The Alaskan way

Alaska is proving to be an ideal place to develop a hydrokinetic power industry. Innovative technology ideas, strong interest from utilities and local communities, plus high energy costs are some of the reasons that look set to pave the way for Alaskan power development.

ALASKA is an attractive market for hydrokinetic power-generating device developers/users because of its high hydrokinetic resource potential, high energy costs (more than three times the US national average in rural areas), and state legislation that establishes a goal of reaching 50% renewable energy generation by 2025.

Many of Alaska's small, isolated villages are located along major river systems, and there is substantial interest in using hydrokinetic devices as a way to reduce energy costs. Tidal resources in locations such as Cook Inlet could be developed to serve the more populous areas of the state.

The production of power using hydrokinetic devices is pre-commercial. Two projects conducted on the Yukon River at Eagle (summer 2010) and Ruby (summers of 2008-2010) are the first demonstration units operating in an Alaskan river system. These pilot projects demonstrated the potential benefits and challenges associated with implementing this new technology in the Alaskan environment.

The Vortex Hydro VIVACE hydrokinetic power conversion device that operates from the principal of vortex induced shedding induced oscillations.

Alaskan potential

The Electric Power Research Institute (EPRI) estimates that 109,000GWh of tidal hydrokinetic power is available in the Alaska coastal region. EPRI site specific studies funded by the Alaska Energy Authority (AEA) indicate that utility scale tidal hydrokinetic resources exist in southeast and central Alaska that range from 9-1600MW of available power with estimated extractable power (assuming a 15% extraction of available power) of 1.35 to 240MW.

The hydrokinetic power potential of Alaska's rivers with discharge rates greater that 113m^3/sec was estimated to be approximately 4.3GW by a 1986 New York University study of the overall hydrokinetic power potential of the US. To refine this estimate, the Department of Energy (DOE) is currently funding a study to re-evaluate the overall river hydrokinetic energy in the US, including Alaska. A 2008 EPRI site-specific resource characterisation of rivers next to six Alaskan communities found that the average annual hydrokinetic power was about 9MW with a total available annual energy of about 78GWh.

Throughout Alaska, the cost of energy (in 2010 US$) can range from \$0.14/kWh–\$0.94/kWh. The lowest costs occur in the Anchorage area, where locally available natural gas is used for power generation. Electric power rates for larger rural utilities, such as the Alaska Village Electric Corporation (AVEC), a utility that serves 53 remote villages, are approximately \$0.52/kWh in 2010 US dollars. Energy costs for other remote villages is often higher and is extremely sensitive to changes in the delivered price of diesel, which is shipped by barge in summer on Alaska's river system or by plane.

The estimated costs of energy that could be expected from hydrokinetic sources (using EPRI study results and updated to 2010 US$) range from \$.11/kWh at Knik Arm (near Anchorage) from tidal resources up to \$0.68/kWh at Igiugig and Eagle from river hydrokinetic resources. While much higher than the average annual costs of energy in the continental US (~\$0.09/kWh), the cost of hydrokinetic energy potentially can be competitive with existing generation in Alaska. In addition to displacing expensive diesel in remote villages and diversifying the energy portfolio, other potential benefits of using hydrokinetic energy in Alaska include, creating local energy related jobs, reducing GHG emissions, reducing energy cost fluctuations, and developing an expertise in renewable hydrokinetic energy technology.

Challenges to development

As a relatively new technology, hydrokinetic devices have significant engineering, economic and environmental challenges that need to be resolved before commercial projects can be effectively developed. Engineering issues for hydrokinetic devices related to anchoring, foundation support (for underwater installations), installation methods, technical and operational viability, performance capabilities, and operating and maintenance requirements are not fully known or understood for Alaskan conditions.

All of these engineering issues can be affected by woody debris that can exist throughout the water column, suspended sediment, river or sea floor conditions, and water turbulence. Debris can collide with, or accumulate on, hydrokinetic devices causing damage or disrupting operations. Suspended sediment can abrade engineering components and sediment deposition or scour around anchors or foundations can affect their performance. Turbulence can reduce the power conversion efficiency of hydrokinetic devices and impose fatigue stress loading on engineering components. In addition to engineering challenges, economic factors, such as determining the best tidal or river sites to locate hydrokinetic devices, and return on investment are not well defined.

In many parts of Alaska it may not be possible to deploy hydrokinetic turbines year-round in rivers due to: low wintertime current velocities (from October–April); the possible accumulation of frazil ice on turbine components; and the formation of river ice covers and moving ice in tidal basins such as Cook Inlet.

Hydrokinetic devices typically need a minimum current of 1–2m/sec to operate properly, with optimal current velocities ranging from 1.5–3.5m/sec. However, some new devices may be capable of producing power at current velocities as low 0.5m/sec, which would greatly expand the number of viable sites and improve economics for projects.

FERC regulates hydrokinetic power production and installations. Any hydrokinetic tidal or river device that delivers electricity to a commercial grid requires a FERC permit before it can be deployed. FERC staff have identified a number of concerns about hydrokinetic devices related to water turbulence, corrosion, anchoring systems, fluid leaks (eg hydraulic fluids), underwater transmission line effects, and installation and maintenance problems. Many of these concerns are the same as the engineering problems that device developers and users are currently working to resolve.

In addition to these technical issues, there is concern from stakeholders and regulatory agencies about potential ecological effects related to marine and riverine fishes as well as marine mammals. Alaskan marine fisheries sustain nearly half of annual US commercial fish catches, including significant salmon resources that migrate and spawn in Alaskan river systems. Additionally, Cook Inlet is home to a resident population of endangered Beluga whales resulting in parts of the inlet being designated as protected habitat by the US National Oceanic and Atmospheric Administration's National Marine Fisheries Service.

The FERC process to obtain permits can be labour-intensive and time consuming for commercial facilities. To reduce the regulatory burden for small, short-term demonstration projects, FERC developed a licensing process that can be completed in as few as six months for hydrokinetic pilot projects intended to test new technologies. The pilot project allows for project installation, operation, connection with an electrical grid, and investigation of environmental effects.

In Alaskan rivers, environmental effects monitoring is primarily focused on salmonid fishes. The Alaska Department of Fish and Game (ADF&G) requires a site-specific study to describe the fish community and their migratory patterns at the installation site prior to issuing a permit for installation of a hydrokinetic device. Once a hydrokinetic device is in operation, ADF&G also requires a study of the interaction between fish and the device to ensure that there are no adverse impacts on the fish community.

Hydrokinetic device technological and economic viability is a function of a specific manufacturer's technology, power-generation costs in target markets, and the ability of hydrokinetic technology to operate effectively in Alaskan conditions. These can only be determined by undertaking specific demonstration projects. Two hydrokinetic projects at Ruby and Eagle, Alaska, demonstrated that hydrokinetic power generation to serve rural markets is possible, but that the challenges to maintain and operate the devices in debris-filled rivers are substantial.

An Alaskan approach

Alaska has a strong commitment to the development of renewable energy resources with a goal of 50% of electricity coming from renewable sources by 2025. The state promotes development of renewable energy using state funds and partnering with US federal organisations to sponsor private and public sector organisations to develop utility power projects, develop new and emerging energy technology, and to conduct applied research.

There are a number of funding avenues for hydrokinetic projects in Alaska. In 2005, Alaska created the Renewable Energy Fund (REF) to award funds to qualified applicants through a competitive process for renewable energy utility projects. This programme is administered by the AEA, a state agency whose mission is to reduce the cost of energy in Alaska. In addition to the REF, AEA administers an Emerging Energy Technology Fund (EETF) and sponsors the Alaskan Hydrokinetic Working Group.

Most recent hydrokinetic projects have been sponsored through the EETF program, which was originally formed in 2009 by the Denali Commission (DC), an independent federal agency whose mission is to provide critical utilities, infrastructure and economic support throughout rural Alaska. The EETF was developed to fund near-commercial emerging energy technology pilot projects and currently uses a combination of federal (through the DC) and state funds to make awards. In addition, DOE supports renewable marine and river hydrokinetic energy technology development projects in Alaska through a competitive proposal process, through a co-funding partnership between DOE and the state, and a guaranteed loan programme.

To facilitate development of hydrokinetic power production in Alaska, there are numerous research efforts underway led by Alaskan companies, universities, research centres and other organisations. Study topics include: determining available hydrokinetic power at selected locations along Alaskan rivers; examining sediment abrasion of engineering bearings; and developing river characterisation methods and applying them to facilitate hydrokinetic device deployment.

River characterisation studies help determine optimal locations for hydrokinetic device(s) and provide information on river conditions that affect hydrokinetic device operations and maintenance. Important river characteristic parameters include available hydrokinetic power, river turbulence, suspended and bed load sediment transport, debris statistics and ice conditions.

Applied research and engineering specifically related to extracting energy from river and tidal hydrokinetic resources are the focus of the Alaska Hydrokinetic Energy Research Centre (AHERC). AHERC, which is part of the Alaska Centre for Energy and Power (ACEP), an applied energy research programme at the University of Alaska Fairbanks (UAF), has developed a strategic plan that describes AHERC's goals and objectives

As outlined in the strategic plan, AHERC will develop partnerships to address technical, political, funding and other issues and rely on an advisory committee to guide research and development priorities. A primary goal of AHERC is to establish a hydrokinetic power generation test facility on the Tanana River at Nenana, Alaska, to facilitate device testing at a well-characterised permitted location.

Case studies

Eagle demonstration project (Alaska Power & telephone – AP&T)

AP&T received a grant from the Denali Commission in 2007 to install a hydrokinetic turbine in the upper Yukon River near Eagle, Alaska, as part of a pilot study to determine the viability of the new technology. AP&T's primary motivation of undertaking the project was to take advantage of the high kinetic energy of the Yukon River at this remote community, and to reduce dependence on diesel powered generation.

The pilot project conducted detailed hydrodynamic and bathymetry surveys prior to deploying a 25kW New Energy Corp EnCurrent turbine generator in 2010. Fish studies were performed to determine the turbine's impact on local resident species and migrating salmon as required by AP&T's operating permits.

The turbine power conversion system was designed by Alaska Battery Supply to allow standalone hydrokinetic power generation into the electrical grid or parallel operation of the turbine with the diesel engine powered generators (diesel is the normal mode of operation). The power conversion system operated well and there were no problems synchronising and connecting to the grid. Power was transmitted through a submerged cable to a cascaded bank of 6kW inverters. The turbine at times delivered 25-30% of the Eagle electrical system load, reducing the demand on the diesel units. In standalone mode, the unit successfully delivered 100% of steady 60Hz power for a load that ranged up to 10kW. Generated power in excess of the system load was dumped into a load dissipation bank. Two specially designed heavy penetrating anchors were successfully used on the relatively smooth river bottom that was covered with close packed rocks to a depth of more than half a metre.

Technical problems included gearbox overheating and nuisance tripping of the power inverters caused by a frequency acceptance range that was too narrow for line excursions that occurred on Eagle's isolated electrical grid. The problems were resolved by adding an external deck-mounted oil circulation and cooling system and by using an inverter with a wider frequency range acceptance. The most significant problems were associated with large debris drifts interfering with operations.

Moss, twigs and trees with intact root balls collected on the lines and equipment. Lines and cables fouled with small material became heavier and very difficult to handle. The larger material collected on the equipment had to be removed to continue operations. Submerged neutrally buoyant debris fouled mooring lines and required great effort to bring to the surface and remove. Drift materials would also amass into large islands upriver and move downstream, threatening everything in their path. Debris removal/clean-up required great effort, personnel and equipment. These operations were very expensive and while the equipment was fouled the turbine was not generating.

AP&T did not determine cost of the hydrokinetic energy. Their operating experiences led them to conclude than actual operations and maintenance costs are variable and that extracting hydrokinetic energy is more involved than just how the turbine element interacts with the river environment. AP&T further concluded that each site will likely have different challenges and require different strategies for overcoming them and that many hours of operations at different locations will be required to determine the impacts of hydrokinetic technology. At Eagle, when the turbine operated normally it required nearly zero effort to maintain and there were no fuel costs so $/kWh appeared to be lower than diesel. However, the cumulative associated costs for operating the hydrokinetic turbine at Eagle through the summer were very high resulting in a $/kWh that was many times greater than that for operating the diesel plant.

AP&T decided that at this time the economics of operating a hydrokinetic turbine in the Yukon at Eagle are unfavourable. The company wants to find alternative electrical power resources for its communities currently served by diesel generation. AP&T is interested in participating in the development of hydrokinetic technologies and is working with DC and ACEP with the idea of the deployment of the Eagle turbine at the AHERC hydrokinetic test facility at Nenana.

Ruby demonstration project (Yukon River Intertribal Watershed Council, IRITWC)

A 5kW in-stream hydrokinetic generator developed by New Energy Corporation was installed in the Yukon River at Ruby during the summers of 2008–2010. The project tested the idea that Yukon River hydrokinetic power could replace high cost diesel fuel used at Ruby. The generator was mounted on a pontoon boat anchored in the Yukon with a V-shaped debris boom attached to the front of the boat to deflect floating debris.

The turbine worked as anticipated, but very little electricity was generated during the project due to slow current (2008), problems with electrical transmission cable abrasion on the river floor (2009), difficulty positioning the transmission cable (2010), and floating and submerged debris. While the diversion system was effective it required regular cleaning, as entrapped floating and submerged debris adversely affected turbine performance. A number of high water events during 2010 brought unusual amounts of debris downriver, which continued to prevent long-term deployment of the turbine barge, even though the debris boom was redesigned twice to better enable it to shed debris.

Cook inlet and Tanana River at Nenana preparatory projects (Ocean Renewable Power Company – ORPC)

ORPC has applied for a FERC preliminary permit, and filed a draft pilot project licensing application, to install and test a series of power systems in Cook Inlet near Fire Island and East Foreland, and in the Tanana River near Nenana.

Summary of funded hydrokinetic projects and studies in Alaska as of 2011

Project description	Funding source
Hydrokinetic resource study of Alaskan rivers (University of Alaska Anchorage)	AEA-REF
Tanana river characterization study at Nenana (Alaska Hydrokinetic Energy Research Center)	AEA-REF
Iguigigt power generation project (Alaska Energy Authority)	AEA-REF
Eagle demonstration project (Alaska Power and Telephone)	DC-EETG
Ruby demonstration project (Yukion River Intertribal Watershed Council)	AEA-REF
National hydrokinetic resource study (Electric Power Reseaerch Institute)	DOE
Cook Inlet Beluga whale study (Ocean Renewable Power Company)	DOE
Sediment abrasion study (Ocean Renewable Power Company	DOE
Delta Junction demonstration project) (Whitestone Power and Communications)	DOE

In the summer of 2009 at the Fire Island site, ORPC conducted in-depth marine geophysical work, extensive current velocity surveys and started a pre-deployment fish and marine mammal study that will continue through 2012. In August 2010, ORPC conducted performance testing in Maine of their Beta TidGen turbine generator unit at flow speeds of slightly more than 2.5m/sec, demonstrating that the turbine produced power within design performance tolerances. In 2011, DOE sponsored laboratory tests at University of Alaska Anchorage (UAA) to test bearings and seals under sedimentary, flow and loading conditions that reflect the expected conditions at the ORPC field site in Cook Inlet. Studies to determine the prevalence of debris, sediment and ice (during winter) will be conducted in the future.

Tanana River site characterisation began at Nenana in 2008 with surveys on current velocities and river bathymetry. ORPC partnered with the University of Alaska Fairbanks, instigating the creation of the AHERC. These studies continue and have expanded to include: modelling of the river resource; baseline environmental data collection (fish and sediment); and analysis of river debris and diversion techniques.

After installation of the turbine, studies will include monitoring potential environmental effects of the installation and operation. The RivGen turbine testing at Nenana will include data collection on device performance, the costs associated with installation, operation and maintenance and extensive environmental studies.

Igiugig hydrokinetic power project (AEA)

Igiugig is a small remote community of less than 60 people in southwest Alaska located at the mouth of the Kvichak River near Lake Iliamna. Igiugig is in the initial stages of implementing a plan to develop hydrokinetic turbine power generation capability, working with the AEA through an REF grant. A preliminary FERC permit has been granted, and baseline studies are planned for 2011. Plans are in place to select a specific hydrokinetic technology for installation in 2012.

Tanana River characterisation project at Nenana (AHERC)

AHERC is conducting an AEA-REF sponsored detailed characterisation of a reach of the Tanana River near Nenana, Alaska in partnership with ORPC to determine the site's available year-round hydrokinetic energy potential and environmental characteristics relevant to hydrokinetic device installation and operations.

Aspects of the river environment of interest include river hydrodynamics measurement and modelling (current velocity, flow lines,

Alaska Site Specific River Hydrokinetic Resource Summary

Site	Average Available Power (kW)
Tanana River	
Nenana	694
Whitestone (Biig Delta)	762
Yukon	
Pilot	1,675
Eagle	4,601
Taku	
Juneau	482
Kvichak	
Iguigig	719

Alaska Site Specific Tidal Hydrokinetic Resource Summary

Site	Average Available Power (kW)	"Average Extractable Power (15%) (MW)"
Cross Sound and Icy Straight		
South Passage (Icy Straight)	480	72
North Passage (Icy Straight)	420	63
South InianPass	150	22.5
North Inian Pass	1600	240
Wrangell Narrows		
Turn Point	9	1.35
South Ledge	12	1.8
Spike Rock	9	1.35
Chatham Strait		
Kootznahoo Inlet	23	3.45
Peril Strait		
Sergius Narrows	25	3.75
Prince of Wales Island		
Tleviak Narrows	18	2.7
Tonowek Narrows	11	1.65
Cook Inlet		
Knik Arm	116	17.4

turbulence and channel stability), suspended and bed-load sediment transport, debris flow, ice interactions and fishes. Study results will facilitate ORPC's efforts to deploy and operate a hydrokinetic turbine in 2012 and beyond, plus provide a well-characterised site that has received necessary permits to operate a hydrokinetic test facility.

An anchor and mooring buoy currently being used for fish studies will be available to allow hydrokinetic device manufacturers to test their technology under Alaskan conditions without the cost and added burden of separately doing river hydrokinetic characterisations or baseline studies to satisfy permitting agencies.

Hydrokinetic energy assessment of major rivers in Alaska (UAA)

UAA is conducting an AEA-REF sponsored hydrokinetic energy assessment of major rivers in Alaska. Seventeen sites were visited on the Yukon and Kuskokwim Rivers during the first year of the project and ten additional sites were assessed during year two. During 2011, UAA plans to study five to ten additional sites including additional sites on the upper Yukon. Preliminary findings indicate that nearly all of the sites have sufficient velocity to allow power generation. The sites furthest upstream have the highest velocities and, therefore, the highest hydrokinetic power density.

Future plans and opportunities

Interest by hydrokinetic device developers, utilities and state agencies in using hydrokinetic energy in Alaska is growing. The AEA-sponsored Alaska Hydrokinetic Working Group has over 50 participants from within and outside of the state. Hydrokinetic device manufacturers have plans to enter the Alaska market to conduct demonstration and proof-of-concept projects using a variety of technologies.

Pulse Tidal, one of the world's leading tidal hydrokinetic technology developers, with over two years of operating experience with a 100kW oscillating hydrofoil prototype unit in the UK, plans to bring 1MW-scale tidal devices to the Cook Inlet over the next few years. Pulse was recently awarded a US Department of Agriculture grant to conduct a feasibility and environmental study ahead of developing deployment plans. Pulse has also demonstrated a run-of-river oscillating hydrofoil hydrokinetic generator that they plan to demonstrate in Alaska in the next few years.

US-based Boschma Research plans to demonstrate its small 'homeowner' scale 1.5kW prototype Cyclo-Turbine technology on the Tanana River and a 15kW system for commercial applications at the Ganes Creek Mine near Talkotna. Cyclo-Turbine efficiency is optimised by continuously changing the blade angle of attack during turbine rotation to maximise lift and minimise drag. A Venturi flow accelerator increases available kinetic energy at the turbine making the system compact, thus suitable for shallow creeks and slow-moving water to expand the hydrokinetic potential to remote small-scale power markets.

Vortex Hydro Energy is working to test a VIVACE 3-5kW hydrokinetic power generator in the Tanana River at the AHERC test site at Nenana, Alaska. The demonstration will assess the VIVACE's: energy extraction effectiveness; ability to resist debris; fish safety; reliability; operating and maintenance requirements; and economic viability.

The VIVACE uses enhanced vortex induced vibration and galloping to generate energy from river or tidal currents. The technology has been well proven through tow-tank testing and deployment in the St. Claire River at Port Huron in Michigan.

Whitestone Power and Communications is planning to conduct testing and evaluation of an undershot waterwheel turbine using DOE funding. The turbine is designed to improve turbine survivability in shallow river environments with extreme weather conditions, debris, fish, and sediment. Finally, Backer Hughes has plans to design and test a reconfigured pump system to function in reverse as a hydrokinetic power turbine.

The variety of hydrokinetic power generating device developers and their innovative technology ideas, the strong interest from utilities, local communities, state, and federal government, and the high energy cost in Alaska make it the ideal place to develop and grow a hydrokinetic power industry. IWP&DC

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