Hydro-BPT | Energy Recovery in Water Services
Adennill Ynni yn y Diwydiant Dŵr

TRINITY COLLEGE DUBLIN

PRIFYSGOL BANGOR UNIVERSITY

NEWSLETTER

AUTUMN 2014

PROJECT AIM

WATER SUPPLY AND wastewater treatment are highly energy intensive processes. The Hydro-BPT project aims to determine the technical and economic feasibility of energy recovery from the water industry through the installation of micro-hydro turbines in water networks within Ireland and Wales. Following this assessment, the project will present water supply and hydropower industries with a clear framework from which to improve water supply sustainability.

This multi-disciplinary project involves collaboration between the Schools of Engineering and Business at Trinity College Dublin, Ireland, and the School of Environment, Natural Resources and Geography at Bangor University, Wales. It is part funded by the European Regional Development Fund through the Ireland Wales Programme (INTERREG 4A).

CONTENTS

PROJECT PROGRESS

WE ARE NOW in month 41 of a 52 month project, having commenced in 2011. Encouragingly, the analysis of existing energy recovery potential of some 300 water infrastructure sites across Ireland and Wales has estimated an annual potential of over 9 GWh in Ireland and over 9 GWh in Wales. This is equivalent to a combined yearly saving of over €2.5 million and over 10,000 tonnes of CO_2 emissions (See Table 1 on next page). These findings were recently presented at the Energy Challenges and Mechanics Symposium in Aberdeen, Scotland in August. Given that the focus of this research has been mainly on the east coast of Ireland and in west Wales, further sites have yet to be assessed so there exists even greater potential for additional savings. It is important to note that only those sites with a potential power output of more than 5 kW are presently considered economically viable.

Work is forging ahead on the development of a water supply network optimisation tool which will ....(Continued on page 2)

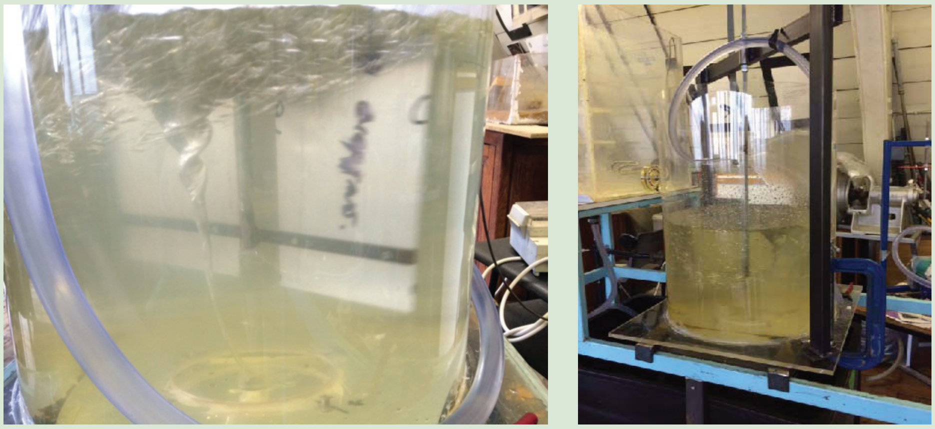

FIGURE 1. Laboratory-scale vortex in wastewater treatment: Christine Power is currently assessing the potential for energy recovery through computational modelling of vortices (more on Page 4).

Two new researchers join the Hydro-BPT team

JENNIFER BRADY JOINED the team in April 2014. Jennifer is an environmental science graduate and is currently at the final stages of her Ph.D. in water demand management. Her role within the team is to quantify the potential impacts of climate change, future energy pricing and government policies on the viability of micro-hydropower (MHP) energy recovery into the future (more on Page 9).

DR. SOPAN PATIL is a lecturer in catchment modelling at Bangor University. Sopan recently joined the Hydro-BPT team and his role will be to assess the impacts of climate change on water levels in reservoirs using catchment models and thus how this will impact on energy recovery in water infrastructure.

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PROJECT PROGRESS CONT...

assist industries and utilities in maximising the potential for energy recovery in water networks (discussed on Page 3). Also lab-scale assessments of prototype turbines across water and wastewater infrastructure are underway (Figure 1), specifically modelling vortices in wastewater networks (Page 4) and also feasibility analysis of pumps-as-turbines (PATs) to recover energy in distribution networks (Page 5). Furthermore, assessments are continuing on the environmental impacts of this technology via life cycle assessments of three specific water industry sites (Page 6) and a GIS database of MHP sites across both regions has also been prepared (Pages 7 & 8).

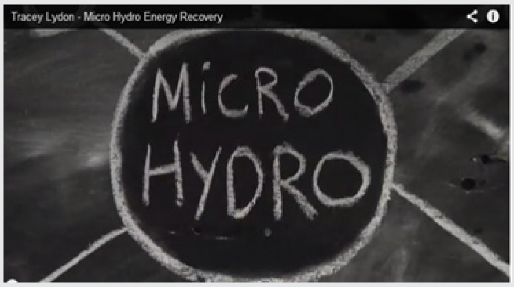
Numerous firms are involved in water supply provision and wastewater treatment and this number increases even further when energy recovery potential is incorporated, which can make stakeholder collaboration more complex. From a business perspective, the project also aims to gain a deeper understanding of optimal organisational development for collaboration in the water industry. This is being achieved through stakeholder interviews and case study analysis which will form the basis of an inter-organisational collaboration model (Page 10). The following pages describe some of the latest research currently being undertaken by members of the Hydro-BPT team.

TABLE 1. SUMMARY OF ENERGY RECOVERY POTENTIAL IDENTIFIED AT EXISTING SITES IN IRELAND AND WALES.

		<1 kW	1-5 kW	5-10 kW	10-15 kW	>15 kW	Total
IRELAND	No. of sites	10	13	6	6	16	51
	Potential (GWh)	0.03	0.25	0.42	0.65	7.91	9.26
	Homes supplied [1]	5	49	84	129	1,578	1,845
	Financial savings [2]	€4 k	€34 k	€58 k	€88 k	€1,084 k	€1,268 k
	T CO_2e savings [3]	14	131	223	341	4,178	4,239
WALES	No. of sites	58	77	30	10	10	187
	Potential (GWh)	0.19	1.68	1.95	1.05	5.94	10.82
	Homes supplied [1]	51	443	516	278	1,569	2,857
	Financial savings [2]	€23 k	€201 k	€234 k	€127 k	€713 k	€1,298 k
	T CO_2e savings [3]	93	810	943	509	2,869	5,225
TOTAL	No. of sites	68	90	36	16	28	238
	Potential (GWh)	0.22	1.93	2.37	1.70	13.85	20.07
	Homes supplied [1]	56	492	600	407	3,146	4,702
	Financial savings [2]	€27 k	€235 k	€292 k	€215 k	€1,797 k	€2,566 k
	T CO_2e savings [3]	107	941	1,166	850	7,047	10,112

1. Average household consumption of 5,016 and 3,787 kW per annum in Ireland & UK.
2. Disaggregated business electricity prices in 2013 of 13.7 c/kWh (Ireland) and 12.0 c/kWh (UK).
3. 2013 figures of 528 and 483 g CO_2e per kWh in Ireland & UK for electricity generation.

Researcher Tracey Lydon wins Environmental Sciences Association of Ireland 'Communicating Environmental Science' Competition for Hydro-BPT project video - www.esaiweb.org



COMPETITION ENTRANTS WERE asked to submit a video describing their research and how it could contribute to society. Tracey's video entitled 'Micro-Hydro Energy Recovery' discusses the innovation in her research and the potential for micro-hydropower to generate clean energy across the globe. This winning video can be viewed on youtube.com or on the Hydro-BPT website (www.hydro-bpt.eu).

OPTIMISING WATER SUPPLY NETWORKS FOR HYDROPOWER GENERATION

LUCY CORCORAN

BACKGROUND

LUCY'S RESEARCH AS part of the Hydro-BPT project has included a feasibility study of the potential for hydropower energy recovery in water supply networks of Ireland and Wales. Initial findings were presented at international conferences and have been published in the journal Water Science & Technology: Water Supply in 2013. The analysis concluded that significant potential exists and pressure reducing valves (PRVs) were identified as a large untapped resource. However, flow variation at PRV sites was found to be highly variable.

Further research was then undertaken on the impact of this flow rate variation on turbine operating efficiencies. An economic analysis was also carried out to estimate the investment payback periods of potential installations. The impact of the ability to obtain a renewable energy feed-in tariff (REFIT) was identified as an important enabler for the economic success of hydropower projects, particularly for smaller generation sites (<5 kW).

UNDERSTANDING LONG-TERM FLOW VARIATION

A long-term study of flow variation at ten potential hydropower locations within both Irish and Welsh water supply networks has also been undertaken. Climate and socio-economic data were investigated for correlations with long-term changes in flow rates at these valves. Both multi-variate linear regression (MVR) and Artificial Neural Networks (ANNs) were applied to develop predictive models for future climate and socio-economic scenarios. The ANN models out-performed the MVRs in their explanation of the variation in flow data. Future scenarios were then modelled for valves based on predicted future values for population etc. for the years 2020 and 2030.

OPTIMISATION OF WATER NETWORKS FOR HYDROPOWER GENERATION

The latest research has involved the development of an optimisation algorithm for application to water supply networks using both mathematical linear programming techniques and techniques derived from heuristics or natural processes. These models find optimal locations for hydropower energy recovery within a given water supply network, ensuring adequate pressure is maintained throughout the network (Figure 2). Pressure management is a key activity for leakage reduction. These models therefore work to optimise both pressure management of a given water supply network, while also locating optimum points to generate hydropower. This algorithm could be adopted by water service providers to aid in the decision making process for location of new hydropower turbines in water supply networks.

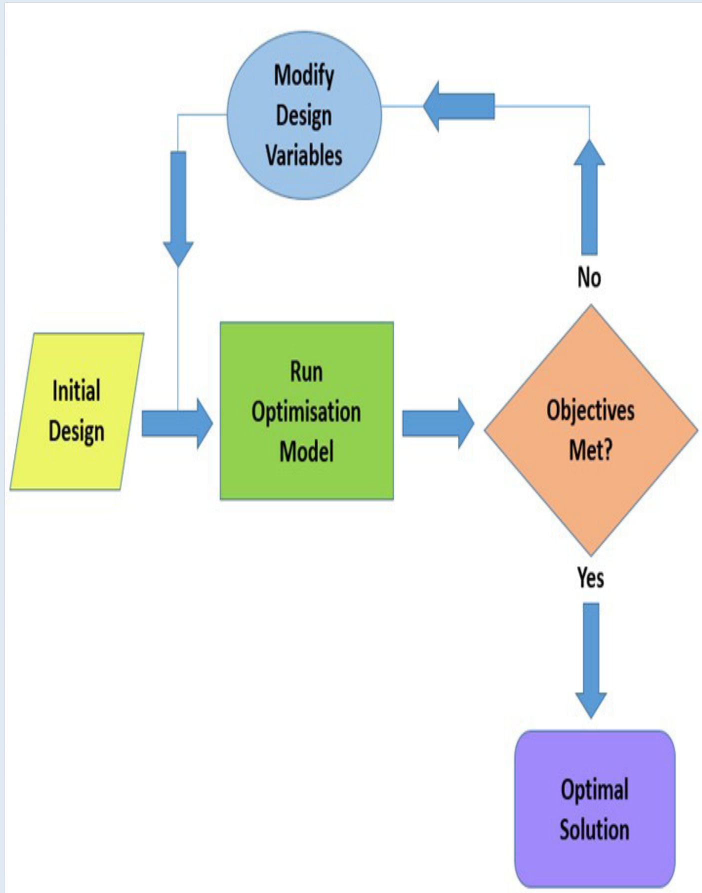


FIGURE 2. Diagram of the optimisation process.

DISSEMINATION

Lucy will be presenting her latest research findings on optimisation at the International Water Association's World Water Congress in Lisbon, Portugal on 21st-26th of September, 2014.

LUCY CORCORAN

Lucy is presently at the final stages of her Ph.D. on hydropower energy recovery in water supply systems and is based at the Department of Civil, Structural and Environmental Engineering in Trinity College Dublin.

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EXTRACTING ENERGY FROM WASTEWATER SYSTEMS

CHRISTINE POWER

GRAVITATIONAL VORTEX HYDROPOWER is the generation of electricity using vertical axis turbines placed in the centre of swirling vortical flow. This is a relatively new concept that has been developed in response to a lack of cost efficient solutions suitable to low-head small hydropower sites. There are only a few published studies investigating gravitational vortex hydropower and so there is considerable scope for valuable research.

Gravitational vortex hydropower is being investigated as part of the Hydro-BPT project because of its potential suitability to the wastewater network.

PRELIMINARY RESULTS

Early results from this project, recently published in the journal Sustainable Energy Technologies and Assessments, revealed that, while hydropower potential does exist in urban wastewater treatment plants with large flow rates, the available head is typically quite low. Various low-head hydropower options were considered, with gravitational vortex hydropower being chosen for further study because of its suitability to the untreated as well as the treated parts of the wastewater network. The presence of solids within raw sewage is not an issue with this type of generation since the centrifugal action of the vortex flow forces the heavier fluid (containing solids) to separate from the lighter fluid in cyclonic separators.

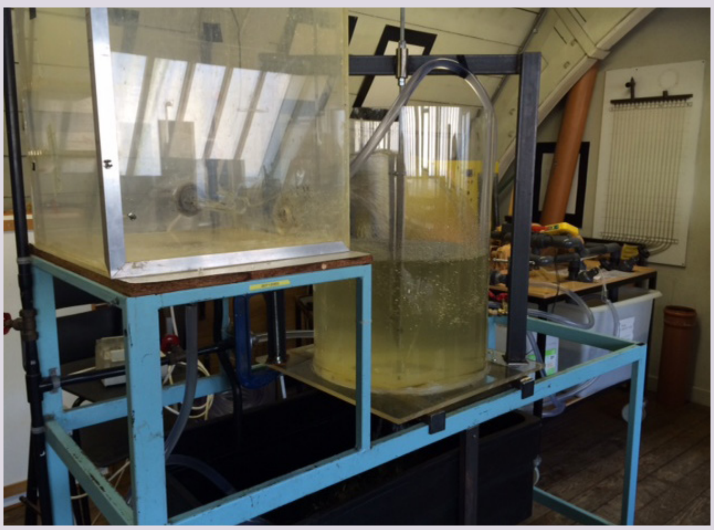


FIGURE 3. Laboratory set-up of supply tank and sink.

LABORATORY-SCALE MODEL

A laboratory-scale model has been developed to explore the operating conditions of gravitational vortex hydropower. As illustrated in figure 3, the model consists of an open-topped cylindrical tank (0.7 m high and 0.5 m in diameter) with a central outlet at the bottom. Water is pumped into the tank and enters through a tangential inlet which, together with the tank geometry, creates a swirling flow. There is a continuous loop with the water from the bottom outlet being re-circulated back into the tank. A vertical axis turbine with two blades (0.5 m high and 0.15 m wide) is situated within the centre of the flow to capture the rotational energy (Figure 4). The parameters being investigated in the study are the height, diameter and flow rate of the inlet, the diameter of the outlet, the blade shape and the number of blades. The impact of these factors on the vortex height and the turbine rotational speed is being recorded.

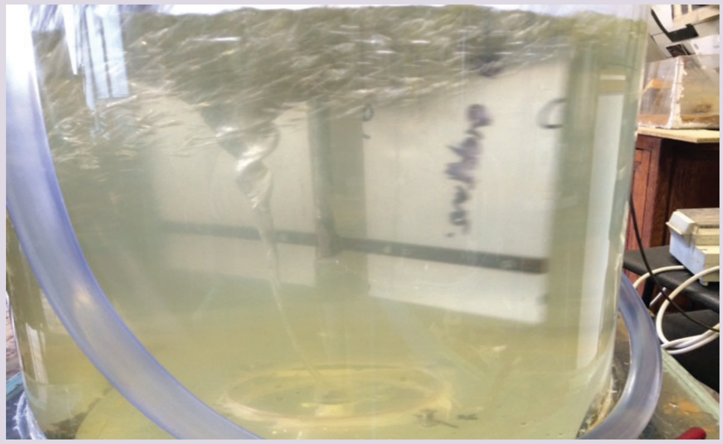


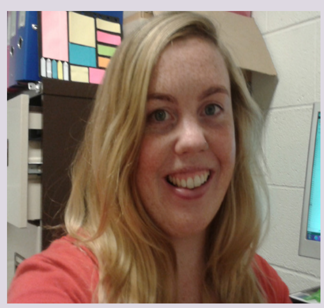
FIGURE 4. Laboratory-scale vortex.

NUMERICAL MODEL

A numerical model of the laboratory set-up has been developed using Computational Fluid Dynamics (CFD) software. The outputs of both models are being compared, with the ultimate aim of obtaining matching results such that the CFD model can then be used for the remainder of the study to determine the optimal operating conditions for gravitational vortex hydropower. While making changes to the physical model requires time and resources, variations in the tank and turbine designs can be easily modelled using CFD. A design envelope will be developed for the optimal operating conditions of gravitational vortex hydropower. The boundary conditions defined by the design envelope will be compared to the conditions in a wastewater network.

FURTHER READING

Additional detail on micro-hydropower energy recovery in wastewater systems can be found in Christine's recent paper in the journal Sustainable Energy Technologies and Assessments entitled 'Development of an evaluation method for hydropower energy recovery in wastewater treatment plants: Case studies in Ireland and the UK'. 7, pages 166-177.



CHRISTINE POWER

Christine is presently in the final year of her Ph.D. on hydro-power energy recovery in wastewater treatment systems and is based at the Department of Civil, Structural and Environmental Engineering in Trinity College Dublin.

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INVESTIGATING PUMPS-AS-TURBINES TO RECOVER ENERGY

TRACEY LYDON

THE HYDRO-BPT project has identified significant potential for energy recovery via micro-hydropower in water distribution networks. 85% of energy dissipated at pressure reducing valve sites could be captured by retrofitting with an energy recovery system.

Turbines are traditionally used to capture hydropower, but are 10 times more expensive than pumps operating as turbines (PATs) at micro scale. Their low cost coupled with their high availability in a range of sizes, makes PAT a solution worth investigating.

A number of factors need to be resolved to enable the development of such a solution:

- **FLOW VARIABILITY:** Potential sites within the water distribution network, although similar in scale, possess unique characteristics of flow and head.
- **PRESSURE REGULATION:** PATs do not have control devices to regulate pressure.
- **ORGANISATION:** The development of such a solution would involve collaboration between numerous stakeholders.

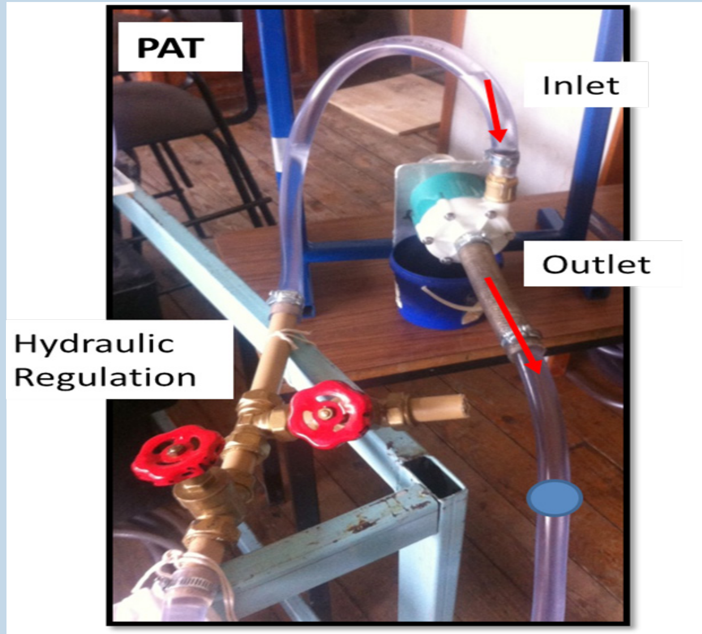


FIGURE 6. The PAT testing apparatus.

FIGURE 5. The supply pump displaying the flow reading and pressure guages.

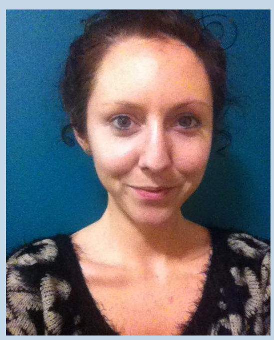
TESTING A PUMP-AS-TURBINE

An experimental prototype has been established to investigate the technical feasibility of using a PAT as a micro-hydropower device to recover energy in water distribution networks and to establish the efficient operating envelope for a PAT operating in a water distribution network (Figures 5 & 6). Flow conditions are varied in order to analyse the impact of flow patterns 'typical' of the water distribution network on the efficiency of a PAT. This will give an indication as to within what range of flow and percentage of time a certain size of PAT will fall within an efficient range and at what point, scaling up to a larger system would be more economical.

Pressure downstream of the PAT is recorded in order to establish the scale or pattern of pressure drop across the PAT. Based on these findings, a number of hydraulic regulation arrangements will be tested to establish which are conducive to achieving both a downstream desired pressure and optimal operation of the PAT system.

DISSEMINATION

Tracey will be presenting her latest research findings on 'Pumps-as-Turbines to Recover Energy in Distribution Networks' at the Water Ideas Conference in Bologna, Italy on 22nd-24th of October, 2014.



TRACEY LYDON

Tracey is presently in the final year of her Ph.D. on the design and development of micro-hydropower turbines and is based at the Department of Civil, Structural and Environmental Engineering in Trinity College Dublin.

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AN ENVIRONMENTAL ASSESSMENT OF MICRO-HYDROPOWER

JOHN GALLAGHER

ENVIRONMENTAL IMPACTS

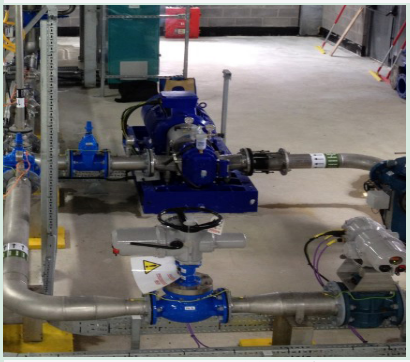
A KEY ASPECT of the Hydro-BPT project involves examining the environmental impacts of micro-hydropower (MHP) installations. Three case studies of MHP installations by water companies were chosen, two sites in Wales (Pen y Cefn & Strata Florida) and one site in Ireland (Vartry) and a description of these sites is outlined in figure 7 below.

CARBON PAYBACK

The carbon payback times ranged from 0.16 to 0.31 years, and a maximum payback of 0.19 to 0.40 years following a sensitivity analysis. These values were much lower than the economic payback of 2.8 to 8.3 years for the case studies.

15 kW

PEN Y CEFN
WATER TREATMENT WORKS



- Location: Gwynedd, Wales
- Dŵr Cymru Welsh Water
- Design capacity: 15 kW
- Power output: 12.5 kW
- Turbine: Zeropex Difgen
- Head: 90 - 105 m
- Flow: 10 - 30 l/s

90 kW

VARTRY RESERVOIR &
WATER TREATMENT WORKS

- Location: Wicklow, Ireland
- Dublin City Council
- Design capacity: 90 kW
- Power output: 78 kW
- Turbine: Kaplan
- Head: 7 - 16 m
- Flow: 580 - 1200 l/s

140 kW

STRATA FLORIDA
WATER TREATMENT WORKS

- Location: Ceredigion, Wales
- Dŵr Cymru Welsh Water
- Design capacity: 140 kW
- Power output: 110 kW
- Turbine: Pelton twin jet
- Head: 183 - 195.5 m
- Flow: 100 l/s

FIGURE 7. Description of the three case study sites.

LIFE CYCLE ASSESSMENT

A life cycle assessment was undertaken for each project. Five environmental burden categories were examined in terms of the potential energy generated over each projects lifespan and the results were compared to grid electricity generated by a natural gas power plant. The results indicated reductions for most environmental burden categories; global warming, fossil fuel depletion, acidification and human toxicity. However, an increase for abiotic resources was noted (due to omitting materials recycling at the end of the project). The environmental impacts differed for each case study due to the quantity of raw materials and construction practices adopted for each installation. The global warming potential ranged from 2.14 to 4.36 g CO_2 eq./kWh as low site preparation was required for the 15 kW installation, but substantial excavation works and materials were used in the 90 kW project as shown in figure 8.

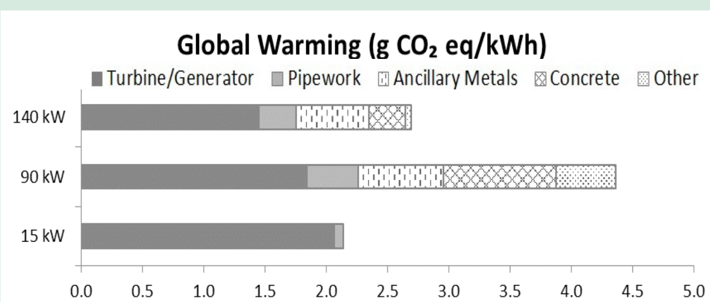


FIGURE 8. Global warming potential for three MHP installations.

This carbon payback was estimated to further increase by 1% annually with a future reduction in the carbon intensity of marginal electricity. The results demonstrate that MHP installations have a strongly positive environmental balance.

FURTHER RESEARCH

For the next phase of this research, we hope to examine all potential MHP installations in water and wastewater infrastructure, and extrapolate previous findings of potential environmental impacts for these projects. In addition, we are underway in examining the environmental impacts of three further National Trust Wales run-of-river hydropower projects to examine their innovative designs and construction techniques e.g. precast concrete sections, to examine methods of reducing the environmental impacts of future MHP installations.

DISSEMINATION

John will be presenting his latest research entitled 'Quantifying the Environmental Impacts of Micro-hydropower in the Water Industry using Life Cycle Assessment' at the [avniR] Conference, Life Cycle in Practice, in Lille, France on 5-6th of November, 2014.

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DEVELOPING A REGIONAL DATABASE OF MICRO-HYDROPOWER SITES AND THEIR ENERGY RECOVERY POTENTIAL

JOHN GALLAGHER

GIS DATABASE

AS PART OF the HYDRO-BPT project a GIS (geographical information system) database was prepared which was used to develop a methodology for assessing MHP sites and to examine the technical and economic constraints for each site category (Figure 9).

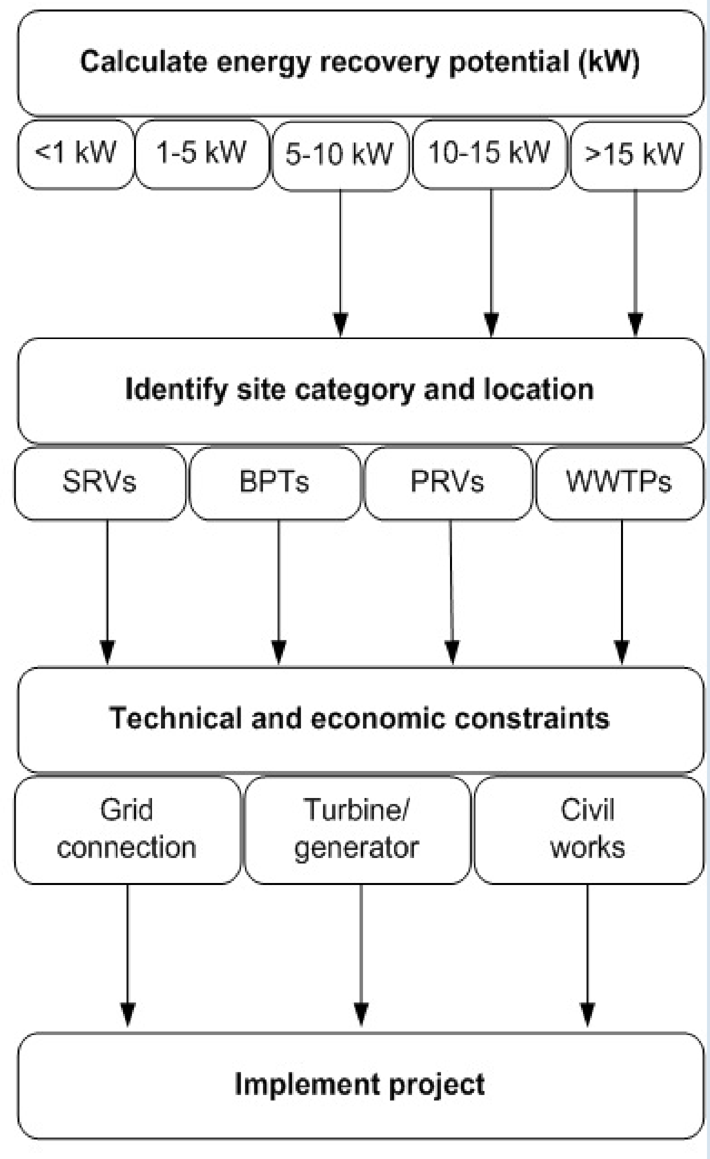

FIGURE 9. Methodology for assessing water industry MHP sites.

The database provides the following key variables:

- Site type (e.g. Break pressure tanks, PRVs, etc.)
- Coordinates (longitude and latitude, ETRS89 grid)
- Site information (place name, county and country)
- Daily site flow characteristics (mean pressure head (m) and flow (l/s))
- Energy recovery potential (kW)
- Population statistics
- Economic costs
- Other site classification details

ENERGY RECOVERY POTENTIAL

The database contains details for over 300 sites in water and wastewater infrastructure in Ireland and Wales. Based on an initial assessment, only 80 of these sites can generate > 5 kW of electricity and in total could generate almost 18 GWh of electricity, enough to supply over 4,700 homes and provide an income in the region of €2 million per year. PRV sites represent two-thirds of these locations, yet these sites represent less than half of the total energy recovery potential.

Water and wastewater sites provide the most notable potential; however wastewater sites present much lower head conditions and lower efficiencies of installations.

TECHNICAL CONSTRAINTS

The technical constraints examined the type of local infrastructure for each site, the availability of a local grid connection and the impact of long term flow variations on energy recovery at different sites. Sites were classified in relation to local population grid statistics and a visual inspection of sites to examine the category (domestic, agricultural or industrial) for each site.

Almost all PRV sites are in urban areas with other site types showing mixed classification results (water and wastewater plants likely to have grid connection regardless of local population statistics). Providing evidence of a suitable grid connection (single- or three- phase supply) near each site remains a challenging task.

DEVELOPING A REGIONAL DATABASE OF MICRO-HYDROPOWER SITES AND THEIR ENERGY RECOVERY POTENTIAL CONT...

JOHN GALLAGHER

HISTORICAL FLOW ANALYSIS

The historical flow analysis presents significant variation in flow conditions (Figure 10), which enhances the challenge of installing a suitable turbine that is viable for future flow conditions in water infrastructure. However, sites which are connected in water networks have shown to present similar patterns, thus including network data can help estimate changes in flow characteristics. The introduction of water metering, changes in local populations and demands, and consumer behaviour can influence future conditions and thus need to be considered.

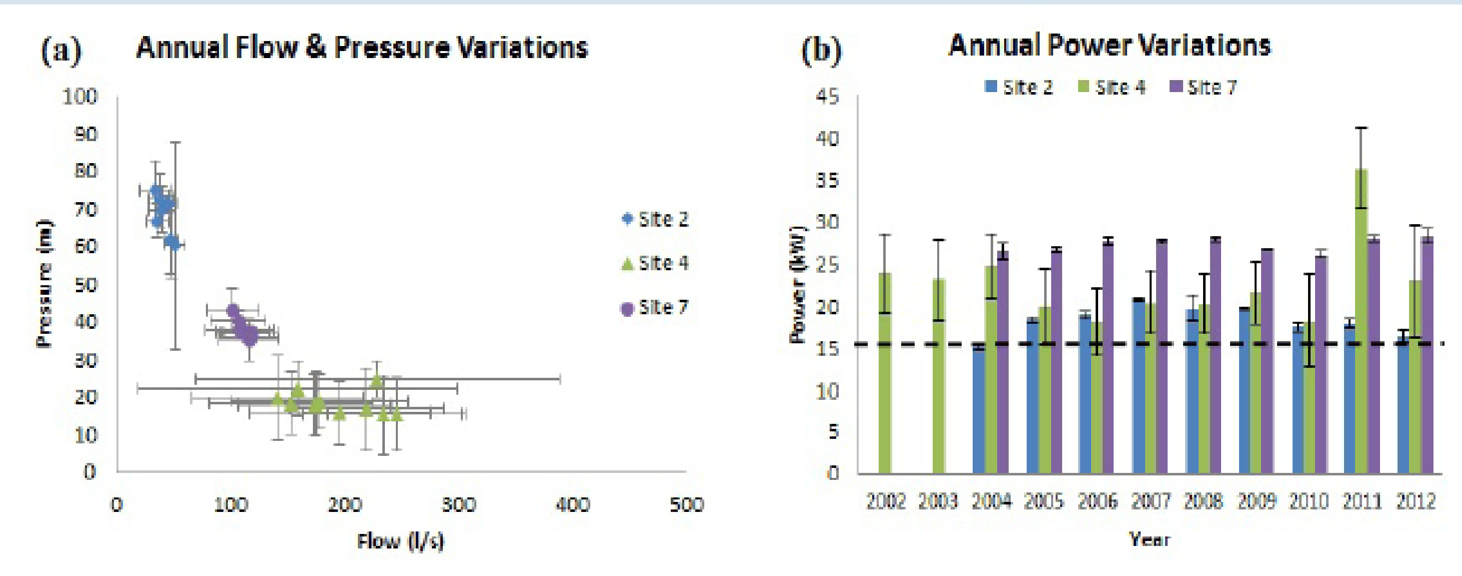

FIGURE 10. Historical flow and pressure variations at three potential energy recovery PRV sites.

CHALLENGES IN IMPLEMENTING MICRO-HYDRO-POWER

Overcoming the technical challenges of implementing MHP turbines at potential energy recovery sites is still constrained by the economic payback of each installation. A turbine that can provide good efficiency outputs in varying flow conditions, the cost of a grid connection, the level of civil works and the administration or consultancy costs can all prevent a project being delivered.

In addition, Ireland and Wales have different regulations for feed-in-tariffs (FITs) and the availability of these FITs for sites where pumping may have taken place elsewhere in the network.

Nontheless, this GIS work package is on course to deliver a database than can be used to provide a better estimation and better understanding of the likely technical and economic challenges for each site. The database will provide a range of estimates for the cost of different technology, grid connection options and a range of civil works.

In addition, the database will include estimations of the environmental impacts associated with these different options so that the carbon payback can also be estimated.

DR. JOHN GALLAGHER

John is the Hydro-BPT Research Officer and is based in the School of Environment, Natural Resources & Geography at Bangor University, Wales. John's role is to assess the environmental impacts of micro-hydropower technology in conjunction with developing a GIS database of the untapped energy potential in water networks across both Ireland and Wales.

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CLIMATE CHANGE IMPACTS ON FUTURE ENERGY RECOVERY

JENNIFER BRADY

ADDRESSING FUTURE UNCERTAINTIES

ENCOURAGINGLY THE HYDRO-BPT project has identified considerable potential for energy recovery via micro-hydropower across water and wastewater infrastructure both in Ireland and Wales. However, these findings relate to present day conditions. Given an investment payback period for MHP installations of approximately 8-10 years, there is a need to assess future uncertainties into the medium-to-long term.

THERE ARE KEY RISK FACTORS RELATING TO:

- **CLIMATE CHANGE**
- **FUTURE ENERGY PRICES**
- **GOVERNMENT POLICIES**

These factors could potentially cause changes in flow and pressure within water networks and thus hinder the economic viability of this form of energy recovery. Such investment risks act as barriers to widespread implementation of MHP and affect industry confidence.

A key aim of this element of the project, which will run until June 2015, is to quantify the impact of these three uncertainty categories on energy recovery potential in water networks in terms of regional impacts and also contrast local impacts within and across Ireland and Wales. It is hoped that the results will allow for more informed decision making across potential sites.

Work has begun on the climate change aspect which involves assessing the potential impacts of climate change on flow and pressure in water networks and thus the energy recovery potential of micro-hydropower across a range of future climate scenarios.

CLIMATE CHANGE PROJECTIONS

Globally, best estimates of temperature increases by the end of the century are currently in the region of 1.1 – 6.4°C which could lead to a higher number of drought events and thus greater water scarcity, directly reducing flow in water networks. Indirectly, these temperature increases could cause behavioural changes among individuals who tend to use more water particularly during the summer months and this could potentially increase overall water demand.

Another factor is severe cold spells which can increase the risk of burst pipes and thus increase the flow within water networks. Many regions are also projected to face more extreme events such as flooding and severe storms into the future which can directly increase flow into wastewater treatment works, affecting potential hydro energy recovery at these sites.

DATA ANALYSIS

This research focuses primarily on flow rates at a number of pressure reducing valve sites and wastewater treatment works across Dublin and Wales. Up to 20 years of high resolution flow data has been collected together with historic meteorological data including rainfall, maximum temperature, vapour pressure and soil moisture deficit. Socio-economic variables to be examined include population, monthly unemployment rates and consumer price index.

An empirical model is being developed incorporating low, medium and high emission future climate scenario data developed by the Intergovernmental Panel on Climate Change. The model aims to project possible alterations in flow rates based on these different future scenarios.

Assessments will also be made as to the potential for increases in the frequency and persistence of drought and flooding events and how these could impact on the viability of energy recovery into the future. Identifying the tolerable ranges within which micro-hydropower is both technically and financially viable is crucial for improved decision making across sites.

DISSEMINATION

Jennifer will be presenting her research findings entitled 'Quantifying Climate Change Impacts on the Viability of Energy Recovery in Water Supply Networks in the UK and Ireland' at the Preserving the Flow of Life Conference in Lyon, France on 29-31st October, 2014.

JENNIFER BRADY

Jennifer is based at the Department of Civil, Structural and Environmental Engineering in Trinity College Dublin. Jennifer's role within the team is to quantify the potential impacts of climate change, future energy pricing and government policies on the viability of micro-hydropower energy recovery into the future.

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ORGANISING FOR ENERGY RECOVERY

INTRODUCTION

A KEY ASPECT of this project involves examining how energy recovery projects can be organised, implemented and replicated in practice. Here, water companies face a range of decisions:

1. **When to initiate an energy recovery project? (i.e. in tandem with water infrastructure upgrades)**

2. **By what means can energy recovery be exploited? (i.e. via a range of sources - hydro, wind, solar)**

3. **How can the company capture and embed that experience for application in future projects?**

The nature of energy recovery is that it has to be integrated within the water industry, involving a range of stakeholders to collaborate (Figure 11). The HYDRO-BPT research is developing research case studies of energy recovery installations in three different settings- water treatment works, wastewater treatment works and equipment development.

CASE STUDY: WATER TREATMENT WORKS

The first assessment of MHP practice involves analysis across two water treatment sites; Vartry water treatment works in Ireland and Pen y Cefn water treatment works in Wales. The overall aim of this analysis is to understand how decisions were made, how knowledge was accumulated and how that knowledge was further exploited for additional energy recovery projects.

CASE STUDY: WASTEWATER TREATMENT WORKS

Energy recovery in a wastewater setting is the focus of the second case study. Here, the project undertook analysis of two case examples of energy recovery installations at Ringsend wastewater treatment plant in Dublin and in Esholt, Yorkshire. These sites, each with diverse approaches towards energy recovery opportunities, allow us to derive key principles for organising in the wastewater sector.

CASE STUDY: EQUIPMENT DEVELOPMENT

A categorically different case study to the other two cases involves the assessment of the design and development of a PAT. This research will achieve a detailed insight into the development process which might enable various new options for PAT application, including modularity of components, site suitability in addition to collaboration among the various actors.

This organisation-focused research feeds into the development of an inter-organisational collaboration approach which will help guide the implementation of energy recovery by the water industry.

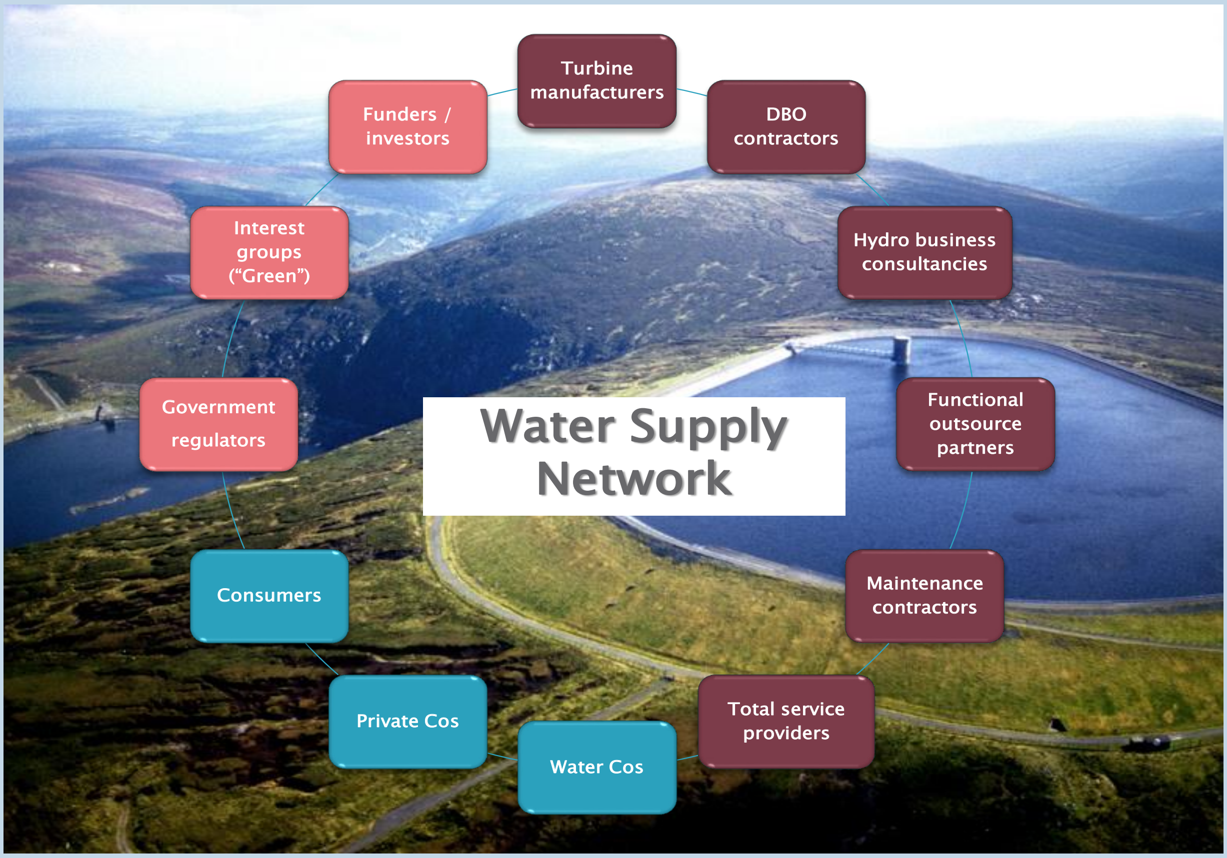

FIGURE 11. The range of collaborators involved within the water supply network.

LATEST HYDRO-BPT PUBLICATIONS

FURTHER READING: LATEST JOURNAL PUBLICATIONS

1. Power, C., Coughlan, P., McNabola, A.
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   Sustainable Energy Technologies & Assessments, 7, 2014, p166 – 177.

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2. McNabola, A., Coughlan, P., Corcoran, L., Power, C., Williams. A.P., Har ris, I., Gallagher, J., Styles, D.
   Energy Recovery in the Water Industry using Micro-hydropower: An Opportunity to Improve Sustainability.
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   http://www.iwaponline.com/wp/up/wp2013164.htm

3. Corcoran, L., Coughlan, P., McNabola, A.
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4. McNabola, A., Coughlan, P., Williams. A.P.
   Energy Recovery in the Water Industry: An Assessment of the Poten tial of Micro-Hydropower.
   Water and Environment Journal, 28, 2014, p294 - 304.

   Web link:
   http://onlinelibrary.wiley.com/doi/10.1111/wej.12046/abstract

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