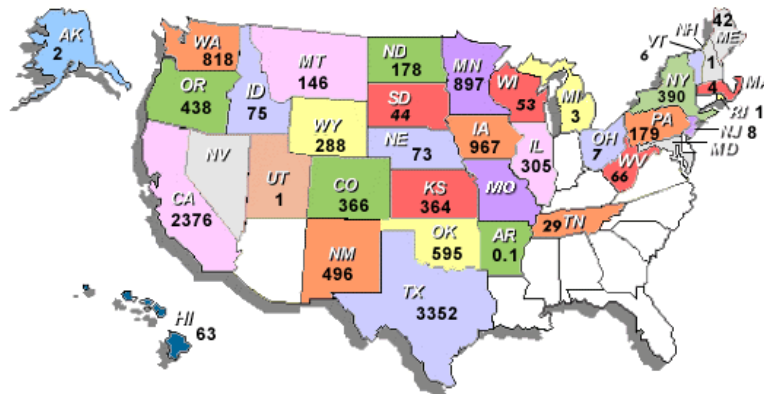


Potential Pumped Hydroelectric Energy Storage Sites in Colorado

University of Colorado at Boulder
Department of Electrical Engineering
Utility Management

Jonah Levine Jonah.Levine@Colorado.edu
Dr. Frank Barnes Frank.Barnes@Colorado.edu



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Outline:

- The challenge intermittent renewables
- Pumped hydro is part of a solution
- Pumped hydro calculator methods
- Examples
 - West Gypsum
 - Horsetooth Reservoir & College Lake
 - Other Examples
- Questions

The Challenge Intermittent Renewables

Wind- Colorado State Summary:

Installed Wind Capacity 366 MW *

Wind Capacity Under Construction 700 MW *

After completion of planned construction
Colorado will achieve roughly 15%
penetration of Renewables, 5% more will be
achieved by the year 2020

* American Wind Energy Association. Available online at:

<http://www.awea.org/projects/colorado.html>

Pumped hydro is part of a solution

- Cabin Creek- 324 MW Pumped Hydro Facility located above Georgetown Colorado

*Utility grid modeling has shown at 10% penetration of intermittent renewables without the use of Cabin Creek the cost to integrate renewable energy doubles**

Pumped hydro installations can facilitate the integration of intermittent renewables.

*EnerNex Corporation. May 2006. *Wind Integration Study for Public Service Company of Colorado*. Prepared for Xcel Energy Denver Colorado. Page 78.

Pumped hydro calculator methods

1. Topographic constraints yield energy and capacity, via: available head, reservoirs size and flow rates.
2. Revenue Module-
 1. kWh sales generation – pumping cost
 2. CO₂ & SO₂ Value
 3. Reduced cost of running NG plants
3. Cost Module
 1. Scaled overnight cost \$1,300/kW to 5,000/kW
 2. Construction time
 3. O&M
 4. % interest
4. Time valued payback

West Gypsum



Technical Output		
Head	393	Meters
Volume	2,720,000	M ³
	2,592	acre feet
Surface Area	39	Acres
Flow Rate Min	50	M ³ /S
Flow Rate Max	107	M ³ /S
Storage Time Min	7	hours
Storage Time Max	15	hours
Power Min	174	MW
Power Max	374	MW
Energy	2,621	MWh

Economic Figures:

\$1300 per installed kW, a construction time of 5 years, an interest rate of 4.9%

Initial Capital Cost of \$500 M

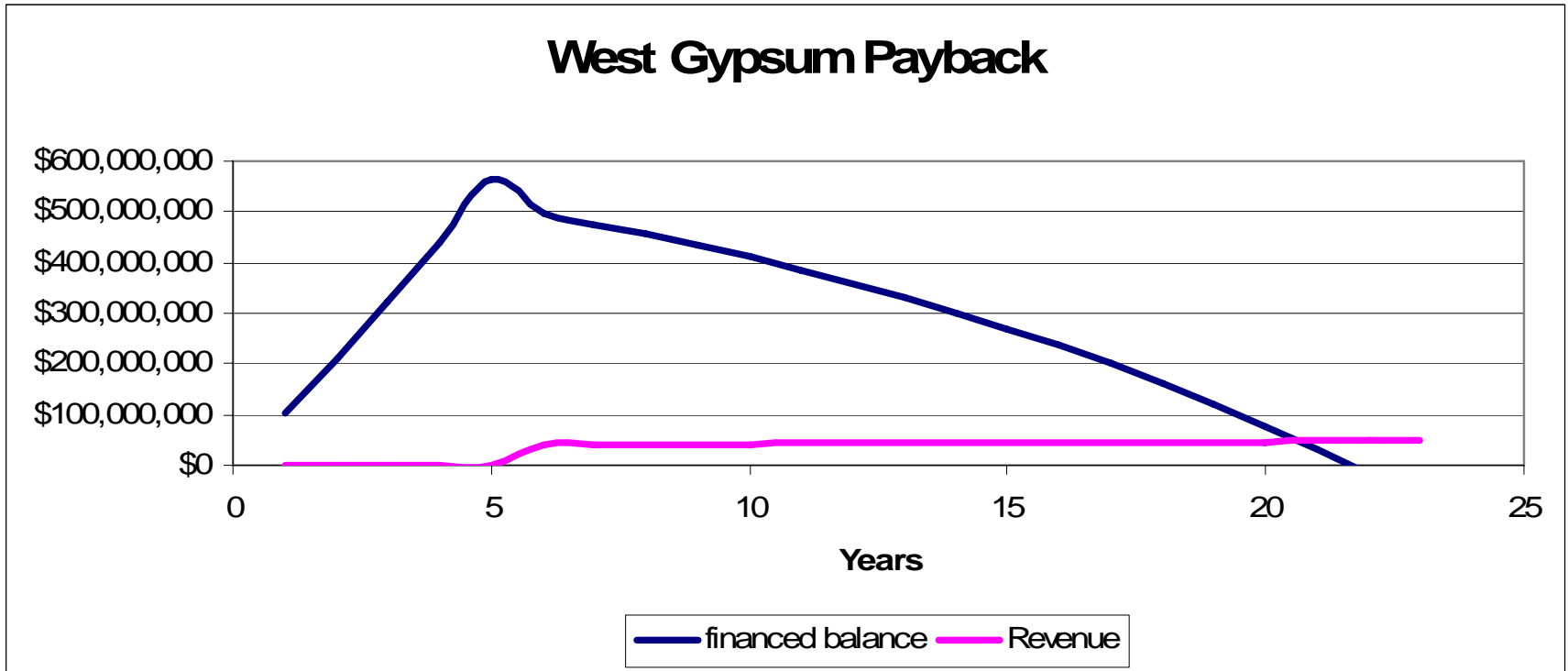
Annual Revenue of \$40 M, \$26 M in avoided natural gas Costs

Payback time of 21 years

Political:

Interest from the county commissioners
BLM land ownership

West Gypsum Economic Payback



Horsetooth Reservoir & College Lake



Technical Output		
Head	65	Meters
Volume	408,000	M ³
	388	acre feet
Surface Area	79	Acres
Flow Rate	22	M ³ /S
Storage Time	5	Hours
Power	13	MW
Energy	65	MWh

Economic Figures:

\$2,500 per installed kW, a construction time of 2 years, an interest rate of 4.9%

Initial Capital Cost of \$32 M

Annual Revenue of \$1 M, \$915 thousand in avoided natural gas costs

Payback time of 27 years

Political:

Reservoirs already in place

Colorado Energy Collaboratory

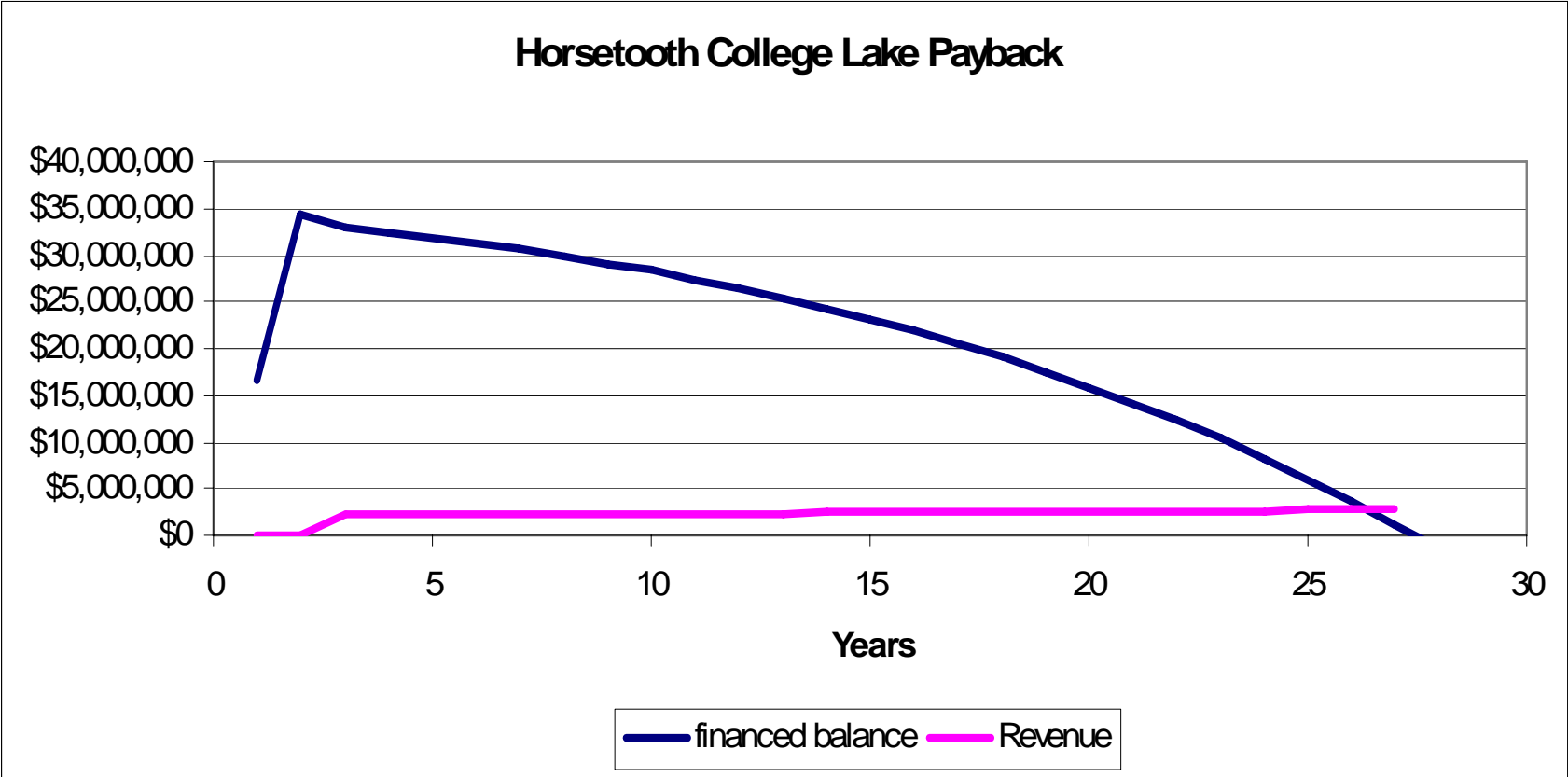
Example of storage and wind development from one entity

Infrastructure assessable for students to learn from

Municipal utilities are smaller and potentially easier to work with

Levine CU Boulder Proprietary

Horsetooth College Lake Economic Payback



Other Examples

Site Name	Power [MW]	Capacity [MWh]	Payback [years]	Comments
Bellyache Ridge	310	2167	21	Adjacent to transmission and water
West Gypsum	375	2622	21	Adjacent to transmission and water
Horsetooth College	15	75	27	Forebay and Afterbay currently in place
Davis Pt	548	2739	25	Adjacent to water and 1km from an oil shale plant
Schoolhouse Pt	630	3148	25	Adjacent to water
Peetz Bluffs	43	213	Does not payback in base calculation	Adjacent to Colorado's North Eastern Wind Plants
Gunnison Hydro	641	3846	22	Afterbay in place Utility right of way exists
Cabin Creek as calculated	329 1.5%	1317 1.6%	39	Plant in operation this site was used to check the assumptions used for calculations

As Colorado, the American West, and the United States develop intermittent generation capacity there will need to be infrastructure and planning that allows energy delivery when it is needed, as opposed to when it is generated. Pumped hydroelectric energy storage sites can be part of that solution.

Future Work

The Horsetooth College Lake example can be improved through further discussion with the entities in control of the facilities. West Gypsum can be further developed by working with the commissioners of Gypsum.

Improved cost modeling through the use of direct cost and contingencies.

Revenue numbers can be improved through the use of real time MWh purchase price data from within the Colorado region.

Thank You

Jonah Levine

Jonah.Levine@Colorado.edu

Dr. Frank Barnes

Frank.Barnes@Colorado.edu

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