Plidayne Energy: Slope-Based Gravity Energy Storage System

A carbon-neutral power grid requires energy storage and existing solutions are challenging to implement.

Collaboration with Pliadyne - an energy startup

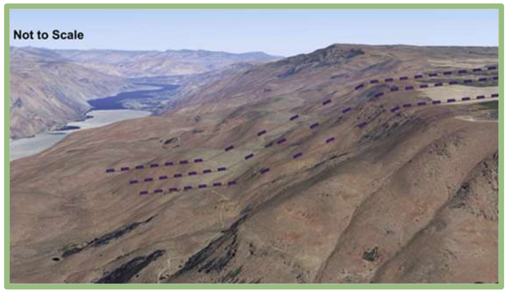
Goal:

- Evaluate mechanical and economic feasibility of a waterless slope-based energy storage system
- Find alternatives to pumped hydro and electrochemical storage

Core Requirements

	Initial	Rescoped
System Power Output	50 MW	25 MW
System Energy Capacity	400 MW-hr	150 MW-hr
Discharge Time	8 Hours	6 Hours
Round Trip Efficiency	>80%	>80%
Capital Cost	<$1.25M per MW-hr	<$1.25M per MW-hr
Operating Cost	$5-10 per kW-Hr-yr	$5-10 per kW-Hr-yr
System Life	25 years	25 years

CAD Mock-Up of Proposed Train Design



Aerial view of proposed site with trains and tracks

Mechanical Considerations

High energy demand requires moving large mass efficiently → prioritized mass transport rate.

Mass must be cheap, dense, and locally sourced → selected on-site aggregate basalt.

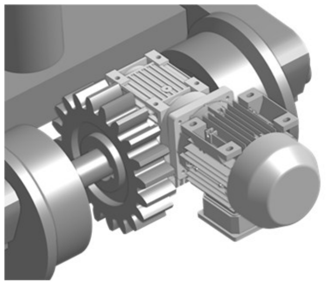
Minimize system complexity and energy losses → avoided systems requiring loading/unloading.

Maximize reliability with proven tech → chose railcars and rack-and-pinion drive using off-the-shelf components.

Operational simplicity prioritized → entire mass remains inside train cars during cycling.

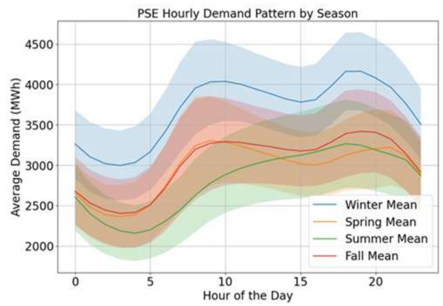
Design tailored to site's slope and space → optimized car spacing and track layout for power output and flow rate.

Drive System Model



CAD Mock-up of Driving Mechanism

Energy Trade Analysis

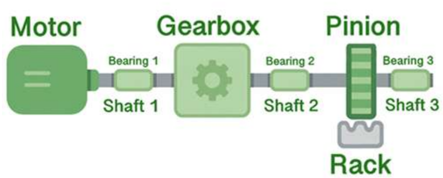


Arbitrage Results

Transmission Strategy	Power Intake Strategy	Annual Revenue*
PSE WA	25 MW, 6 hr (fixed)	$0.4M
PALOVRDE CA	25 MW, 6 hr (fixed)	$1.8M
SMD4 CA	25 MW, 6 hr (fixed)	$1.7M
SMD4 CA	150 MWh (variable)	$2.7M**
SUMMIT CA	25 MW, 6 hr (fixed)	$3.2M
WA <-> CA	25 MW, 6 hr (fixed)	$3.3M

*value includes transmission cost estimate of $40/MWh
**annual revenue extrapolated from 37 samples

Driving System Design



Drive System Black Box Diagram

Economic Analysis

Cost Estimates

Component	Cost
Construction & Materials	$77 M ($54 M with ITC)
Annual Maintenance	$1. 1M
Annual Administrative	$0.45 M
Other Annual Costs	$0.30 M
Total Annual Costs	$2.1 M
Overhaul (every 10 years)	$0.27 M

When calculating for ROI, the current concept requires the investment tax credit (ITC) to make a positive return

- This ROI is 0.5%, lower than favorable
- Revenues ≥$5 M can turn the investment favorable

Recommendations and Next Steps

The specific recommendation is that 1,500 cars can meet our energy target of 0.125 MWh each at 80% efficiency, using standard parts, used equipment, and inexpensive materials such as dirt and rock.

Design:

- Custom vs. Retrofitted train car
- Train car prototype
- Flexible power output instrumentation
- Modeling of car movement
- Power transmission infrastructure
  - Input to motors
  - Output to grid
  - Necessary transformers

Economic:

- Real-world arbitrage modeling
- Exploration of advanced trading algorithms
- Site re-evaluation

General:

- Supply chain engagement
- Regulatory and environmental review
- Stakeholder expansion
- More advanced cost calculations

Acknowledgements:

Thank you to Professor Patty Buchanan, Patrick Doneen, Doppelmayr Group