proposals, i.e. proposals that score 100 and more points in the assessment, will get publicity: they might be mentioned at staff assemblies and receive a write-up in the company newspaper.

We asked one interviewee in a management position to describe the extent to which the bottom-up innovation scheme contributes to energy savings in comparison to top-down management in the steel plant. The interviewee estimated the relation to be about 50/50 if monetized cost-savings are not taken into account. It is not entirely clear what he meant but the most plausible interpretation is that there are as many bottom-up proposals as they are top-down-

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[4] These bottom-up proposals do not include suggestions that concern capital-intensive upgrades or modernisations of production equipment: one interviewee pointed out that such decisions, for example the decision to modernise burners in an oven or to upgrade all pumps in the IWCs are management decisions and that management would not expect operators to make such kinds of suggestions.

[5] To protect potentially sensitive information the exact amount of money paid out to staff members will not be revealed.

proposals. When energy savings are translated into cost-savings, however, the relationship was described as being more like 70/30 in favour of top-down initiatives. This is relatively surprising estimate given the difference in capital involved in the two approaches. A scheme such as a bottom-up innovation programme that is linked to financial incentives can successfully contribute to energy saving in general. In one sense, the scheme can be characterized as introducing a gamification to the general workforce by rewarding successful contributions. Instead of presenting an opportunity to introduce gamification more widely in the studied plant, it is probably more correct to say that this is as far as management is willing to go with gamification as the reluctance to communicate success of individuals' suggestions shows.

3.1.5.5 Training

The other organizational feature is the availability of a range of external and in-house training programmes, which include intranet based e-learning opportunities for all staff at the plant. Especially the internal e-learning platform can play an important role in sensitizing, informing and training staff with regard to the theory and practice of energy saving in general. This concerns both technological and organizational approaches to energy efficiency, i.e. staff can be trained to deal with new technologies or new ways to do things (behaviour change), which should make the implementation of innovative pathways to energy efficiency such as the planned E^3 Platform possible.

3.1.6 Conclusions from German case study

There are at least two main WaterWatt Project relevant conclusions that can be drawn from this case study. First, while companies like the one studied are part of a fiercely competitive landscape in their sector, managers and those in supervisory positions appear to be very reluctant to introduce any form of intra-workforce competition. In interviews, this form of competition has been rejected by citing the desire to maintain intra-workforce harmony, which those with supervisory powers see as crucial to focus the efforts of the workforce on maintaining external (or market) competitiveness.

Second, the importance of what we will call contextual factors or contextual features has emerged. These factors are important in several different ways: firstly, they are important for the WaterWatt consortium as developers of the E^3 Platform. This comprises two crucial aspects: first, determining the future functionality of the E^3 Platform depends on an understanding of the factors that influence a company's investment decisions. What does this mean? There are certain context-independent elements in an investment decision such as the 'maximal theoretical efficiency' (MTE) that an IWC can reach. In principle, the E^3 Platform will be able to calculate the MTE in any given company no matter the location. Knowing the MTE, while highly relevant for investment decisions, is not in itself sufficient to convince a company to invest in IWC to realize as much of the MTE as possible. In the case of the studied company, for example, technical experts would undertake a detailed cost-benefit calculation to establish whether an investment in increasing the energy efficiency of any circuit is also cost-efficient. The problem that

E^3 Platform developers face is that cost-benefit analysis is highly context-specific because such an analysis is based on very local parameters such as wage costs, maintenance costs and energy costs that might not even be the same in the various production sites that make up a large company. Thus, while context-free aspects such as MTE can be calculated accurately using the same formula in any given place, context-dependent aspects require a different formula in any given place. Secondly, contextual factors also help the WaterWatt Consortium to think about marketing the E^3 Platform. The German steel plant case study has, for example, shown that despite the fact that the maintenance division responsible for the IWC understands and knows the circuits very well – recent modernization includes digitalized control infrastructure providing a continuous stream of technical data – certain crucial information needed for the self-assessment using the E^3 Platform, such as pressure loss in specific circuit units or a complete picture of energy use of different elements of IWC, cannot be easily obtained. In this respect, ensuring the provision of 'consultancy' as part of the WaterWatt legacy to help companies obtain the data they need to self-assess their IWC would be crucial.

3.2 Two case studies in Norway: steel plant and non-ferrous metal plant

3.2.1 Background

Sources: material from website of the industrial park; two brief and unrecorded interviews with three people from the energy and water division within the industrial park; informal conversations with a range of people with knowledge about the park; observations in water supply control room

The two plants are located within an industrial park that hosts a wide range of industrial concerns. The park can be regarded as an industrial cluster as it has attracted more than 100 companies. Both the holding company, which runs the park, as well as the companies that populate and use the available infrastructure are locked into a complex network of relationships and interdependencies.

While this complex web of interdependencies appears to be mutually beneficial in many ways, there is also potential for conflicts. We know this because some interviewees hinted at tensions between companies and the park. One interviewee complaint about varying pressure in the pipelines in which the industrial park delivers water to the companies. Another interviewee, apparently not really happy with the prices charged by the park for water, pointed out that the industrial park earns several times: by selling water to companies located in the park, charging for waste water and by operating turbines up- and downstream of the park to generate energy that is then sold to the companies. Other interviewees, however, claimed that no conflicts existed. The few hours spent at the park, however, were not nearly long enough to understand the complexity of the relationships and the potentials for conflicts.

The industrial park holding company operates the infrastructure for the whole park (up to the individual plant walls). It depends on the definition of what a 'water circuit' actually is whether industrial park is operating one or whether it merely supplies water to its users. According to the working definition of the WW project, the holding company is merely supplying water. The water – mainly rain and melt water – is collected on higher ground a few kilometres from the park. A pipe-line system transports the water to all end-users in the industrial park. The park is supplying contractually agreed amounts of water that comes with a naturally generated pressure of around 6 bar. The pressure is generated by the difference in location above sea-level between the water reservoirs and the industrial park. This also means that the park's 'circuit' does not require any energy to move the water.

3.2.2 The non-ferrous metal plant

3.2.2.1 Sources

Two recorded 40 minute interviews, one with a technical person and the other one with two persons with administrative responsibilities; no tour of the plant or the IWC

3.2.2.2 Background

This is a very interesting case as it tells us a lot about the potential limitations of the E^3 Platform. Two furnaces are at the centre of the production of a non-ferrous metal. We conducted two separate interviews with a total of three members of staff. One 40 min interview was conducted with two members of staff responsible for Human Resources and for Environmental Management respectively, while we were also able to speak to the head of technical operations for a similar period of time.

3.2.2.3 The IWCs

There are two separate water circuits in operation at the plant:

1. A cooling 'circuit' to cool the furnaces
2. An open gas scrubbing circuit to clean off-gas

At the moment, the cooling 'circuit' does not use any energy as it simply uses the water-pressure of around 6 bar as it is delivered by the supplier to channel cold water through a dense pipeline network around the furnaces. There is, however, a firm plan in place to change this approach to cooling and create a proper cooling circuit due to regulatory requirements. Due to the dangers of potential water leakage into the furnace, companies are required to account for all the water that is used for cooling furnaces and this is apparently not feasible when water is simply channelled past the furnace. Thus, the company will soon start a NOK 30 m project to build a closed cooling circuit that requires energy. The main energy users in this circuit will be a pair of frequency-regulated pumps (each uses 171 kw/h). Interestingly, frequency-regulated pumps are not really necessary in the plant because production is stable and uniform, which means that the water circuit usually runs in the same way. An interviewee mentioned, however, that the frequency-regulated pumps were the cheapest type of pump available.

The plant has a second water circuit that is used to scrub or clean the off-gas that is generated during the production process. Water is pressed through tiny valves in an enclosed space through which the off-gas is guided. The fine water droplets ensure that some sort of chemical reaction is going on and stuff from the gas mixes with the water. The water is then treated before it can be reused or released. This circuit has 13 pumps at various points in the circuit. The circuit is automated and runs without any specific human intervention.

Interestingly, the plant generates more waste water – between 400 and 450 m^3/h - than its water treatment facility can handle (about 200 – 250 m^3/h). This means that about half of the waste water is kept in the system. This means partially cleaned water is pumped back into the scrubbing circuit. Just taking energy efficiency into account for the moment, pumping water back into the system requires additional pumping capacity, whereas disposing all the used water down the waste water system would not require any additional energy. Thus in theory at least, energy consumption within the scrubbing circuit could be further reduced. From the company's point of view, however, this theoretical possibility to saving energy is likely to be unattractive as it is not cost-effective. Disposing more waste water also means more disposal costs. This would also require investing in additional water treatment capacity. The fact that energy is so cheap in industrial park is a further barrier for making such investment worthwhile as pumping part-treated water back into the circuit is likely to cost very little.

3.2.2.4 The IWCs in production

The production of the non-ferrous metal is seemingly quite simple and centres on a furnace: a specific ore and other raw ingredients are melted and tapped. We were not able to observe production but all seem to happen in one large hall that houses the furnaces. The production does not seem to require many workers as the overall size of the workforce is small – around 85 employees in total and 45 or so operators who work in a five shift system. Production runs 24/7 all year long without breaks or fluctuations – production always runs on full capacity.

While the water circuits are integral to the production process, no human intervention beyond maintenance tasks appears to occur. The limited time and the expertise of our interviewees did not allow us to understand the maintenance regime in the plant. The high degree of automation in the plant also means there is no scope for production-related organizational interventions that could increase the energy efficiency of the circuits.

3.2.2.5 The wider context

A number of valuable lessons for the development and marketing of the E^3 Platform can be learned from this case study.

1. The absolute stability and steadiness of operations as well as the functional simplicity of the circuit means – as far as we can ascertain – that there is absolutely nothing that can be done organizationally to save energy.
2. The plant is an interesting case because it alerts us to the fact that companies operate in a wider context that greatly influences what 'efficiency' means. Energy efficiency is just one aspect of cost efficiency. Saving energy does not necessarily translate into cost savings as it might increase costs elsewhere.
3. Beyond the wider intra-company considerations, the regulatory context further shapes the meaning of 'efficiency'. Again, in the case of this non-ferrous metal plant, the regulatory demands for a closed cooling circuit shape the options for the company. The NOK 30 m investment in new cooling circuits is not welcome by the company but cannot be avoided. In such a context, changing the cooling circuit from a zero-energy circuit to one that will use 171 kw/h can still be seen as an 'efficient' approach even though it is neither 'energy' nor 'cost efficient'. The 'efficiency' is derived from the fact that without complying with the regulatory demands, the plant would simply have to close.
4. This has implications for the decision guidance function of the E^3 Platform: if the goal is to make the E^3 Platform a full-blown tool that can make meaningful investment decisions for companies, it would have to take into account things like 'water prices', costs of production stops (needed to modernize IWC), labour costs, maintenance costs, local costs for new circuit equipment (exchange rates become important) and so on – this list is potentially very long (contextual factors)!

3.2.3 The steel plant

3.2.3.1 Sources

Three interviews, one of them recorded and about 40 min in length with a team leader in the rolling mill, the other two unrecorded (one about 30 min in length with a maintenance engineer and the other one about 20 min in length with an operator in the rolling mill); observations in control room of rolling mill; no tour of the plant or the IWC

3.2.3.2 Background

The plant produces a range of steel products, mostly wire. It has an electric arc furnace as well as a rolling mill. The plant is connected to the central industrial park water circuit. Contractual arrangements regarding amount and pressure of water to be delivered are in place. Access to staff was insufficient to gain any deep sociological insights into the organization of work around the water circuits. We conducted three interviews: one 45 min interview with an engineer working in maintenance, one brief chat (plus observation) with an operator in charge of monitoring the rolling mill and one 30 min interview with a representative of Human Resources.

3.2.3.3 The IWC in isolation

Our interviews focused on three interlinked cooling circuits in the steel plant. They are interlinked because they are all fed by the same pipe that connects the industrial park system and the plant system: a total of 4 pumps – 2 very old ones from the 1950's and 2 frequency-regulated pumps – are used but pressure within the individual circuits is regulated via separate valves.

Significant parts of the water circuits have been put in place in the 1950s. This includes some of the pumps and most of the piping. The IWC is maintained 'on demand' by maintenance teams. While they officially operate under the control of the manager of the rolling mill, interviewees suggested a high degree of autonomy is prevalent in the plant (and Norway in general). Teams of five maintenance engineers or operators work within a five shift system. Maintenance work is project-led, i.e. maintenance workers ought to mainly work on specific projects and only tend to the maintenance of the IWCs in the event of a break-down or a leakage, which were reported to occur rather frequently given the age of the infrastructure. Pumps were prone to breaking down due to their age, while pipes are reportedly internally rusty and could do with replacement.

Maintenance work is reportedly guided by two main priorities: 1) health and safety; 2) uninterrupted production. In addition to that, an interviewee suggested that energy efficiency is a company objective and that certain targets in this respect have to be met, especially with regard to the efficient use of fuel. Given the reported age and state of the water circuit in addition to the fact that apparently no plans exist to invest in the modernization of the infrastructure, it seems that energy efficiency within the IWCs is not of great concern to the company. Water efficiency is apparently also of no concern.

3.2.3.4 The IWCs in the context of production

Given the limited time spent with interviewees, our discussions around the functionality of IWCs in the context of production centred on the ability of production operators in the rolling mill control room to switch off the water that is cooling certain parts of the rolling mill when the usually constant flow of steel bars into the rolling mill is interrupted. While we did not learn much about the water circuits, we learned about local perceptions regarding water and energy use.

We were given access to the control room and were able to talk to the operator on duty. He showed us three buttons that when pressed would stop the water supply for the section of the rolling mill under the operator's control. After talking for a few minutes, the supply of steel bars was indeed interrupted. The operator did not press the buttons to switch the water supply off. Observing for a while, we asked the operator why he would not use the buttons to switch the water off. He gave us several reasons: first, he suggested that the interruption did not seem serious and that production would commence soon (this turned out to be the case since production restarted within 10 minutes). Second, he also suggested that it would not make any difference given that both energy and water are virtually free. Third, he also rejected any suggestion that an intervention would have an environmental impact as the energy is generated by hydropower and the water is effectively rain and melt water from the mountains that would run into the fjord whatever his intervention.

Another interviewee, who is in supervisory relationship with the operator, confirmed the relaxed attitude toward small measures that might save energy and water. He suggested that he would not expect water supply to be switched off unless the production stop would last at least 10 minutes. He insisted, however, that during longer breaks water would always be switched off. The reason he gave was that the company would now pay for the exact amount of water used, whereas until 2005 the company paid a flat-rate for water, which allowed the company to use as much as they wanted. He indicated that electronic logs of actions in the control room could be used to check whether operators really do switch water off or not. Asked if he ever performed such a check, he answered ‘no’.

3.2.3.5 The wider context

As with the non-ferrous metal plant, the studied steel plant also operates within an industrial park and is therefore also benefitting from an environment of low energy and water costs. Such an environment does not provide any external incentives to invest in the modernization of the water circuit infrastructure despite the problems regarding breakdowns of pumps and leaking pipes.

This context also seems to make it harder to instigate behavioural change as members of staff are aware of the ‘pointlessness’ of saving (rain) water and energy that has been generated in an environmentally sustainable way.

The only identifiable incentive to modernize the existing water circuits would be the prospect of saving maintenance costs – both for parts and for staff. Whether a cost-benefit analysis in this direction exists or not was not established during the interviews.

3.2.4 Conclusions from Norwegian case studies

The fieldwork in Norway has yielded several crucial insights for the WaterWatt project. The most important is that the meaning of ‘energy efficiency’ for companies is closely tied together with the notion of ‘cost efficiency’. Certain practical interventions, such as modernizing IWCs or replace certain energy-using parts of IWCs, will certainly lead to ‘energy efficiency’. This in itself is, however, not enough to motivate decision-makers in companies to make these practical interventions. The reasons have become particularly clear in the Norwegian context in which energy costs, compared to other European countries, are very low. The lower the energy costs, the less companies can actually save in costs through energy efficiency. This means that incentives to invest in energy efficiency measures are comparatively smaller in low-energy-cost countries, such as Norway, than in countries with high energy costs, such as Germany. Consequently, interviewees reported about a general reluctance of decision-making management in the two companies to modernize their IWCs despite their relative age.

This seems to be particularly evident in the case of the steel plant, which operates cooling circuits that are almost 60 years old. Apart from the fact that old pumps are usually less energy efficient than new pumps, maintenance staff also reported frequent breakdowns and leaks. At the same time, interviewees intimated that there were no plans for investment in IWCs and that they did not expect any. Interviewees suggested that this has to do with the fact that such investments are not cost-effective: the amount of energy costs saved through modernizing IWCs would not balance the costs expended for modernization measures.

The case of the non-ferrous metal plant drives the point of inter-dependency between ‘energy efficiency’ and certain contextual features even more clearly home. The plant’s planned modernization of the cooling circuit for the furnace turns the current zero-energy circuit into one that will use around 170kw/h. Thus, instead of increasing energy efficiency, the measures lead to increased energy use. This approach by the company can only be understood by taking the wider context into account: first, the modifications of the IWC have been demanded by regulators. Without these demands, the company would not have changed anything since the overall investment costs by far outstrip potential cost savings, even if a pay-back time of several hundred years is assumed. Second, the modifications also lead to a significant reduction of water use, which will save the company costs. This means that there is a distinct possibility that water-related savings – the company pays twice for water, once for the supply of fresh water and once for the disposal of waste water – outstrip the energy costs incurred by the new water circuit design. This is a finding that reinforces the point that energy efficiency is closely linked to cost-efficiency: a company might actually increase its energy use and still save costs.

The context-dependency of the promise of ‘energy efficiency’ as a motivator for behaviour change has also come into focus during the fieldwork. A particular feature of the Norwegian context is the abundance of water and energy as well their low costs relative to other places in Europe. In such an environment, efforts to save energy in IWC either directly by using more energy efficient equipment or indirectly by reducing the amount of water that has to be pumped around do not seem rational to companies and individuals. The lower the costs for energy, the less cost-effective is investment into energy saving equipment because the pay-back of such investment depends on the actual cost-savings that energy efficiency measures generate. The lower the costs for energy, the greater the energy savings have to be to make investment cost-effective for companies. On an individual level, the opinion that saving water or energy is pointless appears to be widespread. Such a position is understandable once it is realized that the water is effectively rain water which comes from the sky and will end up in the fjord no matter whether it is actually used by industries or not and that the energy is from renewable sources and the actual level of energy use does not matter as long as enough energy is available. This represents a challenge for the marketing of the E^3 Platform: neither an appeal to meaningful economic gains (‘cost-saving’) nor an appeal to ecological sensibilities (‘save the environment’) look like promising strategies to interest Norwegian companies in energy efficiency measures related to their water circuits. Lastly, the low appeal of the E^3 Platform for the Norwegian context negates any potential for gamification.

3.3 Two case studies in Portugal: paper & cardboard and sugar

3.3.1 Paper & cardboard factory, Portugal

3.3.1.1 Sources

Site visit on two consecutive days; day 1: 60 min technical interview with head of maintenance and one maintenance engineer, led by ISQ and BFI partners and 30 min tour of paper plant and water circuits; day 2: 4 hours of recorded interviews with head of maintenance (dropped in and out), maintenance engineer, HR person, Environmental Manager

3.3.1.2 Background

The paper and cardboard company is located in a semi-rural area in the north of Portugal. The factory is built on a 100 m by 300 m plot and is split into 2 parts: the cardboard factory that constitutes the core business of the company and a paper factory that supplies the cardboard factory with paper. The split within the factory is quite evident: the cardboard factory is modern, clean, well-lit and relatively free of smell and noise, while the paper factory is old, smells badly, and is dirty and also noisy. It has the feel of a small business, despite employing a total of 230 people (140 Operators, 10 Maintenance Staff + administrators, storage and logistics, etc.): the technical manager knows everyone personally (handshakes are important), people tend to work there for a long time, there are even family dynasties within the workforce (where the father has worked there and then the sons – often typical of heavy industry e.g. steel, coal). There is no ostensible top-down performance measurement system in place. Relevant people in the company either trust workers or have enough personal contact with workers and enough personal knowledge about production processes to know when someone does good work or not.

3.3.1.3 The IWCs in isolation

Our technical and sociological interest in the company is limited to the water, pulp and steam circuits in the paper plant. There is no significant water circuit in the cardboard production facility.

The circuit system in the paper plant looks fairly complex and there is some functional overlap between the three circuits:

1. The water circuit is an open circuit with a range of pumps, tanks, valves, a sand filter and a 'flotation tank' to clean water. Water is taken out of nearby stream and is reused to some extent. No waste water is generated, but some water is lost from the system through evaporation. Its main functions are to supply water to the pulp production, to the steam production and for cleaning purposes.
2. The pulp that is fed into the paper machine contains over 90% water and is being produced and stored in big tanks. It is released in batches and pumped from there towards the paper machine. Before entering the paper machine, pulp is pumped into 'levellers', boxes suspended under the roof of the plant to ensure a steady flow of pulp into the pa-

per machine. This is extremely important to ensure a consistent quality of the paper. The levellers, however, constitute a form of 'legacy technology' that could be made redundant. An interviewee explained that these boxes were necessary because several decades ago electricity supply to the plant was fluctuating. This meant that the output of the pulp pumps would also fluctuate, which leads to fluctuating amounts of pulp being fed into the paper machine, resulting in uneven thickness of paper. These issues are nowadays obsolete due to the fact that energy supply is more stable and due to the availability of modern frequency-regulated pumps and sensor-controlled valves.

3. The steam circuit consists of gas boilers, tanks, pumps and a range of valves. This circuit has recently been modernized and does not use any significant amount of energy. The function of the steam circuit is to fill the drying rolls of the paper machine with steam to heat up the metal roles and ensure that water evaporates from the paper.

There is some room for technology-led energy efficiency gains in the IWCs, mainly in the pulp circuit. Replacing levelling boxes and the related pumps with new pumps and valves will most certainly reduce the amount of energy needed to feed pulp into the paper machines.

The circuits are maintained by a team of ten maintenance workers (different interviewees suggested different numbers, usually between 7 and 10: ten seems to include everyone with maintenance capability, while seven appears to refer to those on active maintenance duty). Due to the age of the paper making equipment, most of the work of the maintenance team is on the paper side of the business. The most common problems appear to be blocked pipes, leakages and broken pumps. Given the level of dirt in the paper plant – basically everything from machinery to walls is covered with paper fibres – these issues are not surprising. At times, there are so many maintenance issues that there is not enough staff to fix things immediately. In these cases, maintenance staff has to priorities jobs and the leading criterion is to keep production going as much as possible, which might result in periods of diminished energy efficiency of the water circuit. As the production is not 'in-line', prioritization is an option. At times, and if possible, maintenance issues can be addressed (or postponed) by slowing down production instead of interrupting it. Larger maintenance jobs, if possible, are postponed to weekends or holiday periods (August, Christmas) when production is halted.

Another significant maintenance issue is the current lack of consistent reporting practices. One of the maintenance engineers, however, is tasked with improving reporting within the plant. At the moment, small repair jobs – whether they are done by experienced operators or qualified maintenance staff – go unreported. Some bigger jobs are orally reported (or talked about between maintenance staff) while some of the larger jobs are recorded electronically using SAP maintenance support software. As we have seen in the German steel plant case study, consistent reporting can improve maintenance practices as it helps to reveal patterns in the breakdown of equipment. While most of the maintenance work is reactive, the availability of the SAP software allows for pro-active maintenance as the software schedules larger maintenance jobs. There is a desire within the company to make maintenance more pro-active as staff believes this to be more cost-effective. Pro-active maintenance almost certainly leads to more energy efficiency but no formal cost-benefit analysis about the advantages of pro-active maintenance has been conducted.

3.3.1.4 The IWCs in the context of production

Water is a very important ingredient in the paper production: it is needed to turn paper into pulp, it is needed to create steam and it is needed to regularly clean equipment. While water is relatively cheap for the company, energy costs are significant. An interviewee suggested that they reach €100,000 per month on average. Given the age of the machinery and equipment, especially the paper machine, there is some theoretical potential for more efficiency with regard to energy and water use. In practice, this potential will remain unrealized as there is reluctance to invest in new equipment. Apparently, the reluctance is related to a competitive advantage that derives from using the paper that the old machines produce. This kind of paper has unique characteristics and helps to position the company as a producer of niche cardboard products, given that the whole of the paper production goes into the cardboard production. The company's own paper production covers about 40% of the paper needed in the cardboard production. This internal solution with regard to paper supply also helps to assure the independence of the company.

There are no obvious or easily identified points in the paper making process at which human intervention could lead to a reduction of energy use (mainly indirectly by reducing water use) like we have found in the steel-industry, for example, where operators can turn off cooling water during production stops. An open question is whether water used to constantly clean the belt of the paper machine at the point just after the paper is released into the drying section, is or can be switched off during maintenance work. We would expect that this water supply is linked to the on/off switch of the machine as a whole but the question here is whether energy (and water) could be saved by switching the water supply off during small repairs or small emergencies (such as paper ripping) that does not necessitate to switch off the whole machine. It might well be the case that this is not an option as the cleanliness of the conveyor belt is important to achieve consistent quality of the paper.

Two subtle options to save energy might be available:

1. decrease amount of water in pulp (less water and less steam means energy savings in steam and water circuit)
2. reduce/optimize cleaning processes

With regard to the first option there is a trade-off between water content of pulp and energy consumption: less water in the pulp means less energy is used to dry paper but more energy might be used to pump the less liquid pulp around. In addition, it might also cause maintenance issues due to the increased risk of blockages. There is also probably a technical limit to the degree of solidness of the pulp for the round former to still work.

With regard to the second option, regular cleaning is very important for the continuous functioning of equipment in the paper plant. Interviewees did not see any scope for increased efficiency. They reported, however, that changes to the organization of production in the cardboard plant has led to more efficient water use. This concerns the cleaning of printers which is required when the colour of the ink has to be changed: production is now organized in such a way that as many products receiving the same colour are processed together to reduce the amount ink cartridges have to be changed and printers have to be cleaned. While such a smart sequential organization of production processes might not be implementable in the paper factory, it might be a useful way of increasing water and energy efficiency in other industrial concerns.

3.3.1.5 The wider context

Thinking about the wider context concerns issues that affect the decision-making of the company with regard to energy efficiency as well as their anticipated engagement with the E^3 Platform.

With regard to the latter, it was instructive to learn that no information was available with regard to the length or the diameter of the pipes used in the various IWCs. According to our technical colleagues on the WW project, such information is vital for the E^3 Platform to be useful. Furthermore, the company lacked the equipment as well as the skills to measure the actual efficiency of pumps. In short, the E^3 Platform as an autonomous device could not be used by technical staff in the company for lack of equipment, skills and information. The interviewees did not express any specific preferences regarding the capabilities of the tool apart from its ability to help with the identification of inefficiencies.

While the water circuits in the paper factory have been modernized in the early 1990s, the actual paper machines are much older. As such, it is likely that the company could save far more energy by replacing the old machines with new ones (or a new one) than it could by improving the water circuit.

Another important contextual feature of the paper plant, which is likely to be generalizable for the sector, is that the production is very dirty. This means the air and the water are constantly contaminated with fibres. Indeed, during our tour of the paper plant, a thick layer of paper fibres was covering anything that was exposed to air, including pumps and pipes and so on. This also means in turn that not any pump or other piece of equipment is suitable for this context. The challenge for the E^3 Platform is to build in the category of ‘resilience’ or ‘robustness’ when suggesting more energy efficient equipment to potential users, otherwise the risk is to make too many practically redundant suggestions. There are different ways in which this could be incorporated into the Platform: for example, a decision-tree at the beginning of the evaluation process could ask users whether they operate in a clean or dirty environment (they could indicate this on a scale, for example) and results for suitable equipment would then be filtered in accordance with the choice. Or users could be given filter options at the stage when products are suggested and one of the filters could distinguish between ‘clean’ and ‘dirty’ environment and if ‘dirty’ is chosen, only robust products are shown.

An additional interesting and potentially important aspect revealed by the interviews is that within the plant there is virtually no exact knowledge about the costs and benefits of certain processes. Rather, decision-makers seem to rely on intuition and common sense. For example, an interviewee talked about the ongoing changes to the maintenance regime (more systematic reporting + emphasis on proactive maintenance), but when asked whether he knew whether this was indeed a change that would benefit the company in a financial sense, he admitted that he had no real idea whether this would save money or not. This is quite an interesting contrast to the German steel plant, where seemingly no decisions were taken without a detailed cost-benefit analysis. In this respect, the E^3 Platform is likely to be more attractive to small companies without a developed cost-control system compared to bigger ones where cost controlling is very developed. The reasoning here is that the E^3 Platform can offer something to the former type of company that they do not have, whereas the latter type of company is likely to have an evolved approach to cost-benefit calculations that is better than the simple calculation that has to be built into the E^3 Platform.[6]

The company does not operate a formal bottom-up innovation scheme such as was found at the German steel plant, for example. Instead, there is a very close and personal relationship between technical managers and operators within the company. Technical managers spend a good deal of their work time on the shop floor, interacting face-to-face with operators on a regular basis. According to interviewees, operators are not inhibited in making suggestions to management that can help to improve processes and working conditions. Operators have the opportunity to make suggestions during staff meetings or when encountering managerial staff during their normal workdays. Such familial and high-trust employment relations reduce the likelihood of engagement with gamification based on competition, but scope for collaborative gamified aspects within the Platform might have some potential. Similar to Germany, gamification inserted as an efficiency intervention between workers and the IWC is not likely.

Management appears to put a lot of emphasis on turning operators into stakeholders. An interviewee reported, for example, that obtaining environmental certification was treated as a long-term, bottom-up process that closely involved operators at all levels. Instead of imposing certain standards and ways of doing things on workers to satisfy the requirements for obtaining environmental certificates, management took the view that workers first need to believe in the sense of the measures as this will then lead to sustainable behaviour change. According to an interviewee, this has been so successful that no special or additional measures have to be taken before an official inspection as the company is convinced that all standards are adhered to as a matter of routine.

3.3.2 Sugar Plant, Portugal

3.3.2.1 Sources

Two separate site visits; day 1: one unrecorded 30 min technical interview with Energy & Maintenance Manager and Control & Automation Manager led by ISQ and BFI, 45 minute tour of plant and IWC; day 2: 2 hours of unrecorded interviews with Energy & Maintenance Manager, Control & Automation Manager and HR Manager

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[6] The E^3 Platform will have a very simple cost-benefit calculation built-in: a new pump will cost money to buy but should pay for itself within a certain time frame through saving energy costs; in a place like the German steel plant, it is likely that they would feed additional factors into their analysis such as compatibility with existing equipment, cost of spare parts, maintenance costs and so on.

3.3.2.2 Background

The studied sugar plant is located within an area of commercial activity (shops, car dealers, storage spaces etc.) in a city. This location presents particular challenges to the company with regard to emissions of all kinds, as well as of access to water. The factory itself looks fairly modern and despite it being smaller than the cardboard company in terms of employees, it looks far bigger due to the professionalization of roles: managers drive big German cars, wear suits and have offices in a modern building with lots of glass. The plant itself is quite large in space: there is a compact production unit that is organized vertically and a lot of storage and packaging space. The company is on a massive efficiency drive which translates into a small core workforce that is supplemented by agency workers. Not everyone in the company is happy with the efficiency policy which has some impacts on maintenance. During the tour, we saw a few leaks as well as pumps lined up for repair.

3.3.2.3 The IWCs in isolation

The focus of the WaterWatt project is on two circuits:

1. An open cooling circuit that consists of pipes, valves, numerous pumps, a cooling tower and condensers.
2. An open supply circuit that supplies water to the refinery processes, to the oil-fuelled boilers for steam production and for a variety of cleaning purposes.

The company has its own well as a source for water, which is supplemented with water from the public water supply. To adhere to standards of food safety, the water has to be treated and cleaned.

The complex IWCs consist of lengthy network of pipes, pumps, valves and, as part of the cooling IWC, a cooling tower. According to interviewees, the layout of the IWC is considered to be optimal given that production is very much concentrated in one building and both cooling tower and boilers are in close vicinity of the production facility.

The IWCs reportedly account for 15% of the annual energy consumption in the sugar plant. Due to more than 25 year of performing annual energy audits, the company is now looking into hitherto neglected area to find energy savings and the IWCs constitute one such area. The company believes that modernizing some technological elements such as pumps, valves and pipes in the IWCs might lead to efficiency gains. While there is, in theory, some room for organizational changes that might lead to enhanced energy efficiency – such as improved maintenance and a general behaviour change of staff when it comes to dealing with water and energy – the challenge is that the company is undergoing a general cost efficiency drive. ‘Leaning’ measures have the potential to undermine energy saving efforts, especially with regard to maintenance.

According to interviewees, the main issues with the IWCs are related to maintenance – mainly related to lack of staff and leakages – and a lack of cooling capacity in the cooling circuit. In addition, a tour of the cooling circuit also allowed us to observe leakages and broken-down pumps. Interviewees stressed that the demand for maintenance within the sugar plant is relatively high due to a combination of:

- Expensive equipment (that cannot be easily replaced so maintaining its functionality is paramount)
- Old equipment (pipes, cooling tower) that requires a lot of attention and has unintended consequences for maintenance (such as clogging of pipes caused by wood splinters from the wooden cooling tower)
- The degree of complexity of the IWC which is necessary due to the complexity of the production process.
- In-line production process (each step in the production process depends on the previous step, which means halting production in one part of the production process has consequences for the production as a whole)

Like the rest of the workforce, maintenance staff works in teams and in shifts although the bulk of maintenance work is done during day time with only a single member of staff working the night shift, but additional staff can be called in on short notice if needed. The prolonged efficiency drive touching all areas within the sugar company has affected the maintenance of IWCs in several ways. It is unclear how this in turn exactly affects energy efficiency within the IWC, but it is safe to assume that lacking maintenance increases the energy use of IWCs. Respondents provided slightly contradictory accounts in this regard. On the one hand, while the maintenance staff numbers have been reduced, the company has made arrangements to access external maintenance services via contract workers. On the other hand, turnover of agency staff is higher and there have been suggestions that external workers are less qualified and less experienced to deal with the IWCs. For example, the maintenance night shift is now manned by one mechatronic while it used to be manned by two people before: one electrician and one mechanic. According to an interviewee the loss of expertise and capacity has detrimental effects on the maintenance of the IWCs, though no concrete examples were given.

Despite the potential lack of maintenance staff, the studied company is pursuing a pro-active maintenance strategy. Regular inspections were mentioned – apparently every 3 months though it remains unclear whether there is daily or weekly check for leaks and other visible faults. The sugar plant's maintenance unit uses SAP software to schedule maintenance jobs regularly. In line with experience that critical IWC equipment such as pumps tends to breakdown after about 2.5 years, major refurbishment and preventative maintenance work for such parts is scheduled every 2 years. The production schedule – work in the plant starts Monday morning and ends Saturday evening allows for bigger maintenance jobs to be addressed on weekends.

We are in no position to assess whether the pro-active maintenance approach is reality or part of 'company PR'. During the tour, we observed a significant leak in the cooling circuit at the point where water is pumped up to the cooling tower. There were no signs that this was treated as urgent or unusual. In the same location, several pumps (back-up pumps were available) were missing as they were apparently being repaired in the maintenance workshop.

The other significant issue with the cooling IWC is a lack of actual cooling capacity, which is reportedly related to both the age of the cooling tower and the high costs for refurbishment or replacement: the lack of cooling capacity is apparently due to the fact that the fans can only run on the lowest level. This is because running them on a higher level would create vibrations that threaten the structural integrity of the cooling tower, which is about 10 meters high and almost completely made out of wood (plywood panels on the outside and wooden latches on the inside). The lack of cooling capacity has consequences for the production process as cooling is required to produce vacuums.[7] We do not know whether this has any implications for the energy efficiency (as producing more air that is too warm with the help of the cooling IWC will not make the vacuum 'better') of the cooling IWC or whether it just prolongs production processes (if the assumption holds that the vacuum is used to get the sugar out of the tanks, suboptimal vacuum (understood here as negative pressure) just reduces the suction effect). This might represent a challenge for the E^3 Platform: the question to ask is whether the E^3 Platform will have the capability of identifying sub-optimal cooling capacity of cooling towers which will have an effect on efficiency (the question is what kind? water or energy or both) in the IWC.

3.3.2.4 The IWCs in the context of production

Production starts Monday morning and ends Saturday evening. During down-times (Sat evening until Mon morning), the IWCs are switched off. Production is structured through the release of raw sugar batches, but is then 'in-line' which means that each production step depends on the previous one.

The functions of the IWCs in the context of production is to supply water for cleaning, for refinery processes as well as to provide cooling capacity for the generation of vacuum. Due to the brevity of our visit as well as the complexity of the production process, we do not fully understand whether organizational changes could help to use energy more efficiently.

According to interviewees, no direct human interventions are required in the operation of the cooling circuit. Also, as far as we are able to tell, water supply required for production purposes is regulated and controlled automatically by computers, which also means that the scope for energy reducing interventions by operators is minimal.

This leaves the water used for cleaning as the only opportunity to achieve energy savings by organizational means. While most of the water used by the company is actually used for cleaning, interviewees intimated that the scope for saving water and energy through a change of cleaning practices is virtually non-existing. Cleaning is highly important due to the fact that sugar and liquids with high sugar content can negatively affect equipment and machinery if they are

[7] We are not sure as to how this exactly works; as far it can be ascertained the vacuum is needed to empty the big trays in which sugar is refined, but it is unclear how the vacuum is actually produced with the help of cold water. One way to do it is that cold water is used to cool the air in a closed container, thereby creating under-pressure (i.e. a 'vacuum' of sorts) in the closed container as the temperature of the enclosed air sinks and the volume of the air is reduced.

not properly and regularly cleaned. The last shift before Sunday shut-down is exclusively preoccupied with cleaning production-related equipment. The two types of sugar produced by RAR have different characteristics and draw on different equipment for their production respectively. Asked whether the production of the different sugars could be organized in a way to require less cleaning, interviewees rejected this possibility as not feasible. They were very confident that cleaning procedures are optimal and that there is no room for any more improvements or efficiency savings. They also suggested that cleaning procedures are context-dependent and that they could not be standardized or formalized. The responsibility for cleaning as little as possible and as much as necessary lies with the operators.

To raise awareness about the energy impact of their actions and to encourage energy saving behaviour of their staff, the company management launched a brand-new initiative in November 2016 that aims at changing staff behaviour to reduce water and energy use. Staff is encouraged to switch off lights or to stop taps from running unnecessarily and so on. The company hopes to achieve 2.5% energy savings over the course of a year.

3.3.2.5 Wider context

There are a variety of contextual features affecting decision-making related to energy efficiency in the plant.

First, and related to the initiative aimed a behaviour change of staff, interviewees suggested that this initiative has been launched because there is barely any scope left for technological improvements. The company has started energy auditing in the late 1980s and after almost 30 years of constant improvements management is struggling to identify further potential for savings. This also makes the company very interested in the WaterWatt project as IWCs are routinely overlooked as users of energy and thus offer energy saving potential even after decades of efficiency drives. This might open a route for more targeted marketing approach for the E^3 Platform: companies that have a long history of energy audits are more likely to be interested in efficiency savings in marginal areas such as IWCs than companies who are just beginning to look for unrealized efficiencies.

Second, the sugar company operates in a context in which energy is cheap, but water is expensive[8]. To interest a companies with similar cost profiles for energy and water in the E^3 Platform, it would be advantageous if not only the energy saving potential but also the water saving potential could be identified and advertised.

Third, interviewees were not able to supply basic data (length/diameters of pipes, pressure loss, and real energy use) that would be needed to operate the E^3 Platform autonomously. In fact, they lack both the equipment and the skills to perform the relevant measurements themselves.

[8] There are however, concerns that energy prices will begin to rise as a result of state policies on renewables.

For the E^3 Platform to be taken up and used by companies, a measurement service needs to be part of any post-funding legacy structure.

Fourth, when asked what they expect from the E^3 Platform, interviewees were quite explicit in what they wanted. They were interested in a tool that 1) allows them to simulate and compare various circuit designs, 2) can estimate potential energy savings and 3) can make suggestions for best solutions.

Fifth, the in-line nature of production has important ramifications for maintenance and ultimately for energy efficiency. On the one hand, addressing malfunctions or leakages related to the IWCs immediately, positively affects the energy efficiency. On the other hand, however, this might make it necessary to stop production, which negatively affects costs. Overall, the costs of stopping production even for a short time are usually assumed to be far greater that costs through a loss of efficiency in IWCs. Accordingly, interviewees reported that the company would do anything to keep production running normally as much as possible. This also includes running the water circuit in a less than optimal way if that keeps production running.

Sixth, just like in the paper factory, the production shut-down over weekends provides important time to address larger maintenance issues without affecting production.

Finally, work relations are seemingly low trust – despite some workers employed at the company for two-decades or more. The rationalization of the workforce has created some unease. Further, it is of note that the plant has used competitive incentive schemes to encourage innovation. Hence, the company might be open to gamification based on (collaboration or) competition (within the E^3 Platform) – being somewhat insensitive to fostering collegiality and strategizing to reduce workforce numbers and 'lean' work processes, including maintenance. Similar to elsewhere, however, gamification inserted as an efficiency intervention between workers and the IWCs has little to no potential.

3.3.3 Conclusions from Portuguese case studies

The two case studies have allowed us to gain further insights into the relevance and importance of organizational and contextual factors. With regard to the former, it was interesting to note the very different approaches to maintenance taken by the two companies. Maintenance in the sugar plant is pro-active and well organized in the sense that interventions are electronically documented. Interviewees pointed out that it this kind of documentation helps to inform the pro-active approach as maintenance schedules are drawn up in such a way to attend to equipment before it is likely to break according to break according to plant-internal data. In contrast, maintenance in the paper plant has so far been reactive and unorganized in the sense that the documentation of interventions has been patchy and incomplete. Nonetheless, the seemingly progressive approach to maintenance in the sugar plant is partly undermined by cost-cutting measures that have left maintenance units short-staffed and created gaps in expertise that appear to have occasional negative impacts on the energy efficiency of the water circuits.

With regard to contextual factors, both case studies have highlighted the importance of water circuits to the provision of water for cleaning equipment and facilities. This is due to the fact that the very materials involved central to production – glucose and cellulose fibres – also have the potential to render the production facilities useless if left in place. In both companies, the last shift before weekend breaks is dedicated to cleaning efforts. This important functional aspect of water circuits has not been central in the steel and non-ferrous metal sector.

It is also the respective context in which both companies operate that explains their interest in the WaterWatt research. Managers in the paper plant were mainly interested in exploring how the E^3 Platform could help them reduce their energy costs, which they perceive to be relatively high. While the management in the sugar plant is also interested in reducing overall costs, their interest appeared to be mainly motivated by their longstanding membership in an EMS and their difficulties in finding as yet unexplored areas to reduce energy use. Their water circuits are one of the rare areas where they have not yet looked systematically for efficiency gains.

3.4 Case study in United Kingdom: steel plant

3.4.1 Sources

Two interviews: a one-hour focus group interview with three engineers working on the Energy Wave project; a two-hour interview with a Process Engineer involved with energy efficiency improvements at the plant.

3.4.2 Introduction

3.4.2.1 Context/Background

Steel Plant UK is an integrated (blast furnace-based) steelmaking site, which produces slab, hot rolled, cold rolled and galvanized coil. The plant directly employs several thousand workers and has a significant annual capacity to produce steel slab. The majority of the slab is rolled at two separate sites to make a variety of steel strip products. The remainder is processed at other plants belonging to the same Group or sold in slab form.

The works covers a large area of land and compared to modern plants the layout is inefficient due to the long-term transformation of the site which originally hosted a variety of different steel producers that were integrated into one plant in the 1940s. This legacy is important inasmuch as large parts of the current plant and infrastructure were constructed in the early 1950s and moreover, the layout of the current production process has been determined by the separate ownership of the past – it lacks rationality, with implications for efficiency.

The plant has recently experienced severe economic distress and its closure was considered as a serious possibility. Following some changes, mainly with regard to pension liabilities, the plant moved back into profit although its medium- and long-term future are far from being secured. As our interviews revealed, this insecure future has important implications for investment in energy efficiency.

3.4.2.2 Company-wide energy efficiency programmes

At the time of the fieldwork, one major energy-efficiency improvement programme, and one smaller efficiency initiative, were being implemented across the plant. Given their direct relevance for this project, it is worth outlining the aims, methods and some outcomes of these schemes, in particular, those of the first scheme. The so-called Energy Wave (EW) programme, which is being run by the Group Environment department (it is thus deemed 'external' to the plant). An EW team, comprised of experts from the site's Energy and Environment departments, locate within different works areas around the plant. The team spends approximately 12 weeks in each area, and is there to improve resource efficiency (focusing on electricity, steam, smaller gases such as oxygen and nitrogen). Thus far, the EW team has worked in the Basic Oxygen Steelmaking (BOS) plant, the blast furnaces, the steel slabs area, and the power plant and coke ovens; at the time of the fieldwork, they were located in the hot mill.

There are three dimensions to the EW: technical improvements (e.g. pump efficiency – if it's not running close to its efficiency curve, replace the pump with one of the right size, put in a variable speed drive etc.), management, and mindset/ behaviour. Thus, with regard to the last two, the aim was to raise awareness as to energy efficiency and try to ensure it becomes a KPI for managers (an agenda item in morning meetings with the plant manager, works managers, because it currently doesn't). As part of the awareness process, questionnaires were distributed across all areas, to shift managers, engineers, maintenance, operators etc. Interviews were also conducted with the most senior managers at the plant. These assessed attitudes to energy as well as behaviours, availability of energy-related training etc. One interviewee said that there is a strong vision on energy but very few KPIs for energy, no targets, no reporting or tracking, no performance discussions or feedback mechanisms. Thus, there is nothing to back the vision. The mindset/behaviour changes had been implemented more successfully in a local sister plant. The latter has developed 'dashboards' so as to visualize patterns of energy use by plant (and various sections of machinery within a works area) and moreover, has linked energy KPIs to financial bonuses.

The interviewee said that at the case study plant, KPIs had been taken on in some areas but not in others, and further, in one or two areas, the KPIs were never developed because the managers in those works areas would not 'buy into the Mindset, Management and Behaviour (MiMB) stuff.' The interviewee went on to say that in some areas, it had been hard to get engagement. Operators were only released for a very limited time, or not at all (blast furnaces), although the original plan had been to have them on the EW team for the twelve weeks. Success on changing mindset and behaviour and developing KPIs then, was limited to the point that the person leading the EW scheme said that it should be dropped with a sole focus on the technical elements and the development of KPIs to be left to high-level management infrastructure problems.

With regard to technical improvements, the EW uses technical benchmarks from a sister plant in another European country, as well as world steel benchmarks. The EW team then works closely with the employees from the area it is located in – the ideas for resource efficiency and process improvements are to come from the workers in a particular area. Data analysis is undertaken and from this, a measure card if developed. The engineers will do a rough calculation as to viability – ideas for the work area are whittled down to about 30, with detailed measure cards developed for each. These are then handed to the works areas for implementation. The resources for projects/improvements are supposed to be provided by that work (but because resources are scarce, this is often a contested matter). The interviewees reported that what tends to happen is that a long list of potential projects is generated but due to the lack of resources in the various works areas, the ideas are not being implemented at the rate the team would like and moreover, implementation is uneven across areas e.g. a lot has taken place in the Mill but nothing in the blast furnaces. However, there have been some notable outcomes: e.g. £ 500,000 was saved in iron-making through rectifying nitrogen inflow into the furnace, which had been flowing at maximum level as the automatic control valves were no longer working. Historically, these had been manually set, but that practice gradually had been forgotten about.

As to whether the EW will continue, there was a slightly mixed response. The focus group interviewees were of the opinion that other priorities would come to dominate, thus diverting resources from the EW. They also stated that there were now few areas left for intervention (the CAPL facility and possibly the harbour). The other interviewee spoke of energy efficiency initiatives rising to prominence every five to ten years, programmes then generally run for a year (e.g. Weathering the Storm) and then disappear. As for EW, this was being driven from the top and from the external 'Group Environment'; he therefore believed it would not be 'going away.'

3.4.3 Production-Independent Factors Influencing Energy Use in IWCs

3.4.3.1 Energy-Using Equipment

As in the German steel case, there are two main energy consumers within the IWCs of the plant: firstly, electric fans that are part of the cooling towers and secondly, a range of pumps needed to move water around. The focus of the interviews at the UK case study was very much on the latter. Pumps, then, fulfil a variety of different functions in IWCs. First, there are extraction pumps; at the UK plant, these take water out of local rivers, the plant's own reservoir, and out of a dock area adjacent to the plant. Second, there are the main circuit pumps that create the required pressure within the circuit and help to move the water along. Third, there are cooling tower pumps that, when required, pump the warm/hot circuit water into the cooling tower to maintain the desired temperature of the circuit water. As one of the engineer interviewees said, 'Our job is to move the water as efficiently as possible … and our key goal is to reduce the cost of transporting it through the system.'

Using concepts introduced further above (see section 3.1.4), this overview will concentrate on two sets of features that impact on the energy needs of IWCs in moving water around the plant: structural (production-independent) and immediate (i.e. IWC energy needs as driven by specific production processes. This overview will begin with the structural factors of the plant's IWCs, or the IWCs in isolation of specific water demands of production at particular stages of operations before discussing some of the IWCs in the context of production processes in various sites of the plant.

3.4.3.2 The IWCs in Isolation – Structural Factors

Historical Legacy in terms of the Plant Layout – Size, Lack of 'Rationality' with Impact on Efficiency

To reiterate, the plant was originally run by a number of separate businesses (and indeed, this has resulted in an 'irrational' and inefficient plant layout); this has resulted in different parts of the plant operating on a fairly independent basis (with concomitant failures of communication between different sections of plant). When the plant was originally built, the separate companies located their various operations without any thought for integration with the other elements of production (owned by different companies). As such, logistics at the current site are problematic. For example, the coke ovens are located several miles away from the harbour (where they should be logically sited for the imported raw materials to feed straight in) and some miles away from the blast furnaces (coke has to be transported to the furnaces by lorry; transport via conveyor belt would be more efficient but the cost of implementing is prohibitive). The 'production line' rationality that would be expected in an integrated works is absent. Another example given was that of the newly-produced steel slabs coming out of the casters: these hot slabs are then stored in the yard until they reach ambient temperature (from 1200 degrees to outside temperature); they are then reheated to 1000 degrees again, when they are sent to the hot mill for rolling. This obviously has huge implications for energy use and is attributed to the logistics and layout of the site.

For IWCs specifically, the abstraction points for the water (the rivers and the docks) are a long way from the hot mill. Of course, this increases the energy needed to transport the water through the system to the right point of production.

Pipework

The main difficulty relating to energy inefficiency in the IWCs, identified in both interviews, was the age of the pipework. The majority of this is over fifty years old. In contrast to the gas pipes in the plant, which have been sectioned and upgraded over the past ten years, the interviewees said that there has never been the budget available to replace water pipes or even to properly maintain them (given the vast scale of the plant, replacing all of the pipework would cost many millions of pounds and take many years). Some money has been made available to replace pipework in the key plant areas in the current year; however, this will be a staged process, carried out over a number of years.

The recent upgrading to pipework has been impeded by the legacy issues outlined above i.e. the irrational layout of the plant, which has emerged from historical patterns of ownership/construction of separate sections of the plant, has led to a situation where different parts of the plant tend to act in ways independent of other sections, as if they are independent businesses (as one interviewee said, 'they don't see the big picture.') The Energy department wants to undertake pipework replacement will affect different works areas. However, the production/circuits in the different areas don't come off at the same time and the engineers said that they don't get feedback from works areas as to when they're coming off, making a smooth and synchronized programme of upgrading difficult.

Furthermore, the Energy department 'owns' the majority of the water circuits in place in different works areas – such as the extraction points, effluent pumping stations around the site and three water treatment plants. However, the Power Plant and blast furnaces receive their water from the dock, one of the extraction points owned by Energy. One of the interviewees, responsible for water, said that he knows nothing about the water treatment plant in those areas, because they don't let him know, despite him owning the extraction point.

Finally, upgrading of pipework is impeded by the fact that a lot of it is buried in very inaccessible places and in inaccessible stuff (slag cement was cited as an example – digging this up may well damage the pipe.

Pumps

As with the pipework, some of the pumps in the IWCs are old and have lost efficiency as a result.

Much of the Energy Wave (EW) initiative was focused on technical issues, such as identifying where pumps are not running anywhere near to their efficiency curve and then replacing it with the correct-sized pump or a variable speed drive (VSD). One interviewee said that he had come across a lot of pumps installed on site that are completely the wrong pump; with "expertise around pumping systems is extremely limited around here." He provided a specific example of the wrong pump being ordered. This is particularly evident in the older parts of the plant, but there is a lot more precision in the new build areas.

He spoke of a capability issue in relation to pumps and pumping – this is absent in senior operators and Maintenance staff. There is no 'on-site pump expert.' There is a lack of expertise as to design of pipework in conjunction with the right pump, or pump efficiency.

Lack of Electrical Metering

A lack of metering was identified as an issue (for both electricity and water). Metering was described as 'limited.' The interviewees from Energy spoke of the need to add more metering, so that they would know 'what we're using and where' as currently, 'it's quite difficult to identify that.'

At the time of the fieldwork, £ 100,000 had been provided for metering improvements, and part of the remit was to put implement them 'where people can actually influence what they're doing … where someone can turn a pump off or something, and can actually see the difference they're making.'

Issues with Water – Sources, Leaks and Lack of Metering

Another set of issues relates to the supply of water, in terms of both sources and lack of metering. To begin with the first – at the time of the fieldwork, drought was an issue with water levels in the main abstraction river and the dock at very low levels (the dock water-level was at 8 metres at the time of interview – if it falls to 7.5 m, they have to start shutting plant off). There is a large reservoir, which feeds into an internal reservoir. However, due to the size and layout of the plant, the latter feeds the hot mill circuit but the necessary infrastructure of pipes and plants to feed this water into the power plant for generation is absent. Millions of pounds would be needed to put this in place; given the ongoing financial difficulties of the plant, this is not considered a feasible option.

Moreover, there is no effluent treatment works on site where water could be recycled and put back into the systems. The focus group interviewees said that there had recently been a meeting with Group Environment, where possible funding options for implementing such a system were discussed. The interviewees said that having such a system would relieve some of the pressure on the abstraction points. There is also a significant cost element: one interviewee spoke of an area which was utilizing domestic water to top up their water needs in that works area: this was costing in the region of £ 90000 a month.

Leaks (which impact on water pressure in pipes and thus lead to an increased need for energy to move water around the system) were also identified as a major issue. The interviewees said that they often go unrecognized for some time: sometimes, they occur underground, in tunnels and culverts; others are on systems (e.g. in the hot mill) but they can't shut the system off. In the latter case, the works area will:

> "live with the leak … they'll overdose it perhaps to keep that system under control but live with the leak, because if they want to fix the leak, they'll have to shut down production, shut the plant off, so it's more cost-effective to live with the leak."

Another issue is the dearth of monitoring of water usage. The water system was also identified as lacking flow meters and this is not really seen as an issue that needs correction – 'most of the consumers are fairly constant; if they're on, they're on.' One of the interviewees compared the situation with that of gas; with this latter, there is a high level of accuracy around monitoring; the gas system has numerous flow meters, with usage displayed in Energy Control. The interviewee stated 'we know exactly what's going on,' whereas in the case of water usage, 'this is not something people monitor.' This was attributed to the potential of large cost-savings in the case of gas (the plant tries to utilize as much 'indigenous' or captured gas, from BOS, blast furnaces and coke ovens as possible; this is used in 'the best work area, but 'this changes every hour depending on production process'; hence the monitoring).

Furthermore, the interviewees said that even if there was a desire to save water in a works area, there is no infrastructure to do much about it, as there are very few control valves. One interviewee said that in previous years, a large sum of money had been put aside for water metering but a lot of the work was never fully implemented. He spoke of how the authorization department had bought around 24 meters, had installed 16 but had never commissioned them. Some had been put in the wrong areas (e.g. Point A but the pumps aren't used there). However, the interviewee said that these issues were to be remedied over the next year. Moreover, over the long-term, he wants to see every 'off-taker' in the plant's water system metered, so all water usage, in each area, can be monitored and measured. The value of each offtaker should add up to that of the main water meter (to be located on the Afan river abstraction point). This will allow for monitoring if any works areas are using more and for what reason (process, leaks etc.).

Where leaks are identified, there is an internal maintenance team but 'core' contractors are also used. In the last eighteen months, repair work has been delayed so that it can be carried out on a 'block basis' by contractors over a six month basis. It is estimated that this 'blocking' or repair/maintenance work brings economies of scale and saves around 15 % of costs than if the work was carried out on an individual basis. However, repair work to leaking pipes has to be prioritised in terms of budget; there are insufficient funds to repair everything found immediately.

Maintenance

Continuous maintenance of IWCs is important as insufficient maintenance can increase energy use: leaking pipes require more energy as pressure has to be kept up, blocked pipes and blocked valves increase the energy use in the circuits as pumps have to work harder than normal, worn or defective pumps need more energy etc.

On this point then, the focus group interviewees said that this had improved in recent years. However, the other interviewee described all maintenance at the plant as being reactive, rather than proactive. He spoke of an ongoing programme called 'Maintenance Excellence' but said that this not shifted the approach. With specific regard to pumps, the process engineer interviewed said that maintenance tends to 'run pumps until they fail and then they fix them.' He also spoke of a lack of expertise amongst maintenance staff regarding pumps, stating that plant Maintenance don't even know what a pump curve is. He also spoke of the scarcity of resources impacting on the efficacy of the Maintenance regime:

> "It's a question of resources as well, there's so many things that break down and so many things to fix, they're not going to worry about pumping."

3.4.3.3 IWCs in the Immediate Context of Production

The situation is different with regard to 'immediate production-related organizational factors' that influence energy use in IWCs. As identified, 'immediate factors' refer to specific events or processes in production that impact directly upon energy use in IWCs.

In the context of this plant, a number of IWCs were discussed. One interviewee said that IWCs now receive a lot of attention in the blast furnaces (and therefore in the Energy Section) because they are safety critical (a blast furnace explosion was caused in 2002 by a major water leak into the furnace when maintenance was being carried out by Energy (Energy 'own' the safety-critical pumps within the blast furnaces) on a pump in the cooling system; this was taken out of service, but the other pumps failed to kick in, leaving the cooling system down to one pump; the Furnace people recognised there was a water leak but because a different department was carrying out the maintenance, there was no communication about it).

However, in other plant areas, IWCs are not safety critical; as a result, 'people hardly look at them.' Although no actual circuits were observed in action, there seems to be a high degree of variation in the level of sophistication of the IWC controls and the extent to which operators can intervene in controlling the flow of water (and therefore, the energy required for operation). This of course has implications for gamification.

Thus, the new Blast Furnace Number 4 was identified as the most sophisticated IWC, with a 'level of automation through the roof', which is 'a water system one that runs itself, requiring minimum intervention' and which 'tends to work properly on its own, make the correct choices depending on what its asked by the operator.' No. 4 was identified as 'really good' on pumping circuits and it also has metering. This system was described as critical for benchmarking.

In contrast, the coke ovens, there is a water and liquor pumping system as well as a water pumping system. However, there are no meters and moreover, there is no automation or even automatic stand-by duties. The interviewee said that where a pump is running and it pours over, they have to manually start the next one by going onto the plant and pressing the start button; there is not even an auto-start mechanically (even though a new pump has just been put in, no auto start was included).

In the condenser cooling systems in the power plant; there are big pumps (Margam A and Margam B) but no metering. The hot mill has a spray cooling system, with 'all sorts of problems;' the efficiencies of the pumps there are not well understood.

The focus group interviewees said that in the hot mill, with the slab cooling, the water is run constantly at the same rate. One interviewee said that there is stop-start management on some pumps; thus, if the hot mill goes down, water goes off completely. However, when the mill is on, the flow is constant. Another interviewee said that most of the circuits are part of a stop-start management where if the hot mill goes off, someone will turn the button off. Other pumps though are on valves so even when the plant goes off, unless the pumps are turned off with it, the pump is still running at fairly high consumption.

An example was also given where in the hot mill, if a water leak was evident, the area 'would live with the leak' so they didn't have to shut down production. It would be more cost-effective to just keep the leak.

3.4.4 Scope for Gamification and Perspectives on the Platform

With regard to the gamification concept, the process engineer interviewee said that he thought the engineering staff would probably be interested but that in plant areas, workers would just not have the time and it would fall by the way, given the pressure on resources. He also said that the concept would work better in a plant that was more progressive on managing energy and the parent company could get sister plants to compete against each other. He did not feel that benchmarking and competition would be possible against the sister plant in the Netherlands as the company 'doesn't have the culture for inter-company competition/collaboration.

As for the platform, the focus group interviewees said that the idea 'sounds great' but that there would be limited appetite for it at the plant, because of 'everything that's going on – and there is a lot going on ...' It was felt that if input was required regularly, this 'would not happen' because of time pressures. Another said that the platform would be seen as just another vehicle to generate ideas and there were already too many of those (they went on to speak of 'initiative fatigue' see below).

3.4.5 The wider context

Whether the reduction of energy use in IWCs is treated as a goal in its own right by a company and whether gamification is considered to be a useful tool in reaching this goal depends to some degree on features that go well beyond IWCs and their function within production processes. We can distinguish at least five contextual areas:

- regulatory (EMS, national, European)
  - makes continuous energy reduction/resource efficiency a necessity (e.g. due to link between EMS certificate and access to state subsidies);
- economic (energy market and the price of energy, competitiveness in sector; financial condition of the firm – survival issues; resource availability);
- cultural ('silo mentalities', production-driven culture; short-term horizons, culture change programmes – generally and around energy)
  - cultural environment in the studied plant – production comes before environmental/energy issues; initiative overload and cynicism as to initiatives – lack of sustainability of previous programmes;
- organizational (communication/intra-firm collaboration/training/education/employee participation/bottom-up innovation schemes/costs v control/):
  - availability of in-house and external training schemes around energy efficiency
  - internal bottom-up innovation schemes to encourage worker-generated ideas over energy efficiency;

The wider context can, however, be analysed with regard as to whether it constitutes a barrier or whether it is conducive to energy reduction efforts. In the following discussion, a range of contextual features are considered in terms of whether they benefit or inhibit energy reduction efforts in general and, where appropriate, energy reduction efforts that involve gamification in particular.

3.4.5.1 Regulatory

One interviewee said that the plant did participate in an EMS, but the focus group interviewees seemed unsure.

The focus group interviewees said that regulation did push them to improve constantly and that it was 'hard work.' They said that regulation, in terms of energy management, was becoming more important. On the gas system, the emphasis is on stack emissions and particulate matter whilst on water, the pressure is on abstraction. At the time of the fieldwork, the abstraction licences were being reviewed by the authorities. There is a distinct push for greater recycling of water.

3.4.5.2 Economic and Financial

Perhaps the most pressing contextual factor, which in turn generated or considerably impacted upon a number of other contextual factors, was the parlous financial position of the plant and the threat of closure/sale that has hung over the plant for the past eighteen months. As stated in the report's introduction, this was explicitly attributed to the intensified competitive pressures ensuing from the dumping of cheap Chinese steel on the European market, the slump in global steel demand following the global financial crisis (GFC), as well as the high cost of energy. Generalised insecurity over the plant's future has been evident since the GFC of 2008. As one interviewee said:

> "I started around the time of the economic crash so since then, we've literally been holding on by a thread. We almost shut last year, the business went up for sale …"

Strongly related to this, is the resource-scarcity, which characterises the plant and forces such a short-termist outlook and an overriding focus on production (linked to plant survival as opposed to sustainability), to the exclusion of other goals (such as energy efficiency). In the words of one interviewee:

> "The key thing for us is that people in the works areas are concentrating on production; so long as they're producing, they're happy."

And:

> "In terms of using energy efficiency or water reduction as a main driver, works areas are more interested in … and really don't want to affect any of their process so obviously, by coming to us and saying, oh we could probably save energy on that, that's probably going to be the last thing they want …"

Another interviewee summed up the short-term, production-oriented perspective as follows:

> "Because the manpower is so stretched, trying to keep the plant operational and people are fire-fighting all the time … I've worked in Coke Ovens, Blast Furnaces, Energy Distribution, Sinter Plant, now joined Energy … it's the same story every-

> where. It's the 'nice to have' compared to the plant running so … you have some clever guys who will do some clever things … but as a constant, is this a day-to-day activity? Regrettably, no. And that's because the resource is so stretched. It's a real struggle."

This constant reactive 'firefighting' approach is engendered ultimately driven by the shortage of resources. The plant's focus on survival, due to its financial difficulties and the harsh economic environment it operates in, obviously limit the budgets and personnel available (there have been two major redundancy programmes since the GFC). This focus on short-term horizons means that an embedded and sustained longer-term, strategic approach, focused on continuous improvements, is not feasible at the current time.

In sum:

> "It's very much the mindset of a business that's trying to survive, cost-cutting and fire-fighting."

Further, although energy is recognized as a significant area for savings, there isn't the resource to do anything about it (the same interviewee also identified workforce capability as an issue – see below).

These pressures have cultural implications.

3.4.5.3 Cultural

The short-termist culture, of course, has implications for energy efficiency improvements. There is some momentum for improved resource efficiency but this tends to focus on the 'biggest wins.' Thus, water is not seen as a priority area as compared to gas; pumping costs are not seen as a priority as compared to reducing raw materials costs. As one interviewee put it:

> "Our raw materials bill is vast – we spend a billion on coke and a billion on iron ore every year … a lot of plant time is taken up with fixing things and then people who do have the ability to think ahead, be a little bit strategic, they're just looking at raw material mixes and trying to make cheaper coke, better fuel rates, cheaper raw material mixes whereas, I would say, no one really has a mandate for energy ... electricity."

In terms of energy efficiency in general and the EW programme specifically, this means that only projects with a short pay-back period will be considered:

> "In order to be feasible, it has to pay back in under two years … anything that pays back within a year … in the last few months, the business just says yes, crack on and do it … [Qn: why is the payback period so short?] Because we are literally in a position where we may not be here in a few years. Although we are making a profit now, we've come from a very bad place … our cash flow at the moment is terrible and I think it's about ensuring that we're still here in the short-term. Obviously when

> things improve and we get to a sustainable profit, then we'll start looking at things that have a five to ten year payback … at the moment, its weathering the storm."

3.4.5.4 Organizational

Training: Capability and training were identified as barriers to greater energy efficiency. One interviewee, when discussing 'pump curves' i.e. measures of actual pump performance as compared to expected system curve. He described such analysis as 'bread and butter' and that senior operators should be capable of carrying out such studies. However, he said that most on site did not know what a pump curve is. He said that expertise around pumping systems is extremely limited. There is no 'on-site pump expert.' There is a lack of expertise as to design of pipework in conjunction with the right pump, or pump efficiency. Moreover, the training programme necessary to endow such expertise has not been forthcoming because of budgetary issues.

Recruitment and retention issues: He also said that there is bias in recruitment towards mechanical engineering graduates; such degrees do not cover topics such as pumps and pipework in any detail. At operator level, there is a lack of any ongoing training/continuous development once an apprenticeship has been completed.

Capability has been 'hollowed out' through two large-scale redundancy programmes, following the financial crisis. One interviewee spoke of the large numbers of engineers that had left the plant over the past five years. He said that this hadn't been as a result of redundancy but rather, because the company wasn't 'fostering talent' and 'tasking people incorrectly', allocating the wrong jobs to them.

Communication barriers: Another organisational barrier, which impacts upon the running of the IWCs is the lack of communication between different areas of the business. To reiterate, the plant was originally run by a number of separate businesses (and indeed, this has resulted in an 'irrational' and inefficient plant layout); this has resulted in different parts of the plant operating on a fairly independent basis and ultimately, failures of communication between different sections of plant. Interviewees spoke of distinct silo mentalities:

> "The way [the plant] works, is … each of the areas are different plants, so blast furnaces are one plant, energy area is one plant so actually, you've got seven plants ... And blast furnaces never talk to coke ovens really… So they really are isolated plants even though its one through-process… they don't sit down and talk things out interrupted."

Another interviewee described the situation thus:

> "We definitely have a culture issue here. People don't look at the big picture, even though we are working towards the same goal. People do put up unnecessary bar-

> riers to things and there’s poor communication between different areas at times. These barriers are attributed to a ‘historical cultural thing… when there’s an issue, people spend more time and effort trying to find blame in a rival department … if they looked to try and resolve the issue, that would be easier than trying to pin the blame on someone else.”

Innovation schemes: At the time of the fieldwork, there was a scheme in place to allow any of the plant’s employees to submit an idea for improvement, the IMAD ‘Ideas Make a Difference’ scheme. However, the interviewee who was in charge of the scheme for Energy said that it was not a particularly effective scheme, that often results in work overload for the engineers who have to look at potential ways of implementing the idea (a duration of three months was referred to). Problems identified with the scheme were that it had not produced many good ideas in recent years (two examples of successes were given – one that cost £ 10000 to implement but saved £ 200000 and another on filters in the water treatment plant and that saved about £ 60000). The interviewees also said that too often, the resources to implement ideas were not available.

As for rewards for workers who make good suggestions, there had been a Recognition Platform but the reward is a £ 25 voucher (however, this had seemingly fallen through at the time of the fieldwork).

The interviewees also identified that there was a feeling of ‘initiative fatigue’ in the plant; due to the constant insecurity and requests from the firm for more and more improvement ideas:

> “There’s always issues, we’re always fire-fighting, we’re constantly looking for ideas and we’ve had ‘Weathering the Storm’, not we’ve got IMAD … there’s constant, more and more focus, on delivering improvements and it’s almost like people have got sick of it to a certain extent. We realise the need for it and even the last year, we’ve got the Delivering the Future project and there’s some excellent work taking place … but people are quite sick of it. [Qn: You feel overwhelmed by all the different initiatives?] Oh yes, definitely.”

Motivation: A generalised problem with motivation across the workforce was identified. One interviewee spoke of the cumulative effects of the redundancy programmes, the pension changes, the lack of development opportunities and people generally being ‘overworked and underpaid.’

3.4.6 Conclusions from UK case study

The main problems identified with the IWCs derive from the age of the plant and the fact that it is a brownfield site with an irrational layout and organisational ordering. This is hugely exacerbated by the financial pressures that the plant is facing and has been for some time. This results in pressure on resources and constant 'fire-fighting and reactivity' at the plant; there is little space for longer-term and proactive thinking and action. Production dominates and this is to the detriment of improved energy/water usage and management. There is a drive to improve the latter from senior management but this is not seemingly shared at the middle management level.

In order to improve the efficiency of IWCs, pipework and pumps need upgrading in places; this is hampered by a lack of expertise, the location of these systems in inaccessible places, weaknesses in the maintenance scheme and the lack of vision for energy at lower levels of management. The Energy Wave programme was implemented in order to improve both technical aspects and change attitudes/behaviours. However, its rollout and success has been uneven across the site. It is unclear whether momentum will continue or whether, as in the past, the emphasis on energy will lessen until the next 'wave' of interest in some years' time.

4. Conclusions

The aim of conducting the case studies as part of WaterWatt Project is to understand how industrial water circuits work in practice and in particular contexts. For our technical colleagues, the case study approach has been important to help them in their efforts to incorporate the modelling of water circuits into the E^3 Platform. From our sociological perspective, the case study approach has proved to be an excellent method to foster our understanding of the organisational dimensions of achieving greater energy efficiency. The case studies have helped us to formulate organisational factors as well as to produce a list of relevant contextual factors, which essentially represent the conclusions of this work (see Report Deliverable D 3.3).

It is difficult to draw generalizable conclusions from this diverse set of case studies – each is different, for example, in terms of the specificities of the IWC and the way it is managed. However, at the same time, identifiable 'organisational factors' that impact on energy efficiency appear to be relatively uniform across different countries and different sectors i.e. in terms of the factors that might be considered. As Report Deliverable D 3.3 will show in greater detail, organisational factors can be identified in three broad areas: maintenance, strategic planning and processes that draw on water. The uniformity is derived from material and functional similarities that characterise all industrial water circuits. First, they consist of material units that are subject to wear and tear as well as malfunctions and break-downs that require some form of maintenance. As Report Deliverable D 3.3 will show, companies have choices as to how to organise their maintenance regime, which has consequences for the degree of energy efficiency of an IWC. Second, despite working largely unnoticed in the background, IWCs are not 'natural' phenomena, but the material expression of certain strategic decisions. Often, these decisions have been taken decades in the past, sometimes by different companies who owned the premises at that point. Despite the rarity of strategic decisions affecting the water circuits, they are critical junctures that can determine the degree of efficiency with which circuits run for years and sometimes decades. Third, water circuits always fulfil a function in the wider production processes, no matter what is actually produced or where the production is located. The way production processes draw water from the circuits has therefore always and everywhere an effect on the energy efficiency of water circuits.

The picture is very different with regard to contextual factors as they can vary even within the same country and the same sector. Some of these factors, such as water prices or exchange rates for example, might apply to a whole country while others, such as the length of participation in an Energy Management Scheme or the topography of a plant, are highly localized factors that require local analysis (see Report Deliverable D 3.3 for more details in this regard) – hence, the difficulties to generalize.

The remainder of this concluding section will be used to reflect upon the method, case study approach, utilised to gain sociologically useful understanding of industrial water circuits. Overall, we feel that the approach taken is appropriate to the task – it is the right one to generate the necessary knowledge to inform the WaterWatt project. Our case study approach has two main characteristics: it is relatively compressed in terms of time and it necessitates the physical presence of the researchers in the plants in which the IWCs are being studied.

With regard to the temporal aspects, in most cases we concluded our site visits within two days. During that time, we always tried to speak to as many people as possible although we were usually restricted to managers and workers that were made available to us. At times, we would have liked to talk to additional people or a different set of people, but overall the cooperation with the industrial partners has been good enough to allow us to gain sufficient insights into the organizational dimensions of the industrial water circuits that were the focus of the WaterWatt project. Of course, with more time and wider access the depth of the sociological understanding could have been improved. Despite this we never left a site thinking that we had not enough time to ask relevant and necessary question. Thus, while we are confident to have gained sufficient insights into the organizational dimensions of the visited water circuits, it is likely that more individual site visits, especially in sectors that have not been covered, would reveal additional organizational and contextual aspects. Those who use this and the report on organizational and contextual factors need to take this short-coming of our research into account and need to be prepared to encounter as yet unexplored organizational aspects in the future.

The actual physical presence of the researchers at the site that is being studied is one of the biggest strengths of the case study approach. This might not be entirely obvious to those who have never undertaken such research and they might wonder whether it is really necessary for sociologists to travel thousands of kilometres to spend a day or two on the premises of industrial plants. The importance of the 'physical contiguity'[9] in the process of knowledge transfer – and that is what we as sociologists are mainly practically involved in: gaining knowledge about organizational aspects of water circuits from informants – can easily be overlooked. An example can illustrate the importance of 'being there': none of the SOCSI staff involved in this project had been to a paper plant before and had no real understanding what is going on there. Once one sets foot into the production area, however, one immediately realizes that this is a fairly 'dirty' business as almost every surface in the production hall is covered in fibres. Realizing this immediately due to simply being there, we were able to ask questions about the impact of fibres on the reliability of IWC equipment such as pumps, which then led to further specific questions about cleaning and maintenance. We cannot be sure that a telephone or skype interview would have allowed us to frame those questions, let alone to ask them. It is of course possible that this tacit (to us!) dimension might have been made explicit by the interview partner on the telephone. Given the short time dedicated to each case study, however, the physical contiguity helped us to gain enough understanding of each research site to make useful contributions to the WaterWatt project.

[9] Ribeiro, R. 2007. The Role Of Interactional Expertise In Interpreting: the case of technology transfer in the steel industry. *Studies in History and Philosophy of Science* 38 (4):713-721.