The Hydro Powered Resort:

Exploring the Possibility of Hydro Power in the Ski Industry

By Bryan Miller

In the western world our society places great value on recreation. Our economic success combined with our increased leisure time has given rise to hundreds of industries focused on keeping ourselves entertained, all of which increase our ecological footprint on this planet. The ski industry is a prime example of this phenomenon. The love many share for sliding down snow has given rise to a huge global infrastructure devoted to getting skiers to the tops of mountains as quickly and efficiently as possible. The rise of skiing as a status symbol and activity enjoyed by the wealthy has created huge resort communities at the bases of many of the most popular ski areas. All of this infrastructure combined creates a need for huge amounts of power all for the sake of recreation, and traditionally this power has come from coal burning power plants and diesel generators. While some resorts such as Whistler Blackcomb and the Aspen Skiing Company have done great work recently in reducing their overall ecological footprint, the industry at large has been surprisingly slow to change. Ironic considering its livelihood is directly tied to the health and well being of the environment. With this in mind, the goal of this project was to find an alternative energy source that could be put into use by ski resorts that would not only be effective at reducing the resorts energy consumption from the grid as well as their environmental impact, but be appropriate for the unique mountain environment these ski areas are located in.

When considering what alternative energy source to use for this project, hydro power immediately presented itself as the obvious solution. The mountain environment of the higher latitudes is not ideal for solar power because the mountains create shade for many hours of the day and daylight is limited in the winter months. Wind is also less than perfect for the sole reason that it is less than reliable. While mountain winds can often be fierce, a calm could halt energy production indefinitely. Hydro then becomes the most reasonable solution simply because, stored as snow, it is the most abundant resource many of these locations posses. The USGS estimates that, “as much as 75% of water supplies in western states are derived from snowmelt.”[1] With such an abundance of water stored on site a local micro hydro plant could produce consistent power for the resort without creating the need for a large infrastructure to transport the power from the source to the user. Whistler Blackcomb has chosen to tackle this problem through the use of a dam on the Fitzsimmons river which flows between the two mountains. While according to their own PR the damn, “would return back onto the grid an estimated 32 Gigawatt hours of electricity annually, the equivalent of energizing 3000 to 4000 homes and also equal to Whistler Blackcomb's annual energy consumption,” it also faces the ecological problems associated with all dams.[2] The trick then becomes how to implement our existing hydro technologies in new ways that would allow for the reliable generation of clean power without the environmental consequences of traditional large hydro projects in areas that do not necessarily feature a dependable body of running water for a conventional system.

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[1] http://ga.water.usgs.gov/edu/watercyclesnowmelt.html

[2] http://www.whistlerblackcomb.com/environment/energy.aspx

The Idea:

The resulting idea required three different components. The first was a way in which to store and harness the water generated by a melting alpine snow pack. The second was a way in which to transport this water to the generating station, which would be the third component responsible for turning the kinetic energy of the water into electrical power and disseminating that power to the resort. The problem of meltwater storage is partly solved by nature and partly solved by existing ski resort technology. Most higher elevation western resorts feature some sort of alpine bowl in the topography of their mountains. These glacially carved concavities in the terrain provide a natural gathering point for snowmelt.[3] In many such bowls a naturally occurring alpine lake is formed, and where they don't ski resorts often create an artificial lake allowing them to store water for their snow making equipment. These artificial lakes provide ideal storage for large quantities of water that can be constantly replenished as the snowpack melts throughout the spring and into the fall.

Once a collection pond has been established the problem becomes using this water to generate power. Most traditional small scale projects have relied on the natural, albeit redirected, flow of the water such as a paddle wheel turning a mill stone or a penstock redirecting flow into a turbine. The problem with these traditional small scale generating station is that they are just that, small scale. A ski resort requires massive amounts of power to spin lifts and run lodges and hotels, and most traditional micro

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[3] see Appendix A

hydro projects only generate between 5 and 100Kw.[4] In comparison a large resort like WhistlerBlackcomb claims to use 32Gigawatt hours of power annually and 100Kilowatt hours is equal to 1/320,000th of that amount. In order to up the output and start to eat at such a huge demand without increasing the environmental impact that a large hydro project would cause, one would have to up the output but use similar water amounts and infrastructure as a small hydro project. The ideal solution would be to increase the force per given volume of water used so that larger turbines can be turned at a greater rate for that volume.

The potential solution to this problem comes ironically from an old piece of mining technology once used to literally destroy mountains. During the California gold rush miners would run water through an ever narrowing channel building up enormous pressure into a hose and through an iron nozzle at which point the water had sufficient power to blast the area to be mined into rubble.[5] Even these antiquated cannons could according to the USGS, "they could throw 185,000 cubic feet of water in an hour with a velocity of 150 feet per second."[6] This high rate of flow and amplified pressure is ideal for producing hydropower. With building a hydropower system one could replace the traditional penstock channel of common hydro systems with a narrow insulated pipeline of progressively decreasing diameter running down from the water source at elevation culminating at a generating station at the base. At this point the water would spin a Pelton wheel which would offer the highest efficiency to powerlevel ratio[7], and generate

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[4] http://www.appropedia.org/Microhydro_power

[5] See Appendix B:

[6] http://ga.water.usgs.gov/edu/gallery/mining-hydraulic.html

[7] Sorensen, 464

usable, clean, and locally sourced power that has a much smaller footprint than a traditional large hydro installation.

How it Works

This system is in effect a fairly simple hydro plant that as been adapted to work in a specific context. Because of the fact that in this situation one has a relatively low volume of stored water compared to the huge reservoir of a dammed river, this system requires the use of lower volumes of water so as to not exhaust the supply. Fortunately thanks to the laws of fluid dynamics, using the repurposed hydro canon offers a way to maximize the output of this volume. According to Bernoulli's principal an increase in the speed of the fluid occurs proportionately with an increase in both its dynamic pressure and kinetic energy and a decrease in its static pressure and potential energy. This is to say that as the diameter of our pipeline is reduced along its length he water flowing through it is effectively being squeezed by the narrowing pipe but is forced through it by the volume of water behind it. This causes the dynamic pressure to increase and the water rushes forward with increased speed and kinetic energy.[8]

In a traditional Pelton wheel generator there is a nozzle on the penstock that transforms the pressure energy of the water into kinetic energy before it hits the turbine.[9] This serves the same purpose, but with this new design the water would be gaining speed and dynamic pressure along the entire length of the pipe line before even reaching the nozzle, thus maximizing the possible kinetic energy of the water available. The difference in vertical drop this alpine system allows for is also beneficial because

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[8] This can be expressed mathematically as: $\Delta Ek= 1/2(\Delta m)V_2^2 - 1/2(\Delta m)V_1^2$. Where ΔEk = the change in kinetic energy. Tipler, 245.

[9] Sorensen, 463.

the height difference between the generator and the reservoir in part makes up for the lack of volume. [10] This would all be accomplished without the use of a single moving part apart from a control valve, or any input other than the water its self.

By the time the water hits the Pelton wheel it should in theory be punching well above its weight in terms of the kinetic energy it is producing for it's volume. The value this is is measured as is the mass flow rate, and because the water has accelerated so much through the pipeline it has a very high flow rate despite a relatively low mass. This is ideal because in a perfect system a pelton wheel's output is equal to the velocity of the buckets collecting water which are equal to the velocity of the jet. Mathematically speaking the power generated by this system equals the mass flow rate multiplied by the difference in the velocities of the jet and the bucket multiplied by the velocity of the bucket.[11] That is to say if the rate of flow is high enough it will exert more force on the turbine buckets crating a higher angular velocity on the shaft which in turn will produce more torque on the system thus generating more power.[12]

Implementing this system should be fairly straight forward and cost effective. The components for the generating station are readily available as nothing in this system aside from the pipeline is different from existing hydro plants. Generating plants like this exist around the world so many contractors who have specialized in hydro plants in the past should in theory be available to build the system should it prove practical in testing. Even the pipeline may prove easier and cheaper to install than a traditional penstock because it doesn't need to be buried provided it is constructed of insulated

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[10] Power= (massflow*gravity)height O'Brien, 206.

[11] O'Brien, 208.

[12] Sorensen, 334.

pipes. Any resort desiring to install such a system would be facing a large price tag, however government incentives would likely be available.[13] Even if incentives were not offered repayment times on this system shouldn't take to long in the grand scheme of things. According to the U.S. Energy Information Administration the average cost per Kilowatt hour for commercial electricity in the United States is 10.32 cents.[14] If we use Whistler Blackcomb's annual use of 32Gwh as a bench mark for the needs of a large resort that works out to $330,240 spent annually on electricity that could be recouped each year if the resort was able to successfully switch to hydro. Ecological damage is negligible because the reservoir pond is created high in the alpine in a manner that mimics natural alpine lakes, and in an area free of fish and most flora and fauna. There are also no fuels required, no pumps, no contaminates from machinery, and the water is fed back into the ecosystem only a few thousand feet from it's source.

While I feel this particular design of hydro plant is an exciting prospect to be explored it does present some drawbacks and would not be appropriate for ski resorts in all areas. The most major draw back is the finite nature of the alpine snowpack. While in good years and in snowy areas the snow melt could produce ten fold the amount of water needed to meet the resorts needs, in lean years the reservoir could run dry. The other obvious drawback is that in the winter during peak demand the pond isn't receiving snowmelt, and while the water could possibly be kept artificially from freezing completely solid by heating pipes or air blowers it still leaves the system with a finite supply. In addition this system is only really appropriate for areas with a large

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[13] Hydroworld.com put the budget for the Fitzsimmons hydro project in Whistler at 28.8 million US, with an estimated 3.04 million in government incentives.

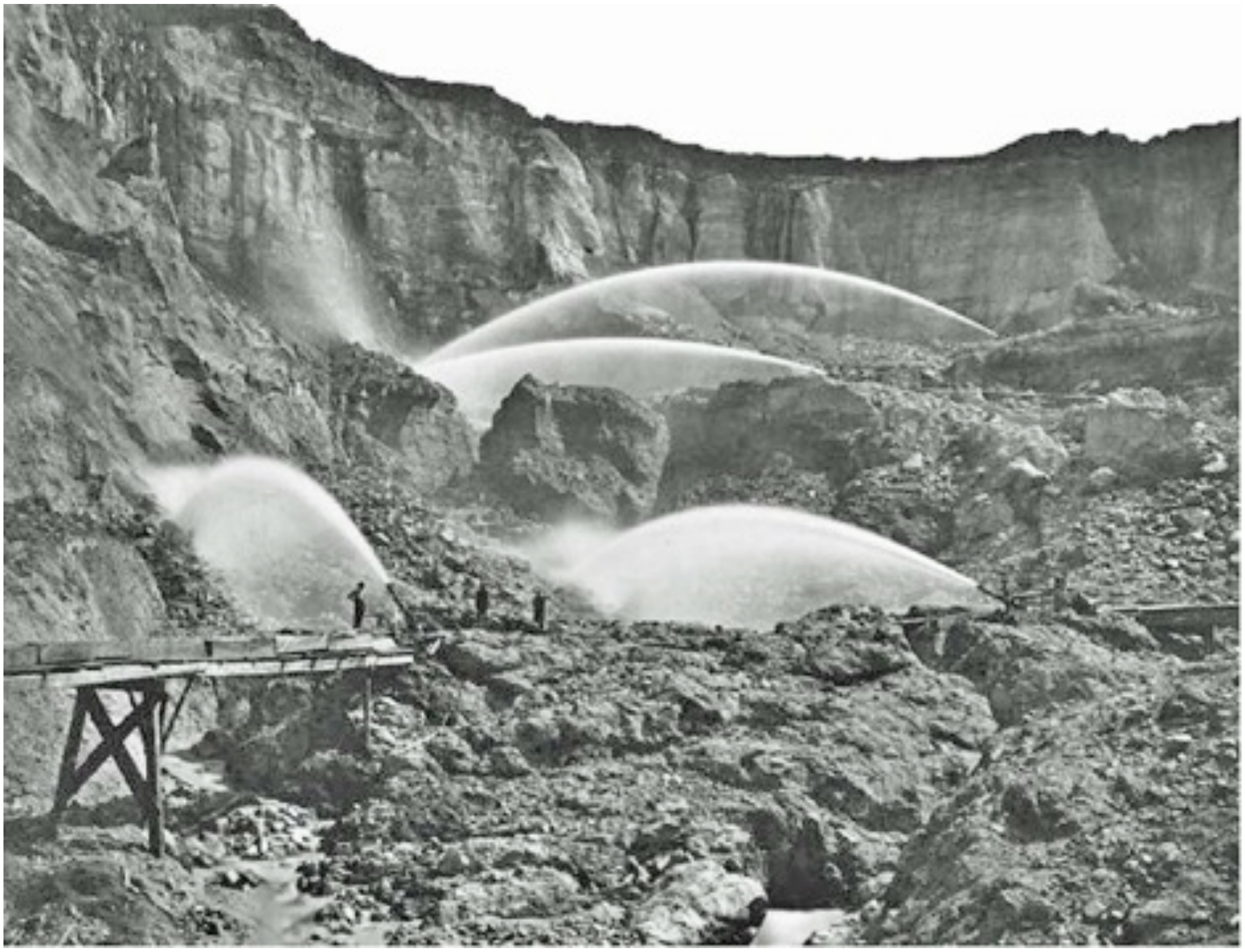
[14] http://www.eia.gov/energyexplained/index.cfm?page=electricity_home#tab2

dependable annual snowpack and the correct topography for collecting and storing the meltwater. In some areas there might be a consistent source of running water that would be more appropriate for the use of a traditional small hydro project. With this being said in an area where this technology is appropriate, for about half the year if not more the system can be generating power, possibly enough to offset the resorts annual demand and at the very least significantly reducing their dependence on the grid. With the ski industry growing, resorts expanding, using more power and putting more and more strain on their eco systems, it is encouraging that there are possibilities for them to decrease their footprints while still providing the recreational experience so many of us have grown accustomed to.

Appendix A:

Natural alpine lakes such as this one can be replicated within the confines of a ski resort and provide a great deal of water storage potential. photo credit: the author

Appendix B:



This image shows the use of Hydraulic cannons being used for mining in the 1800’s. The same principals that power these cannons can be used to get more force out of a given volume to power a turbine.

Photo credit:USGS http://ga.water.usgs.gov/edu/gallery/mining-hydraulic.html

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