LOW-HEAD HYDROPOWER INNOVATION: HARNESSING HYDROELECTRIC POWER FROM LOW-HEAD SITES WITH SUSTAINABLE LOW-COST VETT TECHNOLOGY

INNOVATION HYDROÉLECTRIQUE À FAIBLE HAUTEUR DE CHUTE: UTILISATION DE L'ÉNERGIE HYDROÉLECTRIQUE À PARTIR DES PROJECTS À FAIBLE CHUTE AVEC UNE TECHNOLOGIE VETT RESPECTUEUSE DE L'ENVIRONNEMENT ET À FAIBLE COÛT

Lars Boerner[1]
6 Old London Road, Kingston upon Thames, KT2 6QF, UK
lars.boerner@verderg.com

Peter Roberts, Robert Kettle, Karla Quintao, Dr. Paul Bird
peter.roberts@verderg.com, robert.kettle@verderg.com, karla.quintao@verderg.com, p.bird@brentmt.co.uk

KEY WORDS

Hydropower, waterpower, Low-Head, low head, VETT, Venturi, Venturi-Enhanced, VerdErg, pressure amplification, cost of energy, LCOE, low-cost, fish friendly, environmentally friendly, sustainable, run-of-river, VETT-in-a-Box.

ABSTRACT

Venturi-Enhanced Turbine Technology (VETT) is a novel low-cost hydropower technology for low-head applications developed by VerdErg Renewable Energy Ltd. in the United Kingdom. It acts as a pressure amplification system that changes the operating conditions so that turbines designed for higher head sites can be utilised in low-head projects. Instead of providing the turbine with a large volume of water at low pressure, VETT uses one part of the water in a venturi to achieve a pressure amplification, therefore providing the turbine with a profile of less water volume but at a higher pressure. The driving head is increased by ca. 2.5x. As a result, the turbines can be 3-5x smaller and up to 15x faster (a gearbox is not required) and a reduction in the levelised costs of energy (LCOE) of 23% to 68% is achieved. Fish screening is 5x smaller than conventional technologies as only 20% of water through a VETT encounters moving parts. Impact research encompassing ecology surveys, geomorphological studies, flood risk assessments and live fish impacts tests show VETT is inherently environmentally friendly and allows for safe fish passage with proven zero fish mortality. Zero noise or visual pollution keeps impact on local eco-systems minimal. VETT units are suitable for run-of-river sites with installed capacities from 20 to 130kW (and larger if multiple units are installed), and available head drops of up to four metres. It can also be installed into any low-pressure watercourse such as waste water outfalls or water treatment plants. Very small projects benefit from a design called VETT-in-a-Box. VETT projects fall within the Mini (<1 MW) or Micro (<100 kW) hydropower category, with an estimated minimum of 9.6 GW of projects available for development globally. VETT opens the low-head hydropower market to small community groups whose local potential projects have, to date, proven uneconomical and found no realisation. VETT can help especially off-grid, low-head hydropower projects, which is identified as a crucial element in addressing economic development of poor rural communities in developing countries. It also allows decentralized, locally distributed energy supply models to be realised. This paper introduces the technology and takes a look at the first VETT installation located in the United Kingdom in Eaton Socon in Cambridgeshire on the River Great Ouse. This project used VETT to

[1] Corresponding author

reinstate hydropower at the Grade II listed Rivermill (built in 1847), which is a now a pub and restaurant, utilizing the electricity produced from the VETT installation with all excess electricity being exported to the grid.

RESUME

La technologie de turbine à effet venturi (VETT) est une nouvelle technologie hydroélectrique à faible coût pour les utilisations à faible hauteur de chute, développée par VerdErg Renewable Energy Ltd. au Royaume-Uni. Elle agit en tant que système d'amplification de la pression qui modifie les conditions de fonctionnement de sorte que les turbines conçues pour des sites à hauteur de chute plus élevée peuvent être utilisées dans des projets à faible hauteur de chute. Au lieu de fournir à la turbine un grand volume d'eau à basse pression, la VETT utilise une partie de l'eau dans un venturi pour obtenir une amplification de la pression, fournissant ainsi à la turbine un volume d'eau plus faible mais à une pression plus élevée. La tête d'entraînement est augmentée d'environ 2,5 fois. En conséquence, les turbines peuvent être 3 à 5 fois plus petites et jusqu'à 15 fois plus rapides (une transmission n'est pas nécessaire) et permettre une réduction des coûts nivelés de l'énergie (LCOE) de 23 % à 68 %. Le filtrage des poissons est 5 fois plus petit que les technologies conventionnelles car seulement 20 % de l'eau traversant une unité VETT rencontre des pièces mobiles. Des études d'impact comprenant des enquêtes environnementales, des études géomorphologiques, des évaluations des risques d'inondation et des tests d'impact sur des poissons vivants montrent que la VETT est intrinsèquement respectueux de l'environnement et permet un passage sûr des poissons avec une mortalité nulle prouvée. L'absence de pollution sonore ou visuelle réduit au minimum l'impact sur les écosystèmes locaux. Les unités VETT conviennent aux sites situés au fil de l'eau, avec des capacités installées de 20 à 130 kW (et plus si plusieurs unités sont installées), et des hauteurs de chute disponibles allant jusqu'à quatre mètres. Elles peuvent également être installées dans n'importe quel cours d'eau à basse pression, comme les évacuations d'eaux usées ou les stations de traitement des eaux. Les très petits projets peuvent bénéficier d'une conception appelée VETT-in-a-Box (« VETT dans une boîte »). Les projets VETT entrent dans la catégorie des mini (<1 MW) ou micro (<100 kW) centrales hydroélectriques, avec un minimum estimé de 9,6 GW de projets disponibles pour le développement au niveau mondial. La VETT ouvre le marché de l'hydroélectricité à faible hauteur de chute à de petits groupes communautaires dont les projets potentiels locaux se sont, jusqu'à présent, avérés non rentables et n'ont pas été concrétisés. La VETT peut contribuer en particulier aux projets hydroélectriques hors réseau et à faible hauteur de chute, qui sont considérés comme un élément crucial du développement économique des communautés rurales pauvres dans les pays en développement. Cette technologie permet également de mettre en œuvre des modèles d'approvisionnement en énergie décentralisés et distribués localement. Cet article présente la technologie et examine la première installation VETT située au Royaume-Uni, à Eaton Socon, dans le Cambridgeshire, sur la rivière Great Ouse. Ce projet a utilisé la VETT pour rétablir l'énergie hydroélectrique au moulin Rivermill (construit en 1847), monument historique classé de Niveau II, qui est maintenant un pub et un restaurant, en utilisant l'électricité produite par l'installation VETT, l'excédent étant exporté vers le réseau.

1. INTRODUCTION

Since power is the product of flow multiplied by head, large flows are necessary if a reasonable quantity of power is to be extracted from a low-head hydro resource (in this paper low-head refers to head drops of less than 4 metres). Consequentially, conventional low-head turbines and the surrounding civil infrastructure must be comparably large to handle the necessary flows. Secondly, due to the low-head available the shaft speed of the turbine will be low, increasing the size and cost of the generator as well reducing its efficiency. In some instances, a gearbox will be required to step up the shaft speed for the generator, this will also incur an efficiency penalty and increase maintenance. This large, slow moving machinery and extensive civil infrastructure is prohibitively expensive for many low-head schemes, making them financially unattractive despite the vast number of potential sites globally.

Venturi-Enhanced Turbine Technology (VETT) has been developed to reduce the cost of energy by addressing the challenges encountered by conventional technology. VETT is designed to supply a conventional propeller turbine with 20%-30% of the total available flow but at an amplified pressure (head). Operating with a greater head and reduced flow in low-head hydro settings, reduces the size of the turbine and increases the shaft speed, negating the requirement for a gearbox. Since only 20-30% of the water flows through the turbine a vastly reduced fish screen is required. The remaining 70-80% of the flow passes unobstructed through a constriction in a pipe (known as a Venturi) to reduce the pressure downstream of the turbine therefore achieving a pressure amplification. The novelty of the technology lies with how the pressure amplification is achieved. The mechanical and electrical equipment are all standard, helping to further reduce the cost of installations.

The initial idea for the technology came from Peter Roberts over 15 years ago. Initial development was slow, as funding was not readily available, but in 2014 VerdErg Renewable Energy was established in Kingston upon Thames (UK) with a small but dedicated team tasked with developing the technology. The development over the years has involved three full scale hydrodynamic laboratory tests, one field prototype, two fish trials with hundreds of live fish and several CFD model testing campaigns.

Figure 1-2: VETT laboratory trials in 2013

The first commercial installation was commissioned during 2019 in Cambridgeshire, UK, and has since undergone rigorous testing and analysis, described in detail in this paper. The technology is easily scalable and can be deployed in any low-head (<4m) hydro environment, like run-of-river projects or artificial water sources. For flow rates below $2m^3/s$ a technology variant labelled VETT-in-a-Box is being designed, which can be assembled off-site and easily transported and installed on site with very limited preparational work required. On the other end of the scale, VETT is also being developed for tidal schemes. The tidal development is in an earlier stage with the company currently identifying a test site.

The development to date, which resulted in six patent families with patents granted in 22 countries, had secured several UK government grants over the years (Carbon Trust, Technology Strategy Board, Innovate UK) for which the company is very thankful. The majority of the development has, however, been self-funded. Raising external investment to promote and deploy the technology internationally and grow the company is the next milestone.

2. TECHNOLOGY

Venturi Enhanced Turbine Technology (VETT) is designed to increase the pressure differential across a standard axial flow propeller turbine. Rather than providing the turbine with a large volume of water at low pressure VETT amplifies the pressure and provides the turbine with a lower volume of water but under a higher pressure drop.

To achieve this 70-80% of the flow passes flow through a constriction in a pipe, known as a venturi, where, according to Bernoulli's theorem the pressure drops as the flow velocity increases. The remaining 20-30% of the flow passes through a turbine, discharging into the area of low pressure created within the venturi. The two flow streams mix within the venturi and pass through a diffuser, which decelerates the flow, recovering the static pressure.

By discharging the turbine into the area of low pressure the head (pressure) across it is amplified, increasing for example, a 2m head into a 5m head. As a result, the turbines get smaller (36-17% in size), faster (4x), do not require a gearbox and become dramatically more affordable. By using a VETT the cost of energy and project returns for low-head hydro projects are greatly improved. A schematic of the technology is presented below.

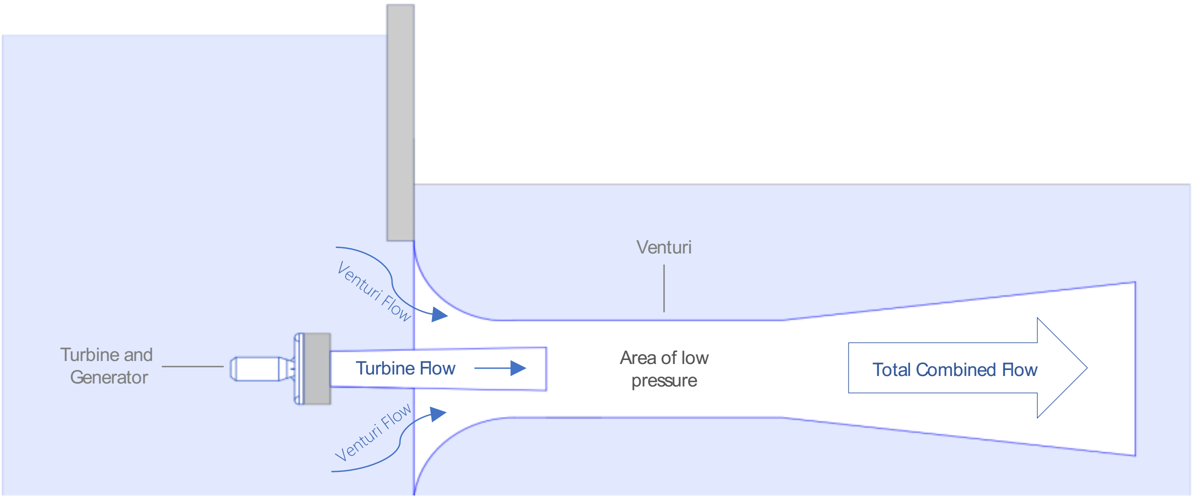

Figure 3: Schematic of VETT technology

Axial flow propeller turbines are typically installed with VETT. These turbines have fixed runner blades and static guide vanes, but by varying the runner speed with head the turbines always operate at their maximum efficiency point. Synchronisation with the grid is achieved electrically, rather than mechanically, with the use of Variable Speed Drives (VSD).

The depth at which the turbines are submerged has a significant cost implication. The submerged depth of the turbines must be deep enough to prevent turbine cavitation and to prevent the turbine from drawing a free surface vortex. Cavitation can be prevented by reducing the turbine speed, the formation of a free surface vortex however is a function of the depth of water above the turbine; a larger diameter turbine therefore needs greater excavations to satisfy the water depth requirements. Since the turbines installed within VETT are smaller, they do not require such deep excavations, significantly reducing installation and maintenance costs.

Whilst VETT is a novel approach to hydropower, all the mechanical and electrical equipment are conventional proven components (turbines, generators, control system, variable speed drives, sluice gates, screens). The know-how lies in how to arrange and scale the VETT pipe and turbine for various project conditions to achieve the maximum return on investment.

Amplifying the pressure within the venturi involves no movable parts so 70-80% of the flow passes through the device unobstructed; this is advantageous for fish which have been proven to be able to pass through the venturi safely. The turbine is screened as per the environmental regulations governing each scheme, however since only the turbine flow requires screening the size and cost of these screens is substantially reduced.

3. MARKET POTENTIAL

The VETT technology is designed for low-head (<4m) hydropower projects. As power from water is dependent on the head, low-head hydro projects usually do not exceed 1 MW and therefore fall within the Mini (<1 MW) or Micro (<100 kW) hydropower category. These two segments, plus the tidal range market are the target markets for VETT deployment.

VerdErg's assessments, based on mini, micro and low-head data available from some countries and then extrapolated to the global data available for Small hydropower projects (<10 MW), results in an estimated 23.7 GW (est. 71,000 projects) of remaining Mini Hydro projects and 24.4 GW (est. 538,000 projects) of Micro Hydropower. 20% of this potential is considered to fall within VETT's low-head hydro sector, providing a combined addressable market of 9.6 GW (121,000 project) or $18bn. These numbers are by all means indicative and if anything on the low side (the UK's Environment Agency identified 25,935 potential sites in England and Wales alone, France has ca. 100,000 old water mill sites dating back to the industrial revolution) but demonstrate large potential for decentralized renewable energy generation.

Low-head hydro projects typically fall within the classification of run-of-river projects, where generation is governed by the natural flow and elevation of the river. For run-of-river projects water is typically diverted from the river and guided through a channel to a turbine before being fed back into the main river. The depleted reach between the intake and outlet can be as short as 20m. Run-of-river hydropower is considered more socially and environmentally-friendly, as tall dams are not required and barriers (weirs) are often in place already and with adequate design and maintenance of fish passes spawning grounds can still be reached.

Beyond the conventional run-of-river market there are other areas where energy generation from low-head pressures is feasible. These areas include: Outfalls at existing high head dams, Water treatment plants/ Wastewater outfalls and Pressure reduction valves.

Despite the estimated worldwide remaining tidal power potential being around 685 GW, only seven tidal power stations have been commissioned to date worldwide. One key stumbling block for the industry has been cost as well as environmental concerns. VerdErg's long term ambition is to unlock some of this potential through the inherently fish-friendly design of the VETT technology.

4. CASE STUDY EATON SOCON

This first VETT installation is located in the UK at the Rivermill in Eaton Socon in Cambridgeshire on the River Great Ouse. The Rivermill is a Grade II listed building built in 1847 and was originally operated by the Jordan and Addington families as a flour mill. The Rivermill used to be powered by three Armfield water turbines fed through three brick arch culverts connecting the upper mill pond (which is now a marina) with the lower mill pond. Two of these turbines were located under the building with the other located along the west side of the Rivermill. Upon removing the Armfield turbines the three culverts were blocked up and a section of the marina reclaimed for a private through road. The Rivermill is a now a beautiful pub and restaurant, utilizing the electricity produced from the VETT installation with all excess electricity being exported to the grid.

On the main river, upstream of the marina, is a weir utilising moveable flap gates, which are (automatically) controlled by the Environment Agency to maintain target water levels.

Figure 4: The flour mill on the river Great Ouse

Figure 5: Image of the VETT location, west of Rivermill pub

The new VETT installation is located on the west side of the Rivermill. The new intake tank is fed by one of the three existing culverts excavation of which took place downstream of the culvert in the existing mill pond. The entire intake tank is situated below ground level and is accessible from hatches above or through the culvert. A new screened intake structure was constructed within the marina to feed the culvert. The old culvert was opened and extended under the road, to the new intake structure.

Figures 6-8: Photographs from the VETT installation at Eaton Socon showing the existing brick arch culvert and new intake and debris screen

A galvanized steel frame, piled from barges into the downstream millpond, supports the VETT pipework which is hung from above. Initially, the VETT pipework was to be installed in a dry cofferdam but due to difficulties in attaining a dry working area the decision was made to position the VETT pipework fully assembled, via a single crane lift, onto the steel frame. This installation procedure proved successful, negating the requirement for such large cofferdams in future installations.

The location of the scheme is in a highly sensitive area on account of being adjacent to the pub and a residential estate. Extra provisions were included into the work schedule to accommodate the local community, including a pause in working for the busy lunch time rush and a significantly reduced working compound to retain the availability of parking for the pub. Whilst these provisions increased the schedule, they were necessary in order to complete the project.

Figures 9-11: Photographs taken during construction looking downstream at the VETT intake tank and fish screen at Eaton Socon

The permitting process for this project was relatively straight forward and took approximately six months. The standard process for hydropower projects of this scale were followed, which involved gaining an abstraction licence and environmental permit (both from the Environment Agency) and a building permit from the Huntingdonshire district council. The installation of an eel pass to allow upstream migration was demanded as well as a ca. 150mm tall upstand along the culvert floor that would guide downstream migrating eels to a by-wash. The turbine flow had to be screened with a 6mm aperture but the remaining 80% of the water flow through the venturi remained unscreened, as per the general technology approval from the Environment Agency for VETT.

The VETT pipe draws flow from within the intake tank and amplifies the pressure across the turbine. To prevent cavitation in the turbine the centreline is located 2.6m below the upstream water level. The total length of the pipe is 25m, which is required to reduce the hydraulic loss and maximize the head amplification. The pipe is manufactured in 3.2m lengths with each section connected via a stub flange and backing ring. The pipe was manufactured in Glass Reinforced Plastic (GRP) formed around a Polypropylene liner. External buckling was the predominant structural consideration due to the low pressure formed within the venturi. To prevent collapse of the pipe during service circumferential stiffening rings were glassed into the pipe. Additionally, structural support lugs were formed into the pipe, from which it was hung. Pressure tappings have also been included along the VETT allowing diagnostic measurements to be made during commissioning and service.

Figure 12: Installing the VETT pipe at Eaton Socon

The turbine is designed with a fixed blade 440mm diameter runner. The nominal speed of the turbine is 750rpm which is designed to operate at variable speed to ensure the system operates at peak efficiency. There is no regulation of the runner or the guide vanes. If the turbine were dynamically scaled to operate without VETT, i.e., with only 1.2m head and the full design flow, the runner diameter would increase from 0.440m to 1.23m. and the speed would reduce from 750rpm to 174rpm. A turbine operating without VETT would require a gearbox and deeper excavations.

The turbine is directly coupled to a permanent magnet synchronous generator, which was designed to be able to operate submerged. The permanent magnet type was chosen to maximize efficiency, since no additional current/power is needed for excitation. Since the turbine operates at high speed no gear box is required. The bearings for shaft support are all located in the generator.

Figures 13-14: Installing the VETT turbine at Eaton Socon

The control system is located in a small roadside kiosk next to the hydro where an HMI (Human-Machine Interface) and a Variable Speed Drive (VSD) are installed along with relays and other electrical components. The control system is operated automatically and continually hunts for the highest power output by varying the turbine speed. The control system constantly monitors the water levels through pressure transducers, and generator temperatures through PT-100 sensors to ensures that the hydro always operates within the required limits; if any limits are exceeded the hydro is shut down and an operator is alerted.

The VSD is used to control the speed of the turbine by varying the electrical load on the generator. The VSD causes the electrical waveforms from the generator to be highly unconventional; to correct this the VSD rectifies the power from AC to DC before passing through an Inverter and inverting from DC back to AC but with a conventional waveform suitable for the grid. The currently installed VSD is a modular drive system including an Active Front End, which significantly reduces harmonics, allowing the generated power to be fed to the grid without issues.

Figures 15-16: The control kiosk at Eaton Socon

The water levels on the main river, upstream of the weir are monitored and controlled by the Environment Agency to ensure the river remains navigable. A condition of the abstraction licence is that this water level must be satisfied when operating the hydro. A water level sensor installed on the intake is calibrated to agree with the EA measurement to ensure the conditions of the licence are always satisfied.

With the hydro intake being in a marina with ca. 30 mooring berths manoeuvring boats during operation could be troublesome. To overcome this the control system allows boat owners to shut down the hydro for 20 minutes by calling or texting to an automated service.

Figure 18: Weir on the river Great Ouse

The intervening decades between the installation of the hydro and the blocking off of the old culverts under the mill saw almost no water flow through the marina and mill pond. Since the installation of the hydro the flow of water has rejuvenated the marina and mill pond making them cleaner and healthier. A recent environmental survey concluded that a large number of juvenile fish can now be seen in the area and the new flows have improved the vegetation around the marginal area leading to a much-improved environmental landscape.

VETT was conceived not to maximise energy output (from a free source of power), but to substantially lower the price per kWh of the energy delivered, hence improving the economics of a project with minimal environmental impact.

Eaton Socon Hydro was built as a demonstrator of the VETT technology. As being the first real project, several areas of improvements for the next installation have been identified.

For example, a power shortfall due to the VSD exists, which is currently dissipating 3kW as heat. The efficiency of VSDs diminishes when they are operated away from their rated power. The rated power of the current VSD is 37kW and is operating at 50% load reducing the efficiency from 97% to 78%. The VSD model below this is 16kW, which is too low for this scheme. Since the installation of this VSD alternative models have been identified which could operate at their rated power, allowing this wasted 3kW to be exported to the grid.

The net head at Eaton Socon is 1.2m which is extremely low and almost impossible with traditional technology. The challenge with any low-head scheme is that any hydraulic head loss is to be minimized since it represents a larger percentage of the available head than the equivalent head loss at a higher head scheme. With a net head of 1.2m the challenge at Eaton Socon is particularly high. Additional improvements to the hydraulic design of the tank are being identified with the aid of Computational Fluid Dynamics (CFD) which would further increase the exported power. While some of these changes can be implemented many are deemed too expensive to retrofit into an already installed system.

VerdErg is currently working on other solutions to extend its list of suppliers. Instead of a bespoke submerged generator, the use of an off the shelf unit within an enclosure is being considered. Another option is the use power offtakes such as chains or belts, which would allow for a generator to be installed out of the water. Any of those alternatives can be used, if proven to be more cost effective.

5. ENVIRONMENT & ECONOMICS

VETT was developed to address two particular challenges: Environmental impact (in particular on fish) and cost of energy reduction for low-head hydropower.

By passing up to 80% of the water through a venturi with no moving parts the risk for blade strike is significantly reduced. The safe limits for the pressure differential within the venturi have been established from independent third-party assessments, including two live fish trials involving hundreds of fish of different species. The turbine itself can be screened, and as the screen only needs to be designed for 20% of the flow it is comparably small and manageable. Therefore, VETT presents itself as a safe downstream migration route.

Low-head hydropower has been around for centuries using various technologies. However, in many instances project decisions are not driven by the pure need for electrical or mechanical power anymore but by project economics, whether expressed as pay pack time, project IRRs, NPV or Levelised Cost of Energy (LCOE), which are all driven by cost in relation to power output. The challenge with low-head hydropower is that due to large volumes of water at low pressure conventional equipment is notoriously large with therefore high material, manufacturing and handling costs whilst the power resource and therefore power output is smaller due to the low-head. Some technologies try to overcome this by making machines more efficient, which has led to better power output but at the same time increased complexity raising costs as well.

The approach with VETT to amplify the pressure for the turbine whilst reducing the flow rate allows the use of turbine-generating equipment that is 3-5x smaller with a 4x increase in rotational speed (eliminating gearboxes), achieving a reduction in LCOE of 23% to 68%.

Absolute LCOE depends highly on the project itself, including scale, geographical location and available supply chain. It is noteworthy that VETT utilises conventional hydropower equipment just scaled to design conditions created by a VETT. This equipment itself is sourced from and manufactured by the existing industry supply chain, which obviously have differences in cost. VerdErg itself is not a manufacturer.

6. APPLICATION

VETT is ideally suited for sites up to 4.0m head and flows starting from 2m^3/s. The design can be tailored to meet the criteria of the site. For schemes with extremely large flows multiple units can be installed in parallel.

For smaller schemes below 2 m^3/s, a self-contained VETT-in-a-box solution will be available which is designed to simplify the civil works and reduce maintenance and commissioning times. The main duct is fed by an inlet pipe or open channel, all of which is designed within the constraints of the site. If used with an inlet pipe a siphonic arrangement is viable which reduces the excavational requirements and allows for the system to be installed on the banks of a river or in a small trench.

Conventional VETT installations can be installed across weirs in rivers or in steep river gradients. The flow is controlled via an on/off sluice gate located on either inlet or outlet. A free surface intake tank is typically excavated into the bank which is fed by a pipe or culvert, such as the first installation at Eaton Socon.

VETT opens the low-head hydropower market to small community groups whose local potential projects have, to date, proven uneconomical and found no realisation. Small hydropower (especially off-grid low-head hydropower) is also identified as a crucial element in addressing economic development of poor rural communities in developing countries. Impact research encompassing ecology surveys, geomorphological studies, flood risk assessments and live fish impacts tests show VETT is inherently environmentally friendly and allows for decentralised locally distributed energy supply models to be realised.

The VETT and associated infrastructure can be designed in materials local to the site location. The VETT pipework can be manufactured in GRP, steel or even cast in concrete. Whilst a permanent magnet generator has been used at Eaton Socon this may not always be the best or most economical solution for each scheme, therefore other generator and power offtake solutions are possible.

7. OUTLOOK

In order to focus efforts, a recent regional focus for the company has been Brazil, which has the highest volume of freshwater resources in the world and an established hydropower industry (67% of its energy mix is hydropower). Due to the substantial environmental and social impacts caused by the large hydro power plants, however, and the high costs of power transmission due to the size of the country, the investments on those projects have decreased drastically. The government is therefore offering incentives to develop smaller, decentralised projects for local supply. The remaining potential is estimated at 4,700 MW ($8bn market) in the mini and micro sector which possesses a favourable licensing and payment regime, especially for projects under 75kW. Hence the country has been identified as having one of the largest potentials for VETT.

Further focus is also placed on the USA, which presents a remaining potential of 2,200 MW ($4.1bn) in the mini and micro sector, largely driven by 80,000 of smaller unpowered dams, a strong appetite for renewable energy with 100% clean energy legislations introduced in several states (Maine, New York, Wisconsin, Virginia, Colorado, Washington, California).

In Europe, the most promising market is France, presenting a remaining potential of 132 MW ($200m), which is substantially smaller than the other markets above. However, France has ca. 100,000 old water mill sites dating back to the industrial revolution, electricity prices that are comparably high ($0.18/kWh), and the permitting approach is well established. Also, France is a leader in hydropower, hence worth the focus.

The UK is the company’s home market and will always remain an area of interest for VETT deployment. Over 20,000 weir sites have been identified in England and Wales alone. However, recent legislative changes, high labour and construction costs combined with comparably low power prices have made the realisation of projects in the UK very challenging though.

The technology has true global potential with most regions of the world possessing hundreds if not thousands of projects requiring a smart approach to low-head hydropower.