Pumped Hydroelectric Energy Storage (PHES)
Utilizing Current Infrastructure in Colorado

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October 8, 2007

Introduction

Part of the challenge of increasing the percentage of renewable energy -to 20% and beyond- in Colorado will be dealing with the intermittent nature of renewable sources. Stated plainly, solar energy is not available at night and wind energy is not available when the wind is not blowing. Increasing the amount of intermittent sources without ensuring it is available when needed still requires the capital costs for other ways to generate energy. The net result is an unnecessary increased cost for electric power and/or a loss of reliability. If legislation encourages system wide planning to ensure energy is available when it is needed, while minimizing the externalities of fossil fuel generation, and maintaining reasonable cost, Colorado has the opportunity to set a positive example of energy systems planning.

What can be done to solve the challenge presented by the need for energy when renewable production is not available? Or conversely, what can be done to handle excess energy created when intermittent generation is high and demand is low? The most effective solution will be an integrated approach, which should include:

1. Diversifying the types and locations of renewable generation sources, while guiding the capacity development with an optimization approach which uses historic wind and solar data to minimize intermittence, while achieving capacity goals.
2. Encouraging demand side management efficiency upgrades (DSM) to serve as a source of energy.
3. Developing adequate transmission infrastructure to facilitate diversified renewable plant locations.
4. Planning for additional energy storage in Colorado's electric grid, providing renewable energy that is available "on demand".
5. Formulate legislation that provides incentives for the first four points, smoothing intermittent generation as well as planning for storage to compensate times of excess and shortage.

None of the above points are silver bullets to facilitate 20% and greater penetration of renewable power sources. Moreover, if only one of the above strategies is pursued it will be less valuable than if a combination are pursued. Each point will increase the reliability of Colorado's electric grid and have synergistically positive effects on the other points. In lieu of the above mitigating steps, additional peaking natural gas plants can be deployed to provide on demand energy in the absence of sun and wind, although seemingly contrary to an increased RPS and potentially more costly in a life cycle analysis.

PHES Sites in Colorado with Developed Infrastructure

Colorado has infrastructure in the ground today that may be utilized to facilitate the integration of renewable generation onto our electric grid. Colorado, due to its magnificent topographic change presents multiple locations for the development of additional Pumped Hydroelectric Storage Sites. Prior to development of new infrastructure all current infrastructure should be utilized for -as Gifford Pinchot would say- "the greatest good, for the greatest number, for the greatest amount of time". That greatest good may now insist that pumped hydro storage sites in the ground today not only function to serve our peaking demands, but also function to integrate intermittent renewable energy generation. Infrastructure currently in the ground is outlined in Table 1 and followed by a brief discussion.

Table 1

Site Name	Ownership	Capacity	Head	Supporting Documents
Mt. Elbert	USBR	200 [MW]	438 [ft]	1
Flat Iron Pumping Plant	USBR	8.5 [MW]	240 [ft]	2
Horsetooth College Lake	USBR	10 [MW]	200 [ft]	3
Pinewood Carter	USBR	108 [MW]	840 [ft]	4
Cabin Creek	Xcel Energy	324 + 35 [MW]	1,226 [ft]	5
Total		685.5 [MW]		

1. US Department of the Interior Bureau of Reclamation. *Mount Elbert Pumped Storage Power Plant*. Available online at: http://www.usbr.gov/power/data/sites/mtelbert/mtelbert.html
2. US Department of the Interior Bureau of Reclamation. *Colorado-Big Thompson Project Engineering Data*. Available online at: http://www.usbr.gov/dataweb/html/gpcbtengdata.html
3. Levine & Barnes. 2007. *Potential Pumped Hydroelectric Energy Storage Sites in Colorado.* EESAT Conference Proceedings Paper. Available online at: http://www.colorado.edu/engineering/energystorage/files/EESAT2007/EESAT_Colorado_PHES_Sites_Paper.pdf
4 US Department of the Interior Bureau of Reclamation. April 1978. *Potential Power Additions To The Colorado-Big Thompson Project Pick-Sloan Missouri Basin Program Colorado.*
5. *Hugh W Hight. Jan 1971. Cabin Creek Pumped Storage Hydroelectric Project.* Journal of the Power Division. Proceedings of the American Society of Civil Engineers.

Mt Elbert as well as the Flat Iron Pumping Plant are fully operational pumped hydroelectric facilities. These facilities are currently used for peaking power production and/or other uses. These facilities may be of greater value if deployed to facilitate the integration of intermittent renewable power. With a listing of duty cycles, operational constraints, drawings, and open dialogue these plants may be able to facilitate integration of renewable power onto Colorado's - and WECC's- electric grid.

Horsetooth College Lake is an example of the presence of both a forebay and an afterbay that represents the possibility of pumped storage without the need to develop new reservoirs. This example is of interest both because of its imbedded infrastructure and the fact that the afterbay lies on the property of Colorado State University (CSU). This example could facilitate experiential education as well as 10 [MW] of pumped storage potential. As CSU looks to develop wind power at Maxwell Ranch they could look to develop PHES to firm that power.

Pinewood Carter was a potential pumped storage addition to the Colorado Big Thompson discussed in the late 1970's. This development was sited to produce 108 [MW] of storage capacity and has reservoirs in place.

Cabin Creek located just outside of Georgetown Colorado operates at a rated 324 [MW]. Xcel Energy is currently making some efficiency upgrades to the plant, which will yield approximately 35 additional [MW] which will total 359 [MW]. This plant is operated to facilitate wind integration and also run to address peak loads.