

Pioneering Sustainable Energy Solutions

Description of the HydroXS[®] variable speed technology



Advanced variable speed micro-hydro turbine technology



Water utilities, industrial facilities and other large water users can use up to 40% or more of their budget on energy to move water and this cost is rising rapidly alongside the price of energy. These customers need an effective way to mitigate these costs while controlling excess water pressure and responding to climate concerns – all without interrupting service or compromising safety or security.

InPipe Energy has emerged as a pioneering leader in the field of sustainable energy solutions, particularly in the deployment of safe and reliable in-conduit micro hydro systems. InPipe Energy's commitment to innovation has brought about a transformative breakthrough in the form of advanced variable speed micro hydro turbine technology, setting them apart as the leader in the industry.

Notably, InPipe Energy's cutting-edge technology stands out by yielding up to 60% more energy generation than other comparable in-conduit hydro solutions. This achievement underscores InPipe's dedication to harnessing the full potential of hydropower within pressurized water pipeline networks, paving the way for a greener, more efficient, and sustainable water and energy future.

Recapturing wasted energy

Within modern water distribution systems, operators balance maintaining minimum operational pressures and avoiding excessive high pressures. To regulate pressure, distribution systems incorporate control valves to manage flow and control pressure. However, these pressure control valves result in substantial energy wastage (Figure 1), an untapped resource that holds potential for decarbonizing critical infrastructure or supplying clean electricity back into the electric grid.

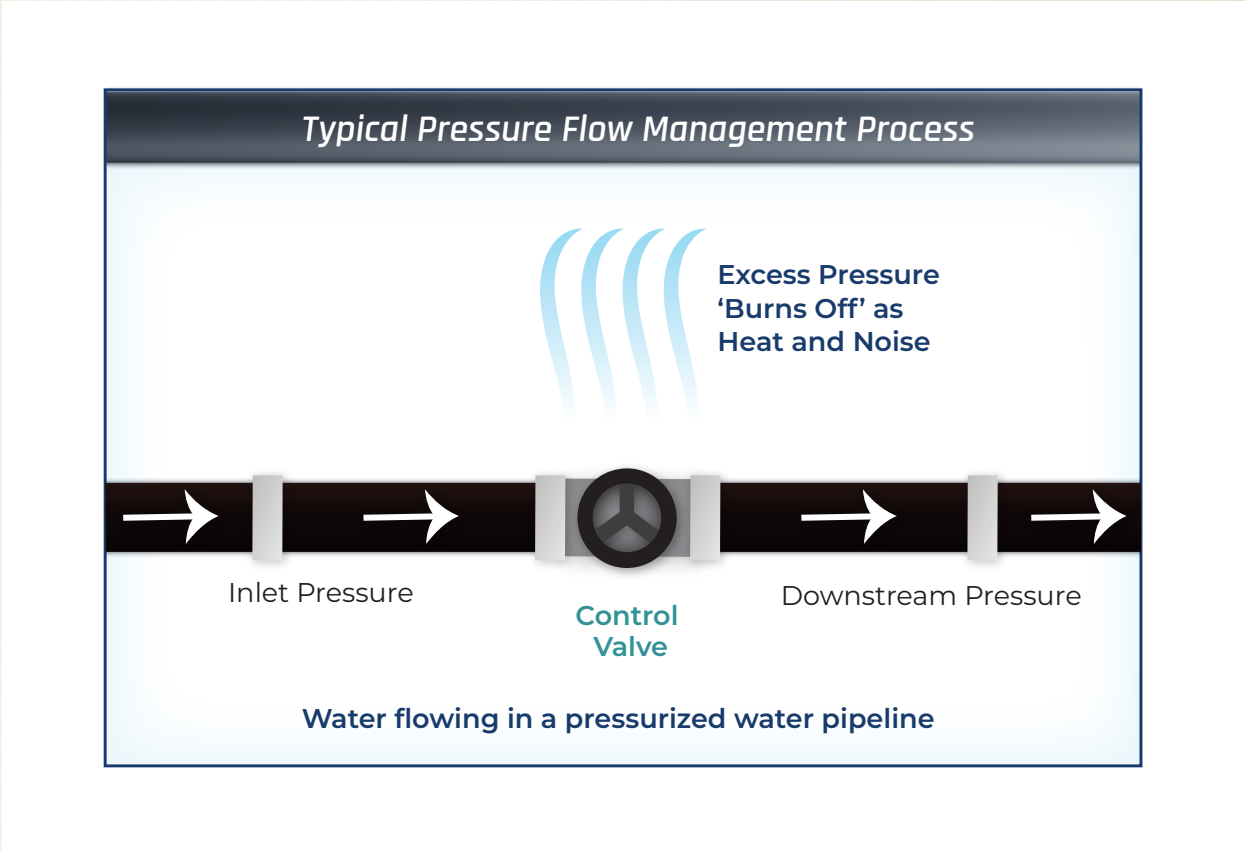


Figure 1: Control valves use friction to burn off pressure.

In the past, in-conduit hydro turbines directly integrated single-speed turbines into the water pipeline. However, this method faced limited adoption due to several critical drawbacks. While the prospect of energy savings was appealing, the risk of disrupting the essential water flow by placing a turbine directly in the line outweighed the benefits. Furthermore, single-speed turbines were ill-equipped to handle the daily fluctuations in water flow that cities experience, as well as the seasonal variations between summer and winter flows.

Variable flow turbine breakthrough

InPipe Energy has ushered in a new era of innovation with the HydroXS (Figure 2), effectively addressing these important challenges. Firstly, InPipe's HydroXS technology has been designed to replicate the functionality of a control valve, and to operate in tandem with existing control valves, creating redundancy. The product offers the flexibility to isolate and shut down programmatically or manually, should any issues or maintenance requirements arise. Critically, this isolation process occurs without disrupting the continuous flow of water through the original main valve.

Secondly, InPipe's HydroXS system has been engineered to accommodate variable flows and pressures, increasing both efficiency and energy production during the daily and seasonal fluctuations that water systems encounter. These two critical technology adaptations not only enhance the product's effectiveness but also overcome previous hinderences to the widespread adoption of conduit hydro power for water systems.

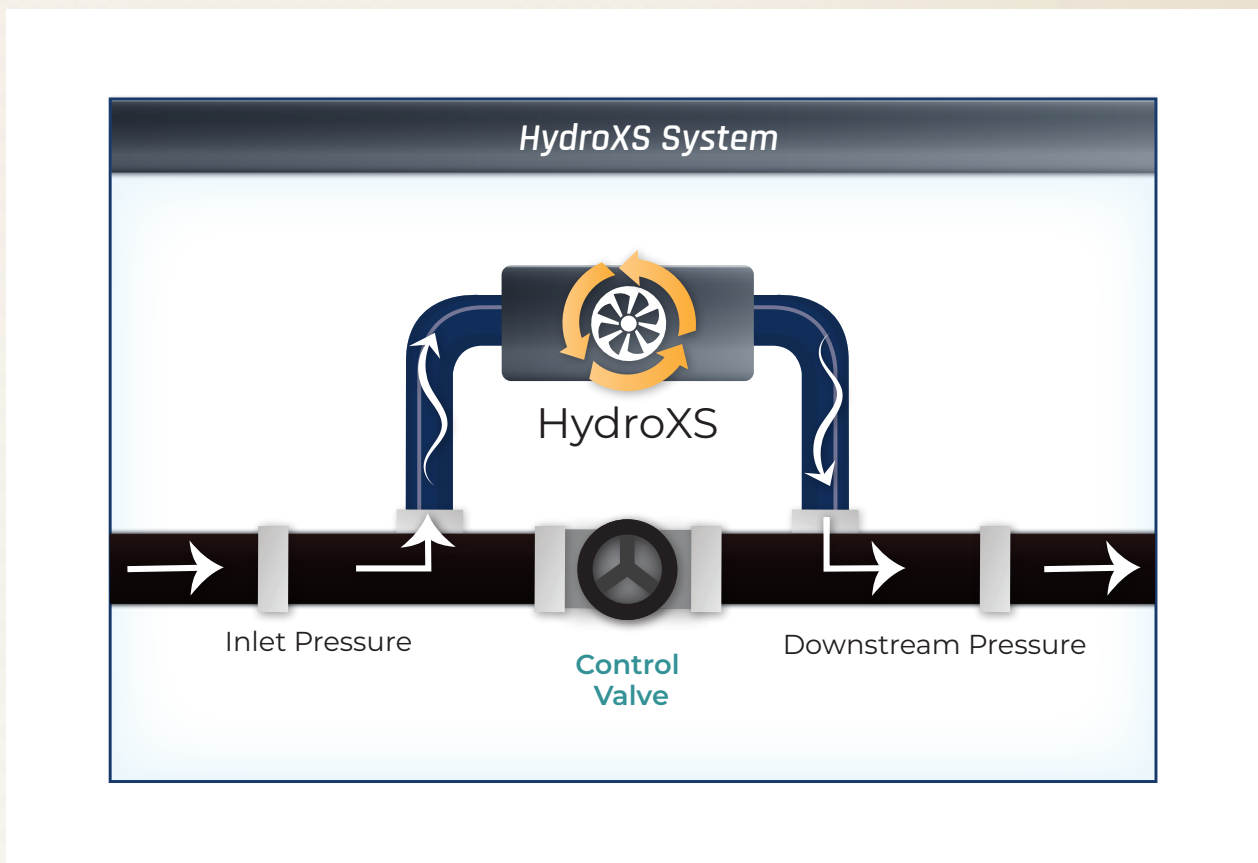


Figure 2: HydroXS system co-located with an existing control valve in a bypass.



How variable flow turbines work

The variable flow HydroXS technology is a system that allows for the generation of hydroelectric power from variable flow conditions in water distribution systems. The HydroXS is a turnkey, end to end system that integrates state-of-the-art control valve technology with a micro-turbine, and a regenerative variable frequency drive (VFD) with sensors connected to a PLC based control system.

The variable speed HydroXS technology utilizes these sensors and the PLC control system to continuously monitor flow and pressure. The control system has been designed and tested to achieve the optimal balance between pressure regulation and energy recovery. As conditions change, the HydroXS responds by adjusting the speed of the micro-turbine to efficiently generate energy while simultaneously ensuring the downstream water pressure is precisely maintained.

Typical single-speed micro-hydro turbines work on an efficiency curve based on a single flow and pressure design point. Maintaining efficiency results in a very narrow operating range. This limits the potential energy that can be generated. The HydroXS is programmed to address multiple efficiency curves. The sensors provide feedback to the control system which then responds by adjusting the speed of the turbine - generating more energy more efficiently.

The HydroXS control scheme is designed to achieve the perfect balance between pressure regulation and energy recovery.



How InPipe's micro-hydro technology works

InPipe's HydroXS utilizes a reaction style micro-hydro turbine. Here's how it converts water flow and pressure into electricity:

- 1 Water Inlet:** The process begins with the inflow of water. This water can come from various sources, a water distribution system, a wastewater treatment plant, or an industrial process. The key is that the water flows into the HydroXS's turbine under pressure.
- 2 Impeller and Blades:** Inside the turbine, there is an impeller with blades. This impeller is designed to rotate when pressurized water flows through it. As the water enters the impeller, both the flow and the pressure forces the impeller to spin.
- 3 Generator Connection:** Connected to the impeller's shaft is a generator or a generator-like component. The mechanical energy from the impeller is transferred to the generator.
- 4 Electricity Generation:** The generator converts the mechanical energy into electrical energy through the principles of electromagnetic induction. As the impeller rotates, it turns the generator, producing an electrical output that can be used or fed into the electrical grid.
- 5 Output and Storage:** The generated electricity can be used immediately to power nearby equipment or stored in batteries or capacitors for later use. It can also be integrated into a larger grid for distribution to consumers.



Want to get more technical?

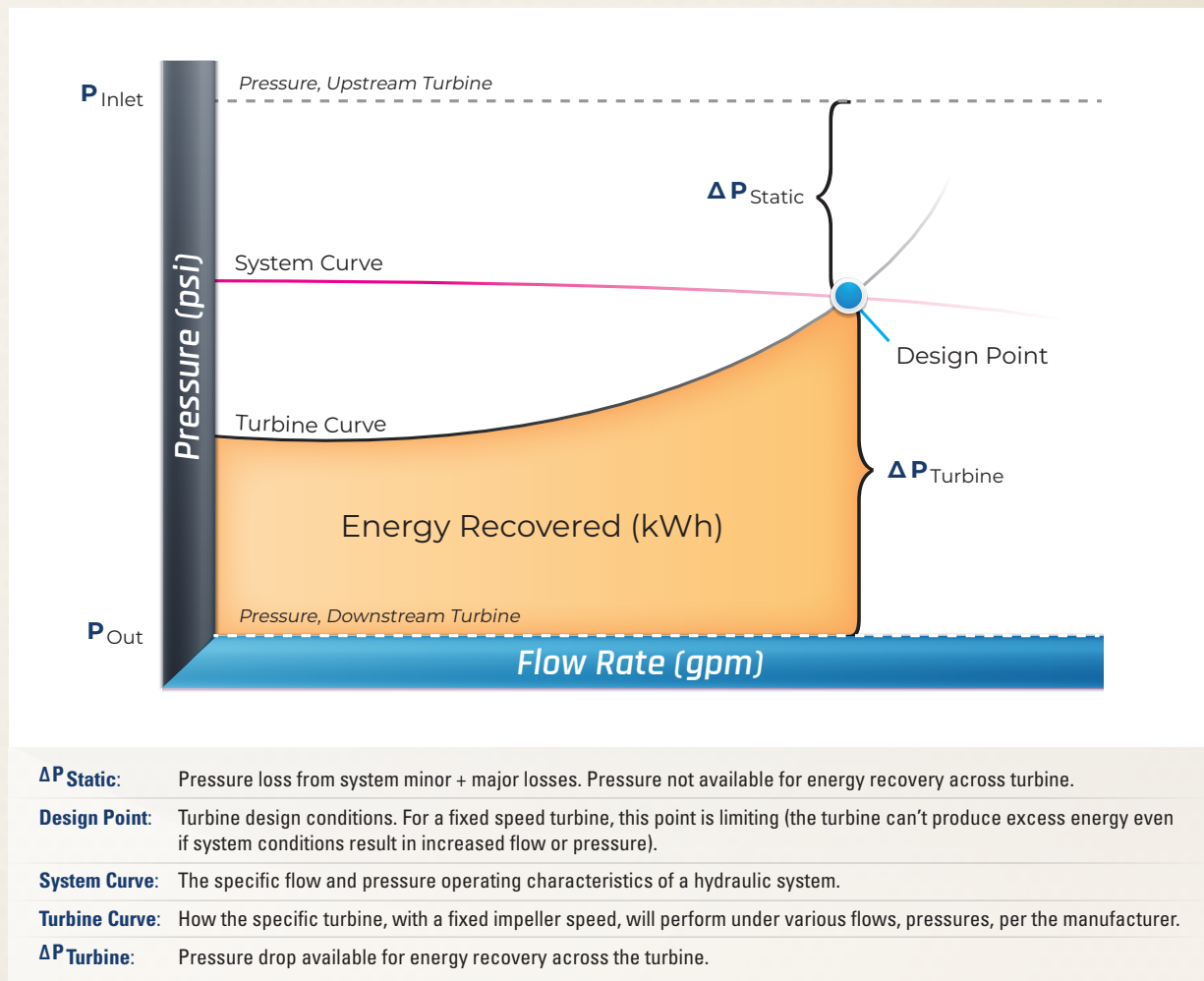
How the HydroXS maximizes power generation

Conventional single-speed turbines:

Typically, a micro hydro-turbine with a generator operates at a single fixed speed, regardless of variations in flow or pressure. To maximize efficiency, a single-speed turbine requires operating at a specific incoming flow and pressure point, or design point. This creates challenges when experiencing flows or pressures outside the design point, where the turbine is either not able to operate, or is not able to operate efficiently.

- 1 Figure 3 showcases the system operating conditions for a single-speed turbine system. Similar to a pump system (but with a reverse or opposite operating curve), a specific turbine model will operate along its “turbine curve” relative to its single-speed impeller.
- 2 The real life hydraulic system operates variably along a “system curve” under differential flow and pressure head availability. The turbine is optimized for use where the curves cross, at a design point with specific flow and pressure conditions.
- 3 The pressure under the turbine curve represents the pressure drop across the turbine and therefore the pressure available to the turbine to generate energy. The static pressure losses are losses relative to the hydraulic system’s minor and major losses and are not available across the turbine. The potential energy generation of the system is then represented as the area under the turbine curve.

Figure 3: Typical operating conditions for a single-speed drive turbine system.



When the natural hydraulic conditions (within water piping) change beyond the design point – whether it is the flow or pressure conditions that vary – the energy generated will not be optimized and will be lower than the energy potential of the hydraulic system.

- 1 Figure 4 showcases the missed potential of single-speed hydro-turbine system when flow *decreases* – which decreases the pressure drop available across the turbine and results in less energy recovered.
- 2 Similarly, if the flow were to *increase* beyond the design point (to the right of Q_{design}), the single-speed turbine would be unable to recover the additional potential energy available as it cannot operate beyond the design conditions.

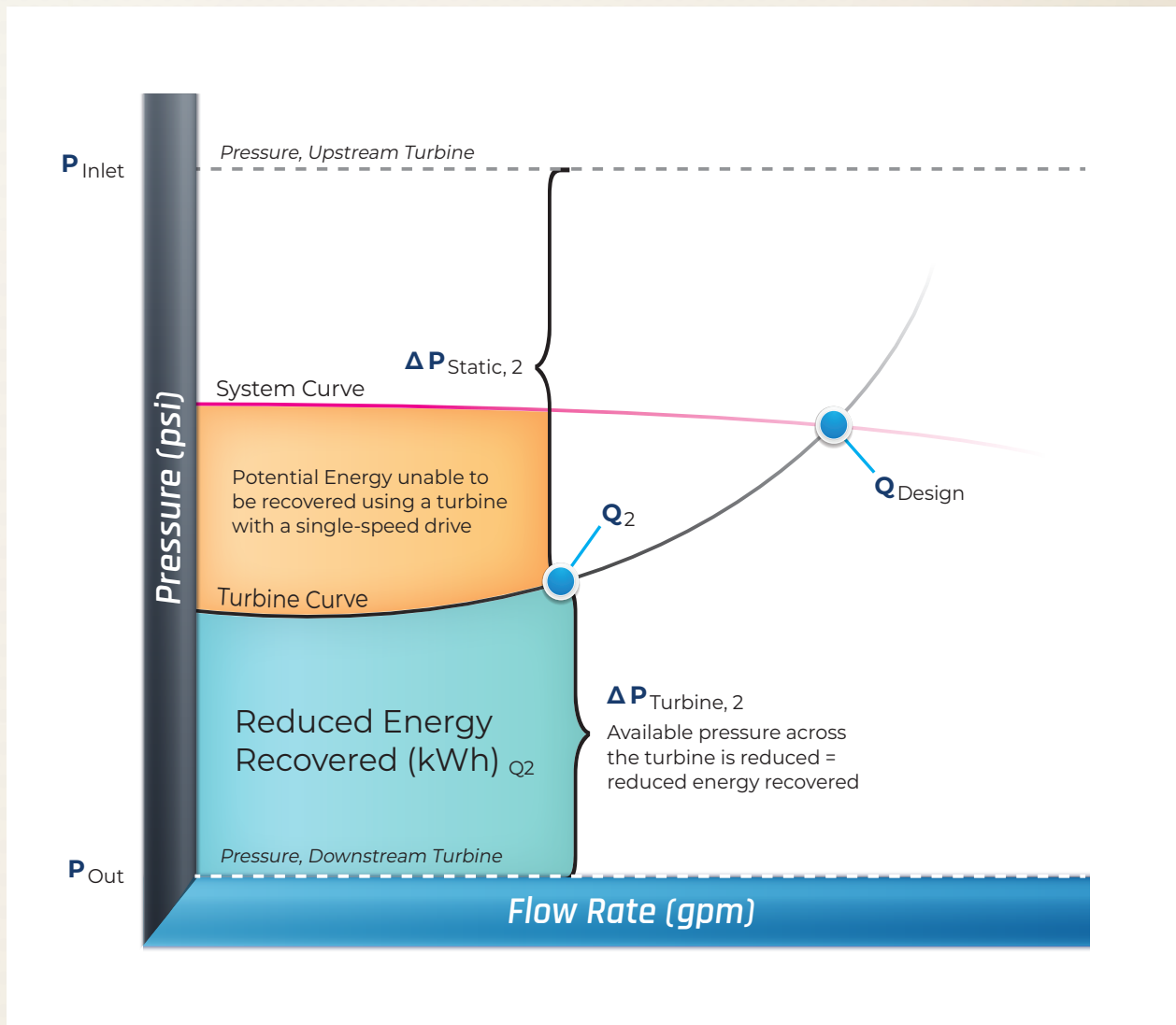


Figure 4: A single-speed turbine can not replace a control valve because it has a limited range for operation. This limitation also reduces energy generation and carbon reduction.

InPipe Energy's cutting-edge technology stands out by yielding up to 60% more energy generation than other comparable solutions.

Maximizing power generation with the HydroXS:

The HydroXS® combines a variable speed drive with an innovative programmable pressure control loop – consisting of a flow bypass, pressure sensors, a control valve, and programming control logic (Figure 5).

- 1 The variable drive varies the frequency of the generator, ramping up or down the turbine impeller speed to accommodate varying flows.
- 2 Adjusting the speed of the hydro-turbine (to match the operating conditions) increases both the available water volume and the pressure drop across the HydroXS® under changing hydraulic conditions, thereby maximizing system electrical power output and performance.
- 3 The pressure control loop in tandem with a control valve, manages downstream pressure given a specific set point by the operator, by telling the variable drive how fast or slow to modify the speed to match the downstream pressure requirements and maximize the pressure drop across the HydroXS®.

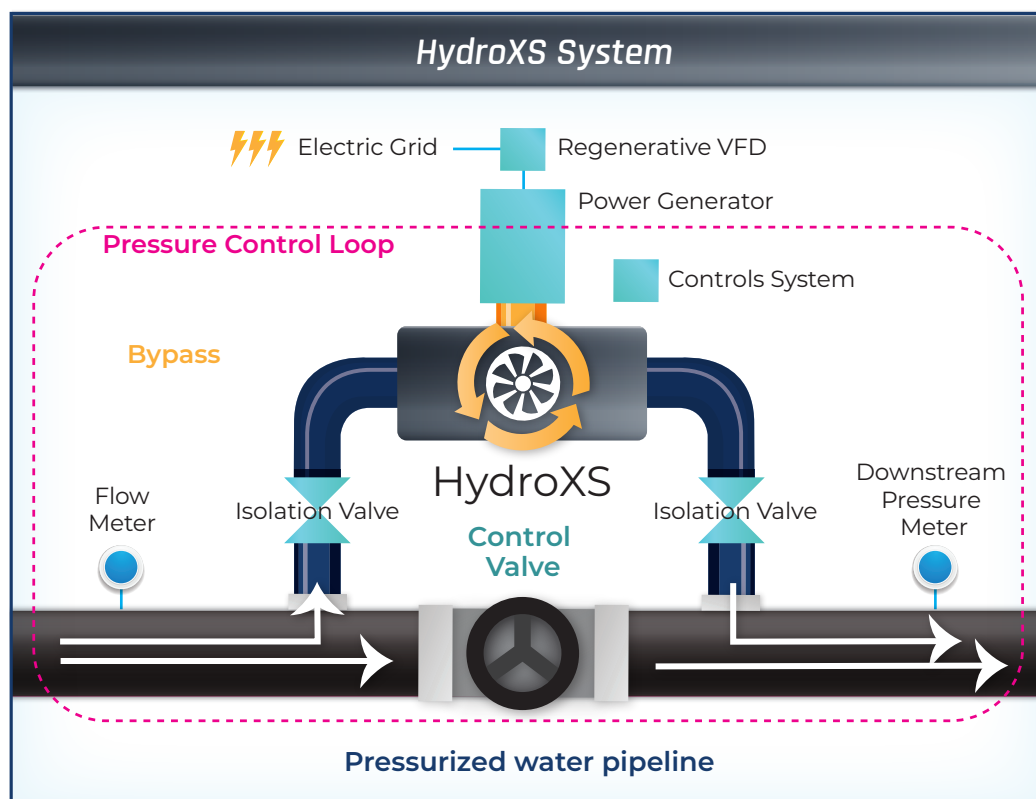


Figure 5: HydroXS with a variable speed drive and pressure control loop replicates the functionality of the control valve for precise pressure management and flow control, and also maximizes energy generation.

Figure 6 shows how adding a variable speed HydroXS operates well outside a single design point, efficiently generating power under various flow conditions. In this example, two additional flow conditions outside the design flow are shown, in which the HydroXS® is able to utilize the full water volume across the turbine system to generate electricity. The variable drive allows the turbine to act like multiple turbine sizes in one, generating power under a larger range of flow conditions more efficiently – this same concept could be explained in terms of varying pressure conditions as well.

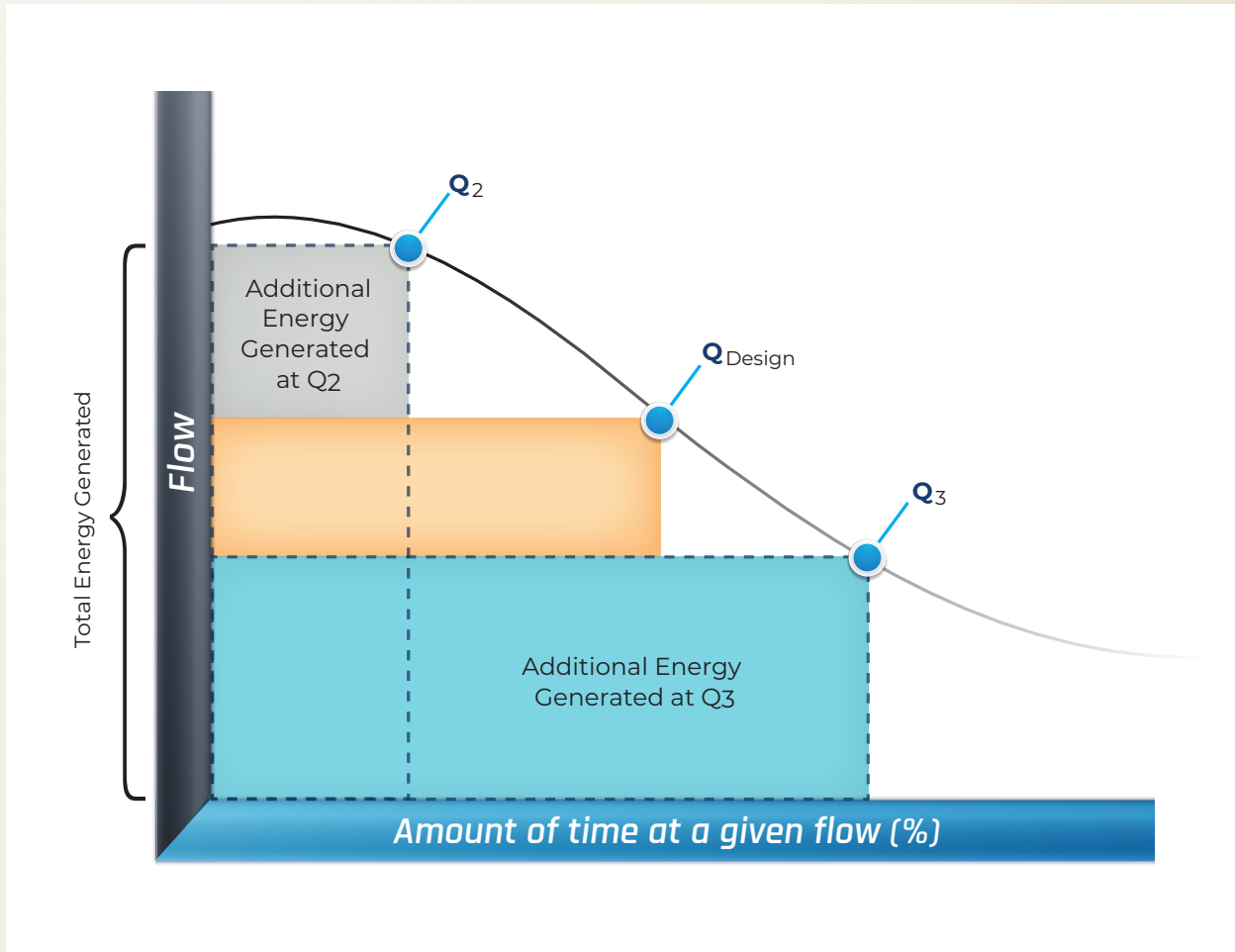


Figure 6: The HydroXS uses proprietary variable speed technology to capture a wide range of flows and pressure to maximize energy generation.

Water utilities, industrial facilities and other large water users use an average of 40% of their budget on energy to move water and this cost is rising rapidly alongside the price of energy.

Figure 7 shows this same concept using a turbine curve and hydraulic system curve. When the HydroXS experiences reduced flow conditions (Q_2), it increases the impeller speed to “lift” the turbine curve to match the hydraulic operating conditions. This maximizes the pressure drop across the turbine and minimizes the system static pressure losses. The energy generated is greatly increased compared to the same reduced flow operating conditions using a single speed system, as shown in Figure 4.

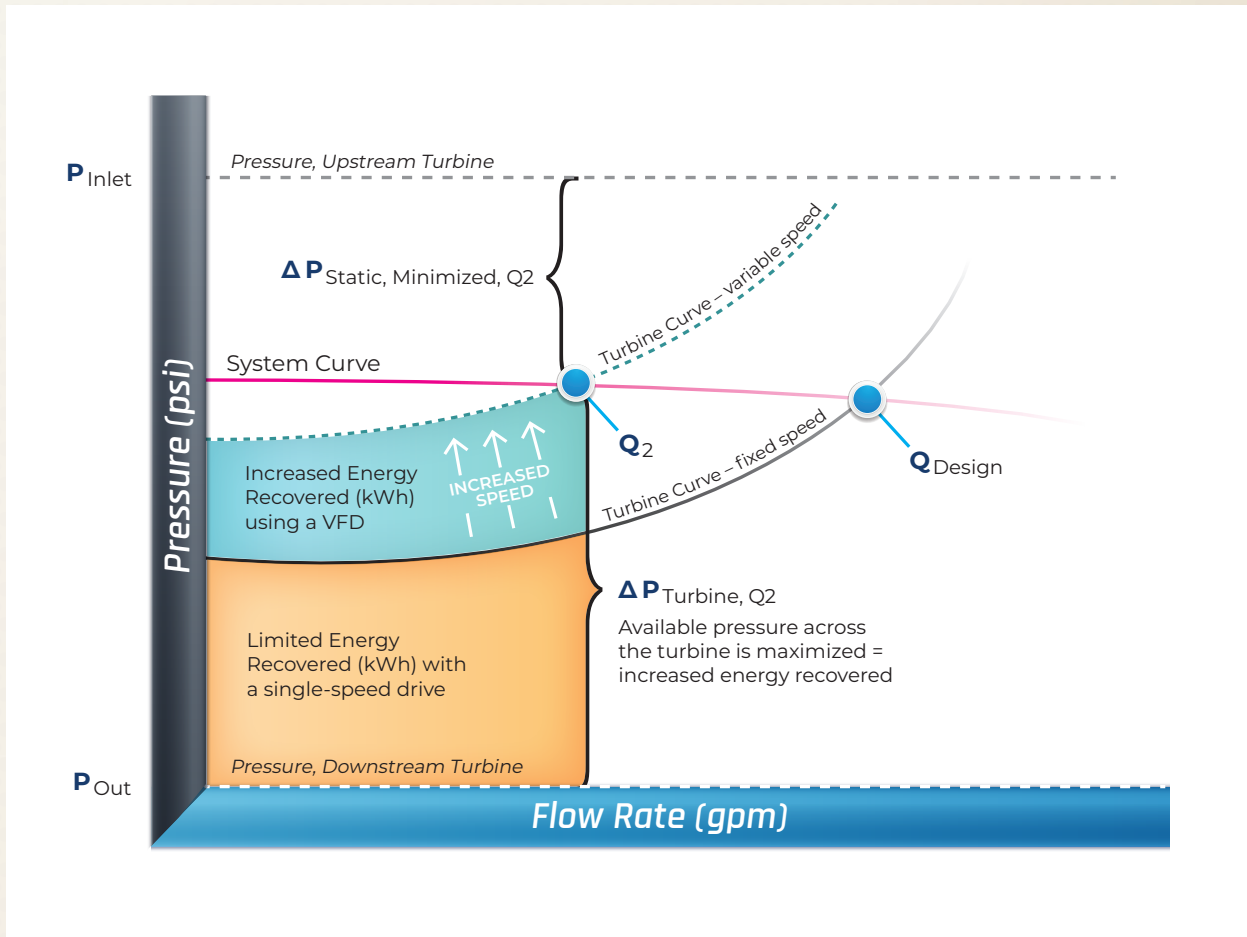


Figure 7: The variable speed HydroXS maximizes energy generation even when system flows are reduced.

The variable speed technology utilizes these sensors and the PLC control system to continuously monitor flow and pressure. The control system has been designed and tested to achieve the optimal balance between pressure regulation and energy recovery.



Learn more

About InPipe Energy:

InPipe Energy developed the HydroXS product line to help the world address the climate crisis with a new source of renewable energy from water pipelines.

We believe in a future where clean energy is as abundant as clean water. Water is often taken for granted because it's cheap and plentiful just as it's underappreciated for its potential to generate reliable energy.

To learn more about the HydroXS with variable flow turbine technology, please contact us.

Website: www.InPipeEnergy.com

Email: info@inpipeenergy.com

Call: 310.906.0783