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Sustainable Energy Authority of Ireland

National Energy Research, Development & Demonstration Funding Programme

FINAL REPORT TEMPLATE

SECTION 1: PROJECT DETAILS – FOR PUBLICATION

Project Title	True Cost of Water
Lead Grantee (Organisation)	Irish Manufacturing Research
Lead Grantee (Name)	David McCormack
Final Report Prepared By	Ana Clara Santos
Report Submission Date	

	Name	**Organisation**
Project Partner(s)		
Collaborators	Ian Ryan	Wyeth Nutrition

Project Summary (max 500 words)
The natural environment and the manufacturing function are inextricably linked. Profitability, productivity and environmental consciousness are increasingly viewed as integral goals of manufacturing organizations, in general, and the manufacturing function in particular. *IMR have previously identified the following problematic areas for the energy-water nexus in manufacturing, reverse osmosis application, rainwater harvesting, wastewater discharge compliance, process metrics, quality profiling, clean in place, energy intensity costs, metering & monitoring, data management and project funding.* *The True Cost of Water in Manufacturing project was aimed to providing a solution to tackle a number of these problem areas. By increasing the knowledge and awareness of water consumption on site, it provided the capability to identify reuse/recycle projects thus saving water, energy and reducing treatment costs. Any potential water saving on a large manufacturing site would of course be felt in wider societal terms by increasing the capacity of the local supply, reducing the pumping costs and reducing the waste treatment costs.*

Keywords (min 3 and max 10)	Industry, Water, Data, design, Analytics, Software, Efficiency

NB – Both Section 1 and Section 2 of this Final Report will be made publicly available in a Final Technical Report uploaded online to the National Energy Research Database.

In the following Section, please provide a clear overview of your project, including details of the key findings, outcomes and recommendations. The section headings below are provided as a guide, please update or add to these as best suits your project.

By submitting this project report to SEAI, you confirm you are happy for Section 1 and Section 2 of this report to be made publicly available. If you wish to request edits to this section in advance of publication, please contact SEAI at EnergyResearch@seai.ie.

SECTION 2: FINAL TECHNICAL REPORT – FOR PUBLICATION (max 10 pages)

2.1 Executive Summary

The main objective of this work was to provide an understanding of the necessary steps in order to acquire the total cost of water at industrial facilities. Water used for process and utility applications in the manufacturing context requires pre and post treatment. Moreover, further energy input is also required from utility systems such as cooling towers, chillers and boilers to meet temperature requirements. These factors are interconnected and increase the real cost of water, while introducing system inefficiencies, representing a significant challenge faced by companies and energy/utilities managers. The present study focused on the energy-water nexus, promoting energy systems thinking, removing technical barriers, and providing an internationally replicable solution to calculate the true cost of water. A meta-analysis approach was used to examine of data from a number of independent studies of the water management, in order to determine overall trends. The sources utilised during the study were water-related scientific publications, Master thesis, books, companies and standards` websites, aiming at a general overview of Water Management, coupled with specific standards, Indicators, for water management. Water technologies and specific techniques as such LEAN and Value Stream Map (VSM) principles, Pinch Analysis and Leakage detection were also reviewed. The results of the study highlight the main characteristics of Water Management and how to apply it in order to generate data for the calculation of the true cost of water. From Water Management conception, Auditing can be used to investigate water flows within entire productive processes, as well as within individual process units and operations. It demonstrates the incorporation of water-related thinking in regard to supply and demand costs, opportunities and strategies. Thus, seeking to identify the necessary steps to implement Water Management in a manufacturing facility, this research was developed in three parts:

a. Water Audit developed in the context of a dairy industry as case study - analysis and discussion of results achieved.
b. IIoT device deployment to utilise low cost sensorisation to plug metering gaps in the water monitoring infrastructure.
c. Software development to allow the calculation of the true cost of water as it flows through a manufacturing facility.

2.2 Introduction to Project

Understanding the necessity of knowledge of the total cost of water within manufacturing comes first with the fact that Global industrialization is increasing water demand: nowadays water use in industries represents 19% of global water consumption (Bavar *et al.*, 2018). The expectation is that it increases by 400% in 2050 according to O`Connor *et al.* (2018). Even in places with ample water supply, as it is the case of Ireland, water issues have created new business challenges for Industrial consumers.

Water used in industrial processes and utility applications requires further energy input from cooling towers, chillers and boilers to meet temperature requirements (Agana, Reeve & Orbell, 2013). In addition, water treatment may be required pre and post the processes. These factors are interconnected and increase the real cost of water, while introducing system inefficiencies.

Demonstrating the incorporation of a water-related thinking in regard to supply and demand costs, opportunities and strategies, some water initiatives have been created from 2010. Global organisations like Nestlé (Vittel Water), the Coca-Cola Company and PepsiCo have already implemented strong water stewardship policies within their operations (Sustainable Brands, 2016; Khalamayzer, 2017) and are on the AWS (Alliance for Water Stewardship) certification list. It has not only allowed these companies to gain good publicity, but also has allowed them to navigate all of the potential regulatory, reputational and physical water risks in a manner that promotes improved social, economic and environmental performance for the business (EPA, 2018).

A large variety of options are available for improving the efficiency of water use, such as applying regeneration, reuse and recycling strategies (Gomes, Queiroz & Pessoa, 2007). In other to identify potential energy savings, an audit can be performed to understand and characterise the water system. A water diagram can be generated using gathered data, which presents a steady state snapshot of water use in terms of inputs and outputs. Critical processes can then be identified, and cases can be made for the application of conservation strategies, optimisation software and further investment in technology (Agana *et. al.*, 2013). Conservation philosophies can be applied, such as minimising the liquid discharge where possible (Barrington & Ho, 2014). Pinch analysis tools can be implemented to match process sources with sinks (Abdulaziz, Vasiliki, & Mahmoud, 2005), thereby reducing wastewater discharge (Wan Alwi *et al.*, 2008). This method can be applied graphically (Feng, Bai & Zheng, 2007), for simple cases with few inputs, or using available software (Etienne *et al.*, 2008). Therefore, a diversity of methodologies and tools to improve water management and efficiency of water have been available in the industrial context and should be selected according to each particular case.

Thus, seeking to identify the necessary steps to implement Water Management in a manufacturing facility, this research was developed by checking through Literature review how a State-of-Art audit procedure could be designed for a specific factory case study (Wyeth Nutrition Askeaton); how this knowledge could be transferred into a tool for making the process smother in other companies in Ireland and which IIoT devices could be developed to facilitate. Through the course of the project, the methodology for Water Management

and the tool were demonstrated as successful, however the IIoT device would need further research. Furthermore, new stuff was developed and deployed as per the case study necessities, they were a water dashboard to improve water communication onsite, water savings project such as a RO (Reverse Osmosis) reject reuse, seal water pumps recovery and the True Cost of CIP. They are all case studies that could be applied in other factories.

References:

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O'Connor, E., Ryan, A., Lohan, G. and Cronin, P. (2018). Investigating process water recovery within the Irish dairy industry. Procedia Manufacturing. Vol. 17: 1179 – 1186.

Wan Alwi, S., Manan, Z., Samingin, M., & Misran, N. (2008). A holistic framework for design of cost-effective minimum water utilization network. Journal of Environmental Management. Vol. 88: 219 - 252.

2.3 Project Objectives

The main objective of this work was to provide an understanding of the necessary steps in order to acquire the total cost of water at industrial facilities. Specific objectives would be:

- Design a State of Art Methodology for improving Water Management and demystify the True Cost of Water within an industrial facility.

- Deploy an IIoT device that could serve as auxiliary for important measurement in the industrial water context.

- Develop a software tool that would serve as an audit calculator for the methodology application within any industrial facility.

2.4 Summary of Key Findings/Outcomes

Describe how your project has furthered the current state-of-the-art, current knowledge or current practice. Clearly highlight the degree of novelty and innovation demonstrated by your project.

Address each innovation in a bullet point below. Add as many bullet points as you need:

- **Key outcome 1 - Innovation:** Software the True Cost of Water Calculator

  A method for systematically mapping a full factory water system was applied, including the measurement of water flow rates, using appropriate non-invasive instrumentation, minimal measurement, virtual meters and simple models. Moreover, a cost matrix was developed in a way all water billing information follows a strategic sequence in terms of be associated to the existent types of Water identified in the Water Map.

  All this source of data is then organized into the True Cost of Water Calculator, a tool which will deliver the outputs in several visualisation formats that can be utilized by site personnel to identify and target water efficiency gains.

- **Key outcome 2 - Innovation:** Water Dashboard as a Communication mechanism

  The Wyeth dashboard, containing Wyeth sensor data, factory building and water treatment processes information, is intended to engage staff and visitors, encouraging conversations about water usage at work, home, in Ireland and internationally. By informing the viewers about cost, quantity and quality of water usage at Wyeth and around the world, such conversations will help to inspire real change in water usage awareness, resulting in cost and water saving.

- **Key outcome 3:** Alliance for Water Stewardship (AWS) Platinum certification achievement

  The AWS Standard is the global standard for measuring responsible water stewardship across social, cultural, environmental and economic criteria. The Platinum rating is the highest level of certification available.

  As a consequence of all work done through the Water Site Audit proceeded before, especially the True Cost of Water demystification within the case study industrial facility, Wyeth Nutrition at Askeaton in Limerick was awarded the accolade, also becoming Nestle's first food manufacturing factory in Europe to reach the milestone.

- **Key outcome 4:** Case Studies – Register of Opportunities

  As a result of the Water Audit, a report for Wyeth Nutrition Askeaton site were developed, considering water site analysis, pinch method application and the full description of opportunities in terms of potential savings, ease of implementation and simple payback. Opportunities such as a RO (Reverse Osmosis) reject recovery registered 4% of site savings, seal water pump optimization that is still ongoing but can potentially save 6% of water usage. A further in depth study around the True Cost of Clean in Place (CIP) has also began based on the significant water user analysis during the project.

- **Key outcome 5:** Low flow water measurement IIoT solution tested

  This research project aimed to provide the tools to assess current efficiency by profiling the water as it moves through the facility. During site audit, gaps into current measurement systems were identified, mainly production process wastewater outlets. There was no way currently of quantifying

the water flowing to drain from each process. Therefore, an IIoT innovation opportunity was recognized to measure and separate production wastewater flows, IIoT allows low cost solutions to be deployed without significant impact tot the process. The IIoT solution can be deployed to prove a hypothesis thus capturing the required dataset to make informed decisions in relation to water management.

In the case study, production works on batches, and drains do not receive water constantly. Therefore, pipes are not full, and conventional flow meters cannot make measurements. The research has been carried out in order ascertain can low flow be accurately measured.

2.5 Project Impact

Clearly position the impact of your project with reference to the needs of the Irish Energy Sector, national and international policy objectives, and SEAI's remit.

Discuss the key impacts of your project: societal, economic, technological or otherwise. Clearly identify and highlight the value of your project in the wider context.

Worldwide, energy is expended to treat and distribute freshwater. In return, water is used for cooling thermal power plants, extracting shale gas and other fuels, and producing biomass-based energy feedstocks. This inter-dependence of water and energy is often referred to as the "water-energy nexus" in the industrial environment.

Water quality monitoring, conducted routinely over time at fixed sites, has been a part of most water quality management efforts for many years. It has been assumed that such monitoring plays a major role in management. However, the lack of routine data analysis and reporting indicates that the exact nature of the role of routine, fixed-station monitoring is poorly defined. There is a need to clearly define this role in the design of such systems if routine monitoring is to efficiently and effectively meet the information expectations placed on it. Design of routine monitoring systems therefore have to consider not only the where, what, and when of sampling, but also why. Understanding both these variables would allow companies to identify significant water/energy users and challenge current practices, thereby informing industrial energy efficiency policy.

2.6 Recommendations

The factory Wyeth Nutrition Askeaton has been seen as a reference for Water Management not only within Irish companies' context, but also within the Nestle group internationally. This project really developed a feasible methodology for analysing and saving water usage that can be applied into other companies, its communication is crucial for Ireland to spread this knowledge and have other successful cases on other companies, supported by software that can make the whole process of Water Audit quicker –The software

treats meter data statistically, provides Sankey diagram and other useful types of flow maps, very useful for a full comprehensive way of Water Management on site, apart from the current calculation of the true cost of water onsite. This tool can help other factories in Ireland to quickly get to grips with their water costs, balance etc .

During site audit, gaps into current measurement systems were identified. From the perspective of the IIoT innovation opportunity, it was recognized to measure and separate production wastewater flows, IIoT allows low-cost solutions to be deployed without significant impact tot the process. Project timelines allowed for the team to choose a particular ultrasonic metering setup for testing purposes, it is recommended for future work multiple sensor types of ultrasonic flow meters should be tested. The evaluation would involve adding IoT functionality to the flowmeters and reverse engineering the mounting bracket to assess to materials and construction method. Communication on water was also found as a gap to the site, and the approach of a TV dashboard has been proven the power of this user interface for educational purposes, meeting the objective of bringing employees closer to the scene of where water is important to the site, even when their roles do not co-relate specifically with the top. We do recommend this type of projects on other companies across Ireland as well.

2.7 Conclusions and Next Steps

This study presented a structured approach which walks through the Water Auditing process, from which a state-of-art procedure to acquire a holistic framework to implement a Water Management system capable of demystify the true cost of water within an industrial facility was possible. The audit process could be organized in a way that the indicators established is in line with water stewardship standards, and a water map that can be further interrogated based on that. Therefore, allowing a better understanding of the water baseline consumption on site, as well as the true costs at points of use, identification of leaks requiring investigation and the development of an optimum site wide metering strategy, highlighting of quick wins in relation to reuse, recycling and new conservation opportunities, aiming at a Circular water and Zero Liquid Discharge conception application. The Audit tool was developed aiming at a practical view into the True Cost of Water (TCW) at different manufacturing sectors. The software is able to compile data typed and uploaded by the user, to deliver the following outputs

- the connections between systems (Fluxogram);
- flowrates (eSankey)
- water consumed / discharged;
- the true cost per type of water used in the facility

Next steps now for the case study factory is to maintain the system, use the True Cost of Water as a powerful tool to justify new water-energy saving projects, move forward with the opportunities listed. On the industry context, next steps would be for sure developing the Water Management systems as per new knowledge acquired, mirroring the good example of Wyeth Nutrition. New water technologies can rise up, and best way is checking routine in the industrial environment to create best fittings.