WASHINGTON STATE UNIVERSITY
Energy Program

# Pumped Storage Hydropower Siting Information Study

## PSH Siting Topics: Other Gravity Energy Storage – Rail and Abandoned Mines

WSU Energy Program

January 23, 2025

# How to Access Captions/Como Ver Subtítulos

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Escanea el código QR para acceder a los subtítulos

Scan the QR code for captions

# Welcome and a few reminders…

- This meeting is being recorded and will be available on the study website—along with the slides and a meeting summary
- Please remain muted unless you are speaking
- As needed, please rename yourself with your affiliation or workplace in Zoom
- Attendees will be able to chat everyone in the meeting
  - If you are experiencing technical issues, please chat directly to "hosts and panelists" (or email hsherrow@rossstrategic.com).
- To ask questions or join discussion, please use the "raise your hand" button to indicate you would like to speak; chat can also be used for Q&A
- Please be respectful of this process. Allow everyone the chance to speak and listen actively to understand others' views

# WSU Energy Program

- Self-supporting department within Washington State University based in Olympia
- Other programs: green transportation education and outreach, community solar, Washington state energy codes (residential) support, community energy efficiency, emerging technologies, and more

WSU Energy Program website: https://www.energy.wsu.edu

# WSU Pumped Storage Hydro Siting Study Team

- Karen Janowitz


- Terri Parr, Tribal Relations


- Tom Beierle
- Susan Hayman
- Hogan Sherrow


- Jeff Boyce

# Today's Meeting Objectives

- Learn about other mechanical/gravity energy storage:
  - Advanced Rail Energy Storage
  - Pumped storage using abandoned mines
- Hear from attendees and promote discussion about key takeaways from the PSH study process

# Agenda Overview

| | |
|---|---|
| 9:30 – 9:45 am | Welcome |
| 9:45 – 10:00 am | Study Overview and Update |
| 10:00 – 10:30 am | Advanced Rail Energy Storage |
| 10:30 – 11:00 am | Pumped Storage Using Abandoned Mines |
| *11:00 – 11:10 am* | *Break* |
| 11:10 – 11:55 am | Group Polling and Discussion |
| 11:55 – noon | Next Steps, Wrap up, and Adjourn |

# Online polling

- We will be using PollEverywhere today to elicit insights from participants
- When prompted, please use a phone or browser screen to access the polls using the QR code or website address: PollEv.com/lavishnature521
- You will be initially asked to share your name, but this can be skipped
- PollEverywhere will stay open throughout the webinar
- For short "word cloud" responses, you can join_words using an underscore

Join by Web
PollEv.com/lavishnature521

Join by scanning the QR code

Now, lets try it out on a quick icebreaker question:

***In a word, what outdoor activity would you be least interested in if it was -10 Fahrenheit?***

# Study Overview and Update

Karen Janowitz, WSU Energy Program

# Pumped Storage Hydropower (PSH) Siting Study Goal

Identify and understand issues and interests of federally recognized Tribes with territories in Washington State, WA state agencies, and various stakeholders related to **areas where pumped storage might be sited in Washington State**.

**No specific PSH projects are being promoted or sited in this study.**

*Section 306 of House Bill 1216 (2023) on Clean Energy Project Siting:*

https://lawfilesext.leg.wa.gov/biennium/2023-24/Pdf/Bills/Session%20Laws/House/1216-S2.SL.pdf?q=20240327114612

# Why a PSH Siting Study?

- Support goal of WA Clean Energy Transformation Act (CETA) (SB 5116, 2019)
- Explore PSH, which is an existing proven technology, long-duration, and provides grid reliability
- Understand issues concerning PSH siting to work towards avoiding impacts and disputes

Study ends June 30, 2025 with a report deliverable to the WA State legislature.

# WA Statewide Online Public Meetings

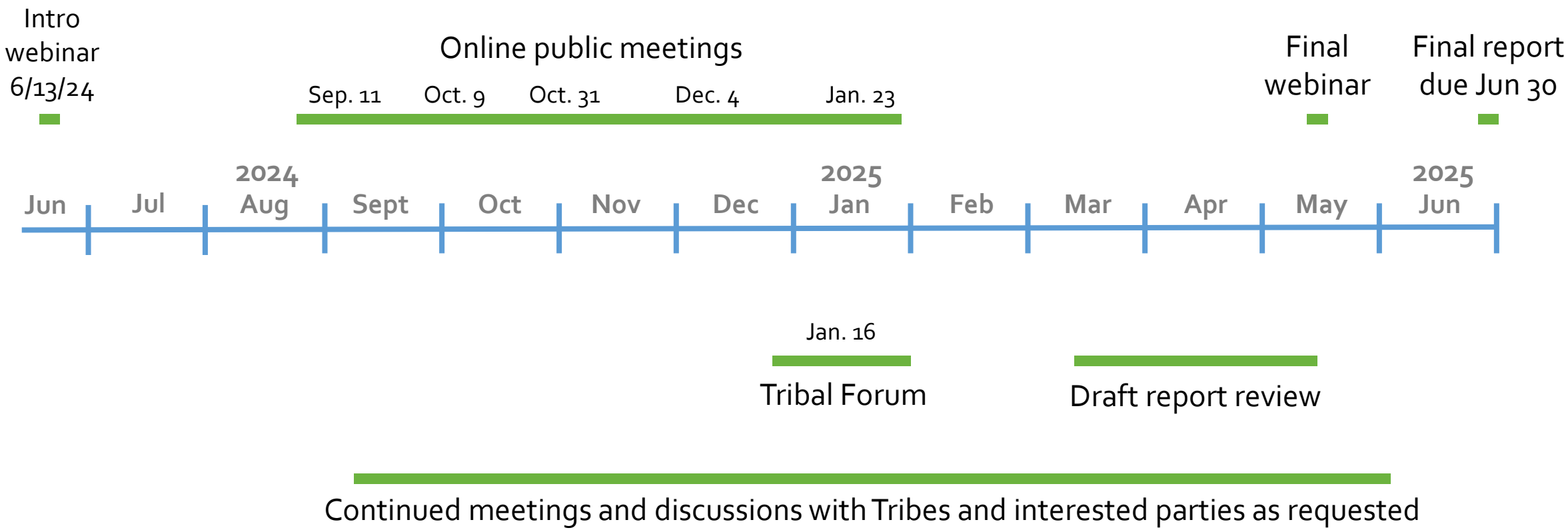
- Today's online public meeting
  - January 23, 2025
    - Mechanical/Gravity storage – Advanced Rail Energy Storage, PSH in abandoned mines
- Past statewide online public meetings
  - June 13, 2024 introductory webinar
  - Sept 11, 2024 – pumped storage overview, traditional cultural resources
  - Oct 9, 2024 – water quality, water resources
  - Oct 31, 2024 – terrestrial ecology, geology, land use, access
  - Dec 4, 2024 – federal and state permitting, licensing, and environmental processes

- Slides, video-recordings, meeting summaries can be found at https://www.energy.wsu.edu/CleanFuelsAltEnergy/PSHSiting/Meetings.aspx

# Tribal Engagement

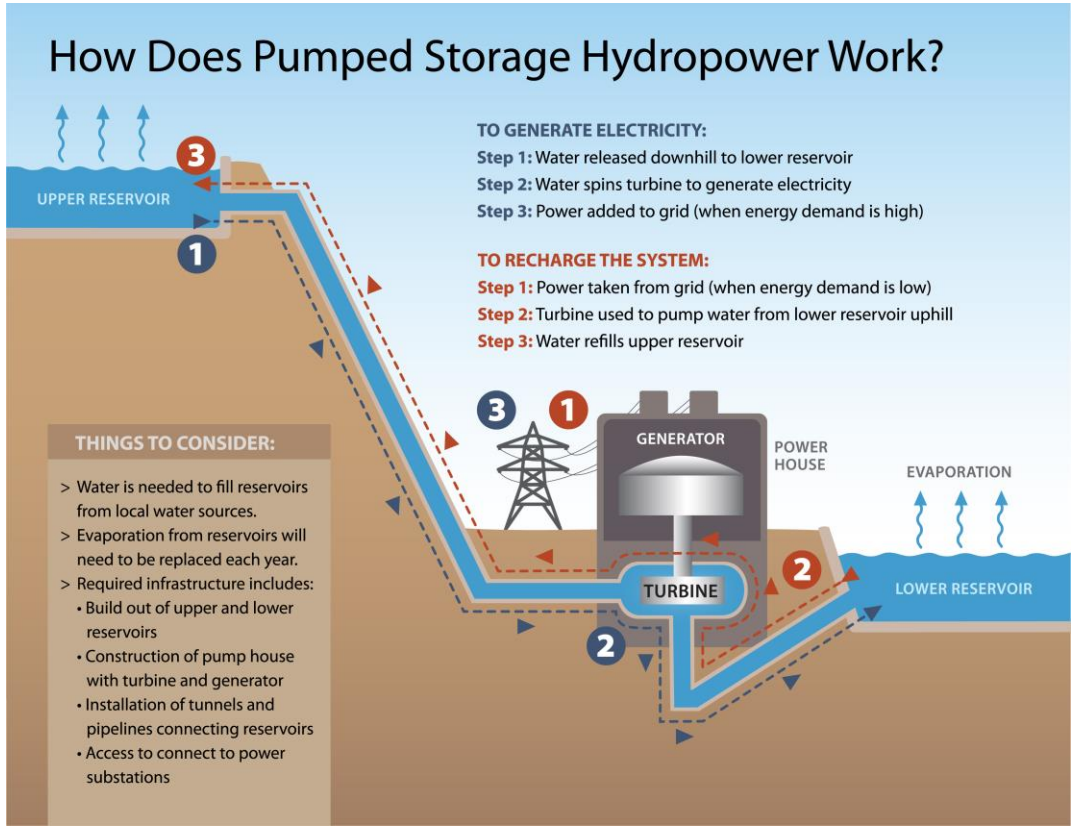
- Attendance and discussion at Tribal conventions & conferences
  - April 2024 – ATNI Tribal Leaders Climate Summit
  - September/October 2024 – ATNI Annual Convention
  - November 18-20, 2024 – ATNI Natural Resources Summit
  - January 27-30, 2025 (upcoming) – ATNI Winter Convention
- Tribal Forum(s)
- Meeting and discussion with individuals and groups

# **Timeline** *(subject to change)*



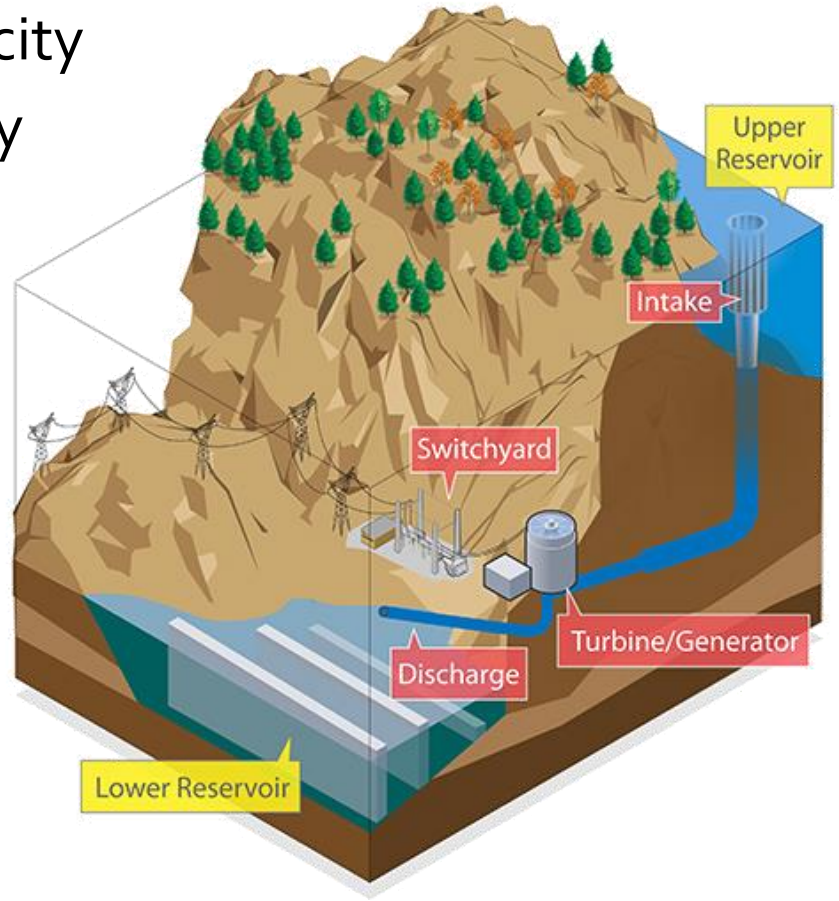
# What is Pumped Storage Hydropower?

- "Water battery"
- Long-duration energy storage technology
- Stores energy in an upper reservoir, generates energy when water flows to a lower reservoir
- 43 existing plants in USA
- Well-established technology



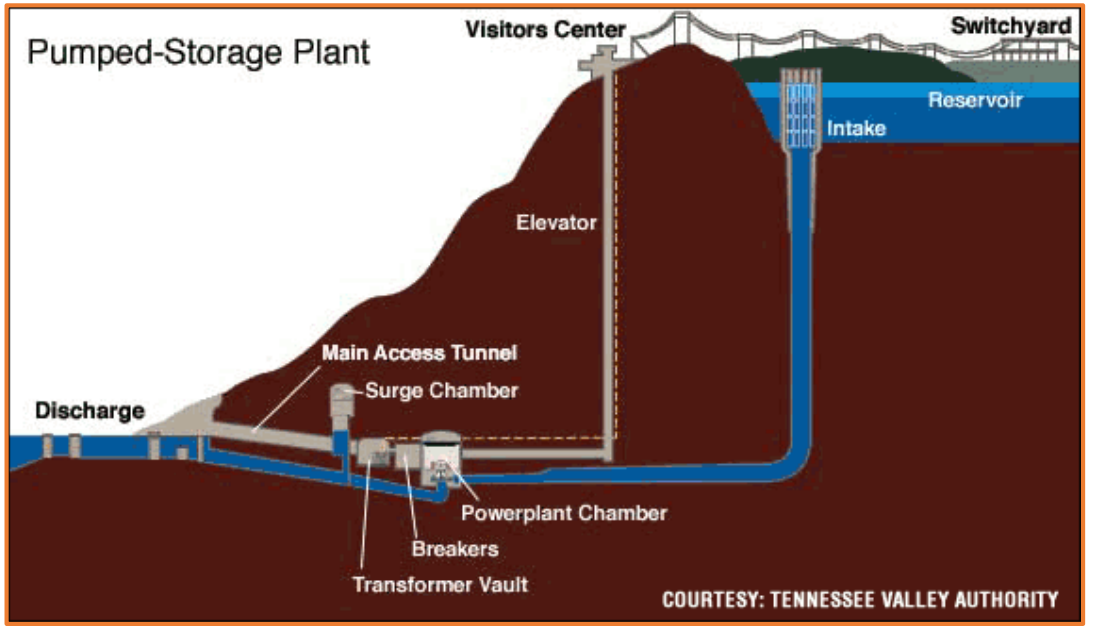
# PSH Benefits

- Provides over 90% of U.S. energy storage capacity
- Can provide up to 12 or more hours of electricity
- Supports grid reliability
- Systems last long (up to 50 – 100 years)
- Low life-cycle cost
- ~80% efficient



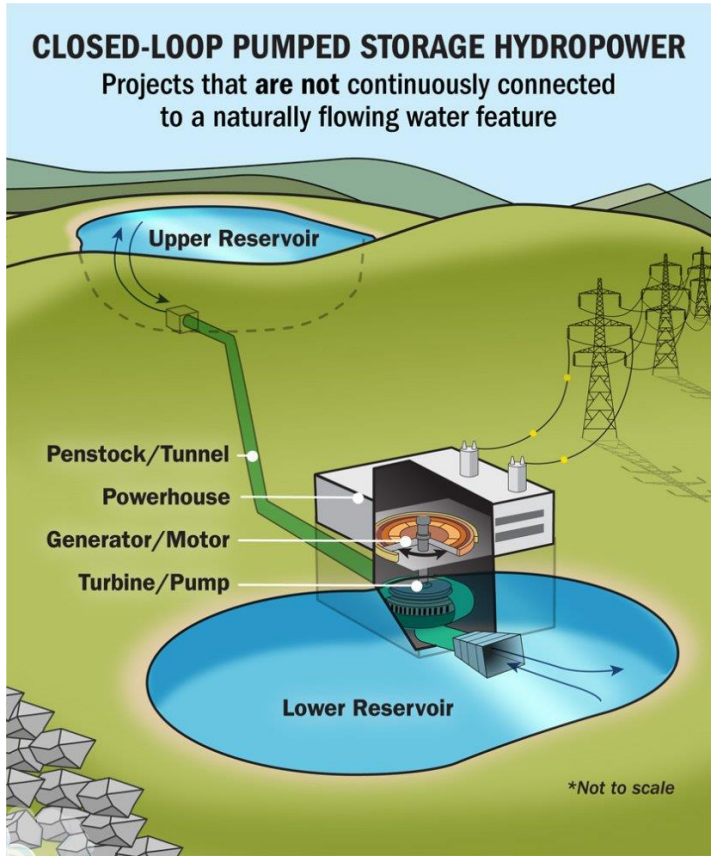
# PSH Drawbacks

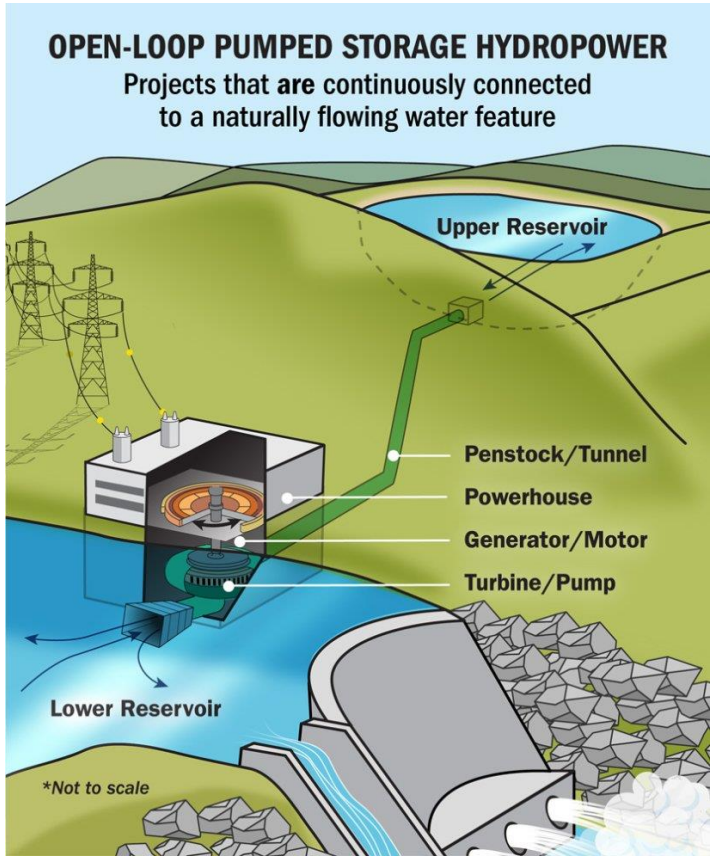
- Needs water to initially fill closed-loop reservoirs, and "top" off
- Long construction period, expensive construction costs
- Potential environmental and cultural impacts



# Closed-Loop PSH and Open-Loop PSH

This study focuses on closed-loop, where reservoirs are not connected to any existing water bodies.




U.S. Dept of Energy, 2019

# Water Availability

- Closed-loop systems
  - Need water for initial fill and for replacing evaporated water
  - Little impact on fish and aquatic ecosystems
- Open-loop systems
  - No need to fill reservoirs
  - Connected to waterways so greater impact on aquatic ecosystems

# PSH Potential Impacts

- Cultural resources
- Water resources
  - Surface water
  - Groundwater
- Water quality
- Aquatic habitat and species*
- Terrestrial habitat and species
- Access
  - Traditional cultural access
  - Public access
  - Recreation access
- Air quality and noise
- Visual and Aesthetics

*Aquatic ecology impacts are fewer in closed-loop systems

# PSH Responsible Siting Practices

- Engage early and often with Tribes, local communities, and governments
- Avoid sensitive and sacred areas
- Utilize previously developed sites if possible
- Site and design to minimize footprint and accommodate pre-existing uses
- Enhance existing conditions if possible
- Conduct risk assessments and develop avoidance/minimization plans for specific impacts

Photo by WDFW

# Increasing PSH Capacity without New Projects

- Capacity upgrades of existing pumped storage plants
- Pump Back: Adding PSH capabilities to existing hydropower plants
- Add-on: Construct an upper reservoir and partner it with existing lower reservoir
- Connect two existing reservoirs to develop a PSH project
- Hybrid: For example, combined PSH and water desalination plant (shared infrastructure)

# Questions?

# Advanced Rail Energy Storage

Ray Wiseman, General Manger, Yakama Power

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## Advanced Rail Energy Storage

# Rail-Based Gravity Storage - The Advantages of Pumped Hydro without the Disadvantages


Southwest Sustainability Innovation Engine (SWSIE)
Long Duration Energy Storage Symposium
Walton Center for Planetary Health
December 3, 2024


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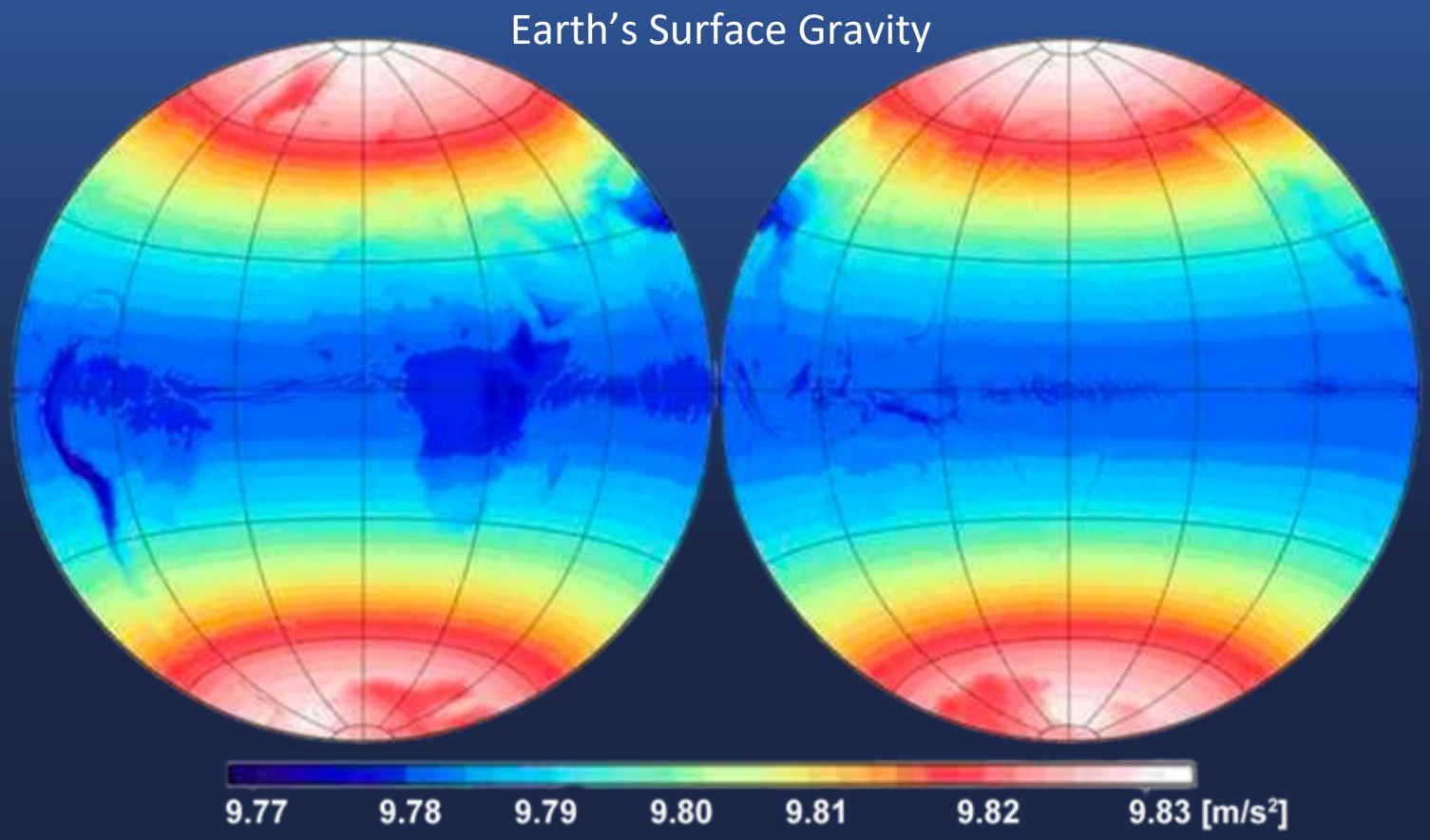
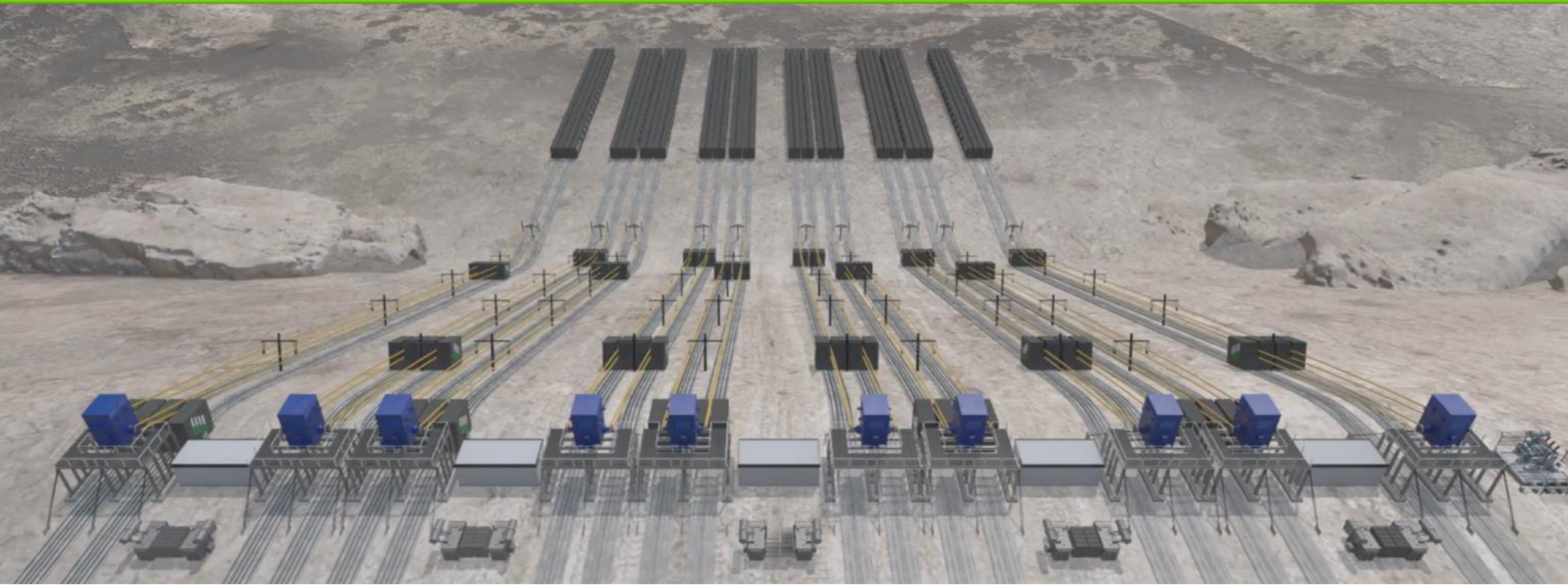
# Gravity is a natural resource like wind or solar




**Acceleration of gravity ≈ 9.8 m / 32 ft per sec$^2$**

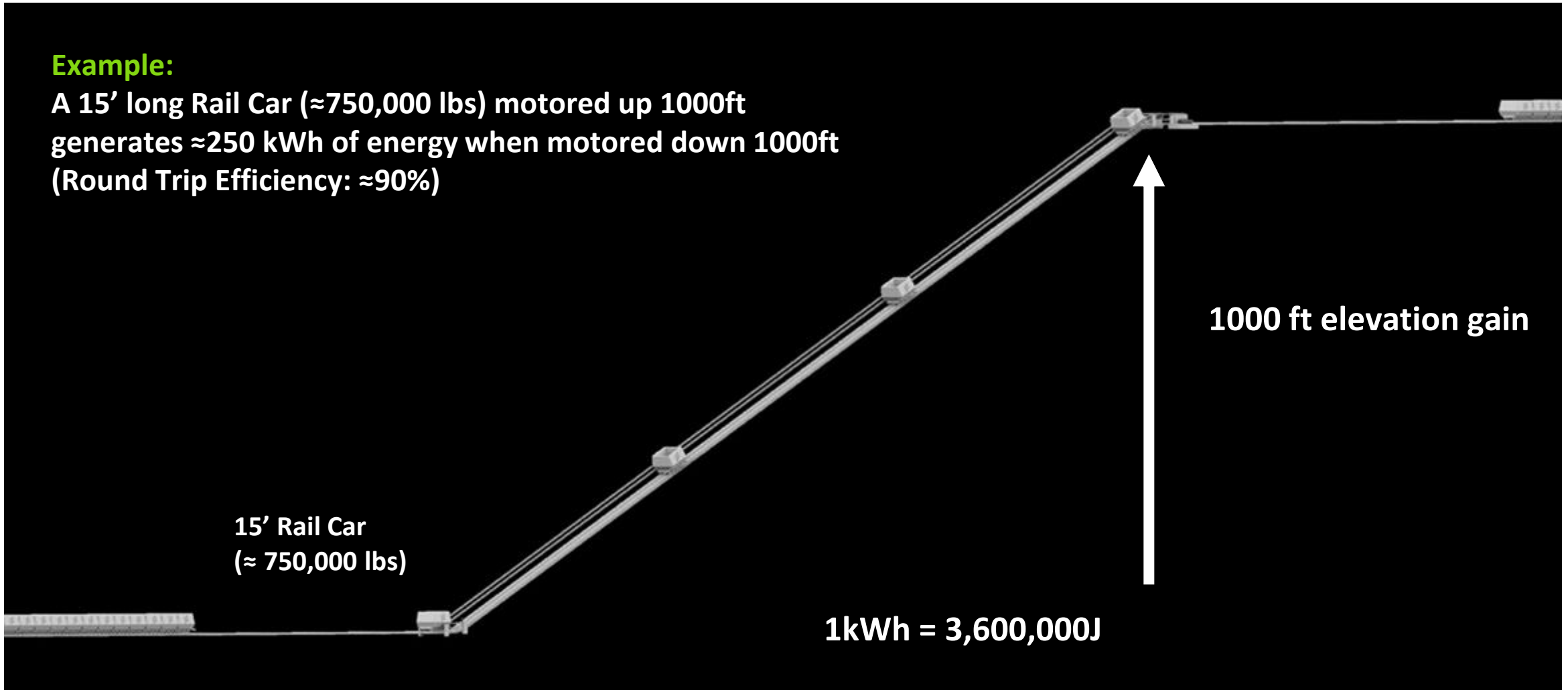
# How ARES Works



**Mass cars connect to 5.5 MW motor/generators with a chain drive system. The motor pulls mass cars uphill to store energy. The generator releases mass cars downhill to power the grid.**

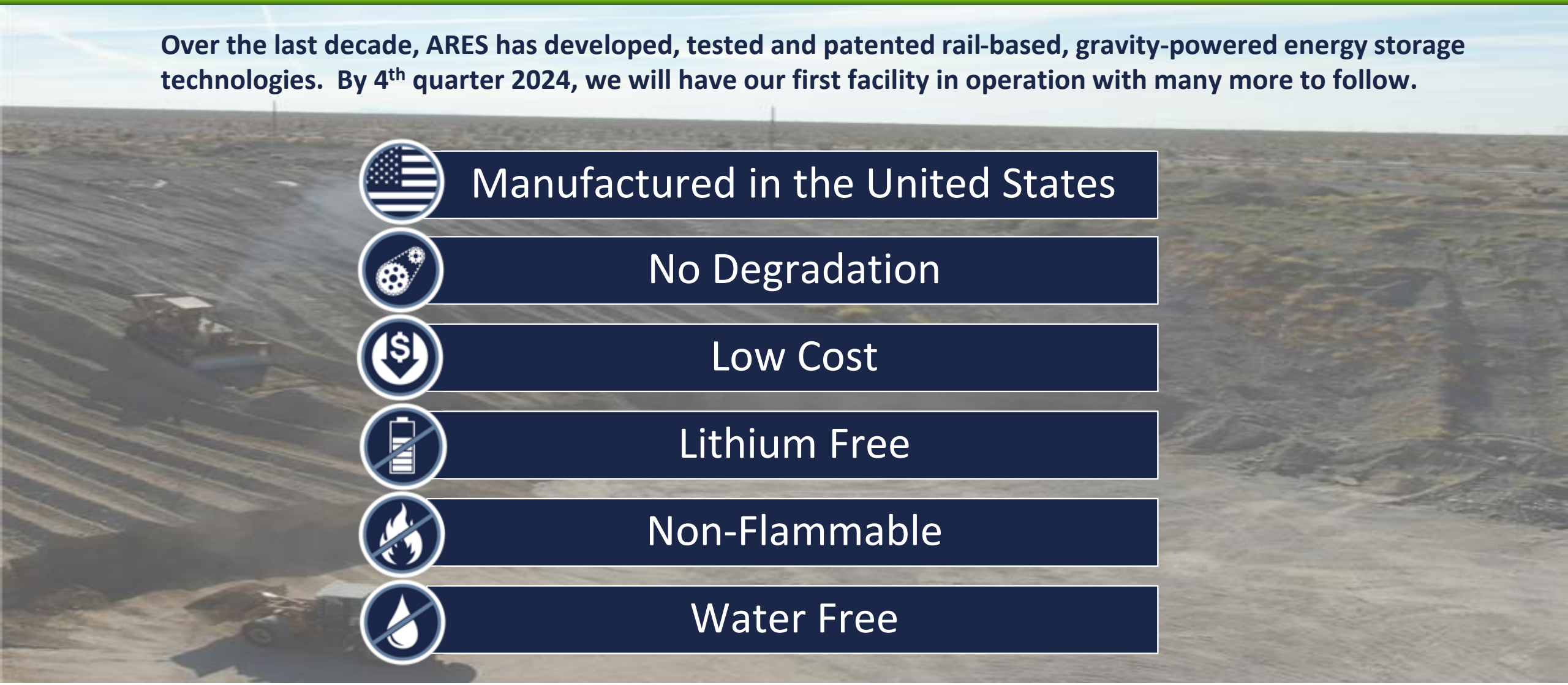
# Energy Capacity of Mass Cars

**Example:**
**A 15’ long Rail Car (≈750,000 lbs) motored up 1000ft generates ≈250 kWh of energy when motored down 1000ft (Round Trip Efficiency: ≈90%)**



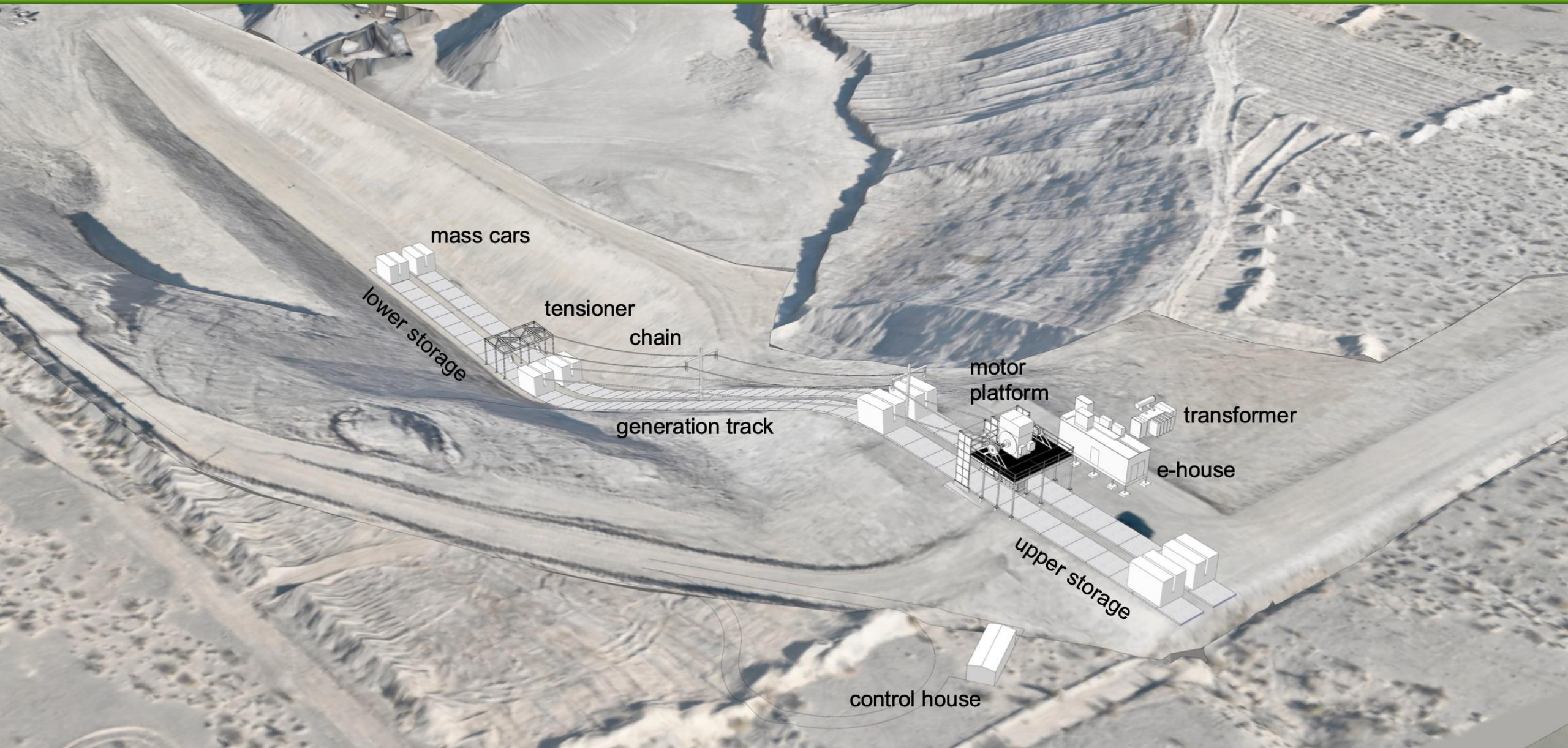
# Rail-Based Gravity Storage

**Over the last decade, ARES has developed, tested and patented rail-based, gravity-powered energy storage technologies. By 4th quarter 2024, we will have our first facility in operation with many more to follow.**



- Manufactured in the United States
- No Degradation
- Low Cost
- Lithium Free
- Non-Flammable
- Water Free

# Major System Components



# Motor/Generator (5MW$_{AC}$ )

# Mass Cars

## ARES makes renewables work

- We allow renewables to generate, regardless of grid demand
- We provide a solution to the generation intermittency caused by renewables
- Energy storage solutions will regulate the supply and demand spikes acting on the grid

## ARES provides grid-based inertia

- Inverter-based energy does not supply enough inertia for the nation’s grid system
- Without enough inertia, the grid will fail

## ARES offsets carbon production

- Our energy storage is scalable to address long-duration seasonal needs
- Using stored energy for peak demand times reduces Peaker Plant greenhouse gas emissions

## Further benefits include:

- The ability to provide needed inertia to the electrical grid
- The system can cycle multiple times daily
- Delivering ancillary grid-related services such as black start and voltage support
- Time-shifting and arbitrage reduce system cost to developers and, ultimately, consumers

# Unique attributes of the ARES energy storage system

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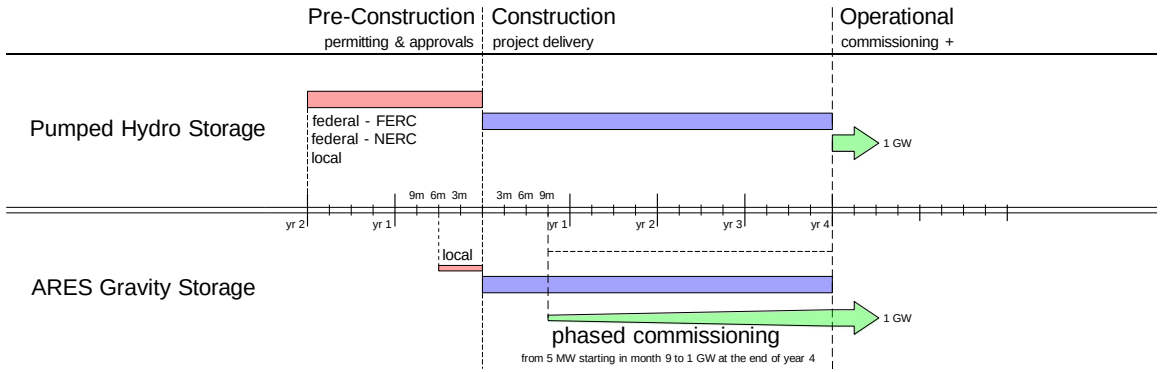
## ARES as compared to Lithium-Ion battery storage

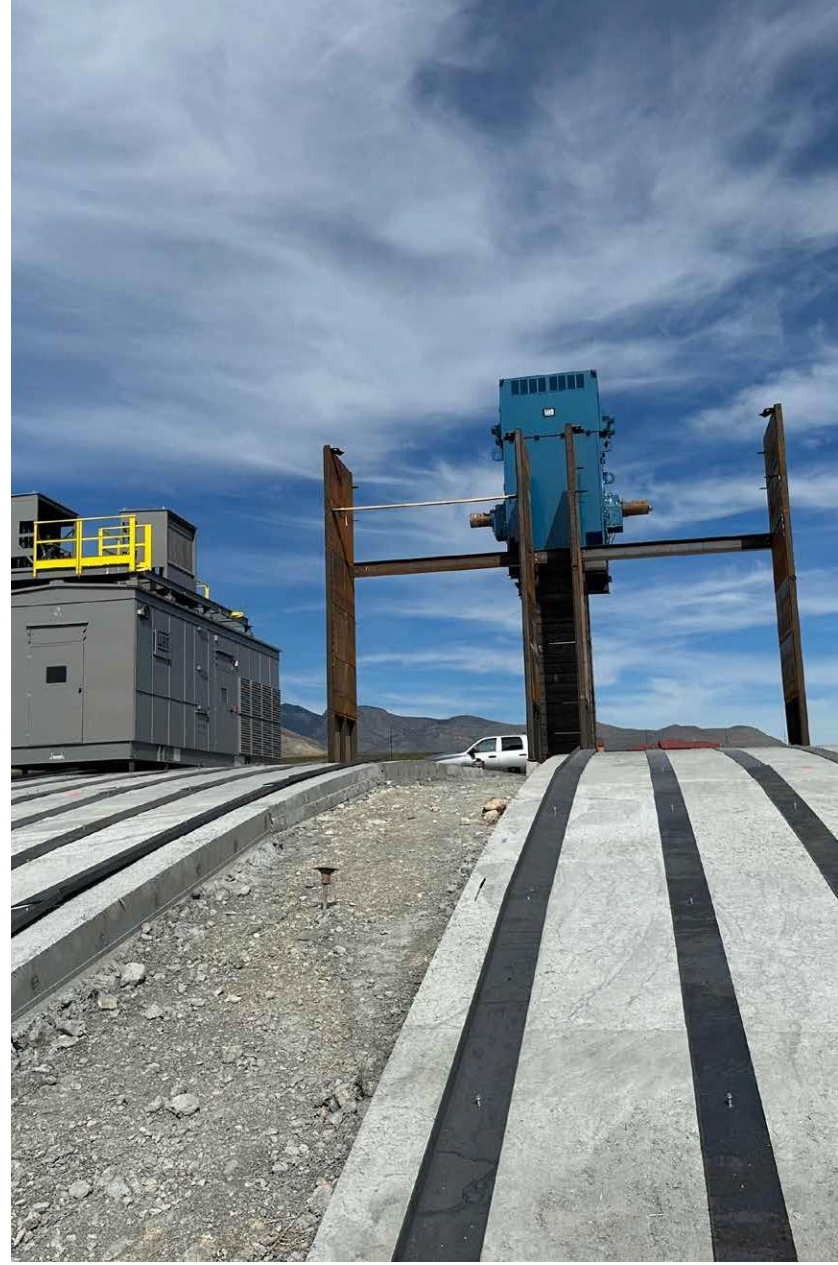
- ARES is more efficient than Li-ion
- ARES has no risk of thermal runaway
- ARES is fully recyclable at EOL and has none of the hazardous materials concerns found in lithium-ion
- ARES is manufactured locally, avoiding the environmental and geopolitical issues associated with lithium and cobalt
- ARES can cycle multiple times a day with durations far exceeding those of Lithium-Ion batteries

## ARES as compared to pump storage

- ARES has no operational impact on local water resources
- ARES avoids the long approval processes required by FERC and other water-related regulatory agencies
- ARES projects have significantly-reduced project delivery schedules
- ARES employs a modular design to allow for phased commissioning during construction (see comparative project schedules below)
- ARES unique ability to deliver phased commissioning results in reduced construction costs and borrowing risks

*Project schedule comparisons*



# Advantages of ARES over alternative energy storage systems

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# ARES Product Comparisons

| | ARES | Lithium Ion | Pumped Hydro |
|---|---|---|---|
| Scalability | 5 MW – 1 GW+ | 10kW-1 GW | 250 MW – 3 GW |
| Duration | 15 minutes – 24 hours | 15 mins – 4 hours | 12 – 16 hours+ |
| Roundtrip Efficiency | 90% | 87-89% | 75-78% |
| Cycle Limitations | Unlimited | 6,000 | Unlimited |
| System Life | 40+ Years | 5+ Years | 40+ Years |
| Density of Storage Device | 2.4x density of water | | |
| Price | $ | $$ | $$$ |
| | | | |
| O&M | | | |
| Quick Scalability Based on Need | | | |
| Ramp Rate | | | |
| Rotating Mass for Inertia | | | |
| Water Usage | | | |

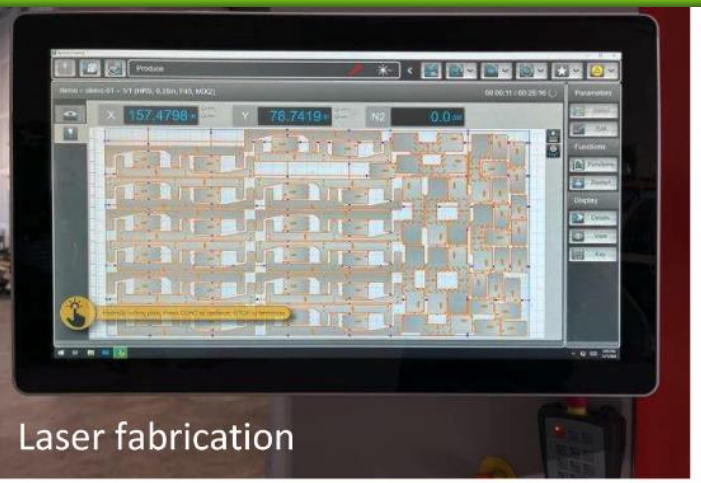
# Competitive Advantages

| | |
|---|---|
| **Fully Sustainable** | Comprised of a recycled steel superstructure, foundation, track(s) and chain(s); low carbon mass cars – with recycled steel bases – filled with locally sourced crushed aggregate; highly efficient electric motors; and freely available gravity.<br>• No rare earth minerals |
| **Scalable** | Project size is a function of number of mass cars, elevation differential and distance.<br>• 15 minutes to 24+ hours duration |
| **Flexible** | Low impact design allows customers to build (and buy) as much as needed at any given time, with ability to quickly scale up or down in the future. |
| **Reliable** | Motor and chain drive system are proven technologies with a low maintenance burden.<br>• The system's division into 5 MW track sections allows for isolated repairs ensuring the majority of capacity is available at all times. |
| **High Ramp Rate** | Steep grades enable quick responsiveness. |
| **Easy Siting** | Operates effectively on elevation differentials as low as 300 feet. |
| **Cost Effective** | Leverages readily available equipment. |

# ARES Manufacturing

Bystronic Laser for precise cutting and part production at the ARES Manufacturing facility (Las Vegas, NV)

# ARES Manufacturing

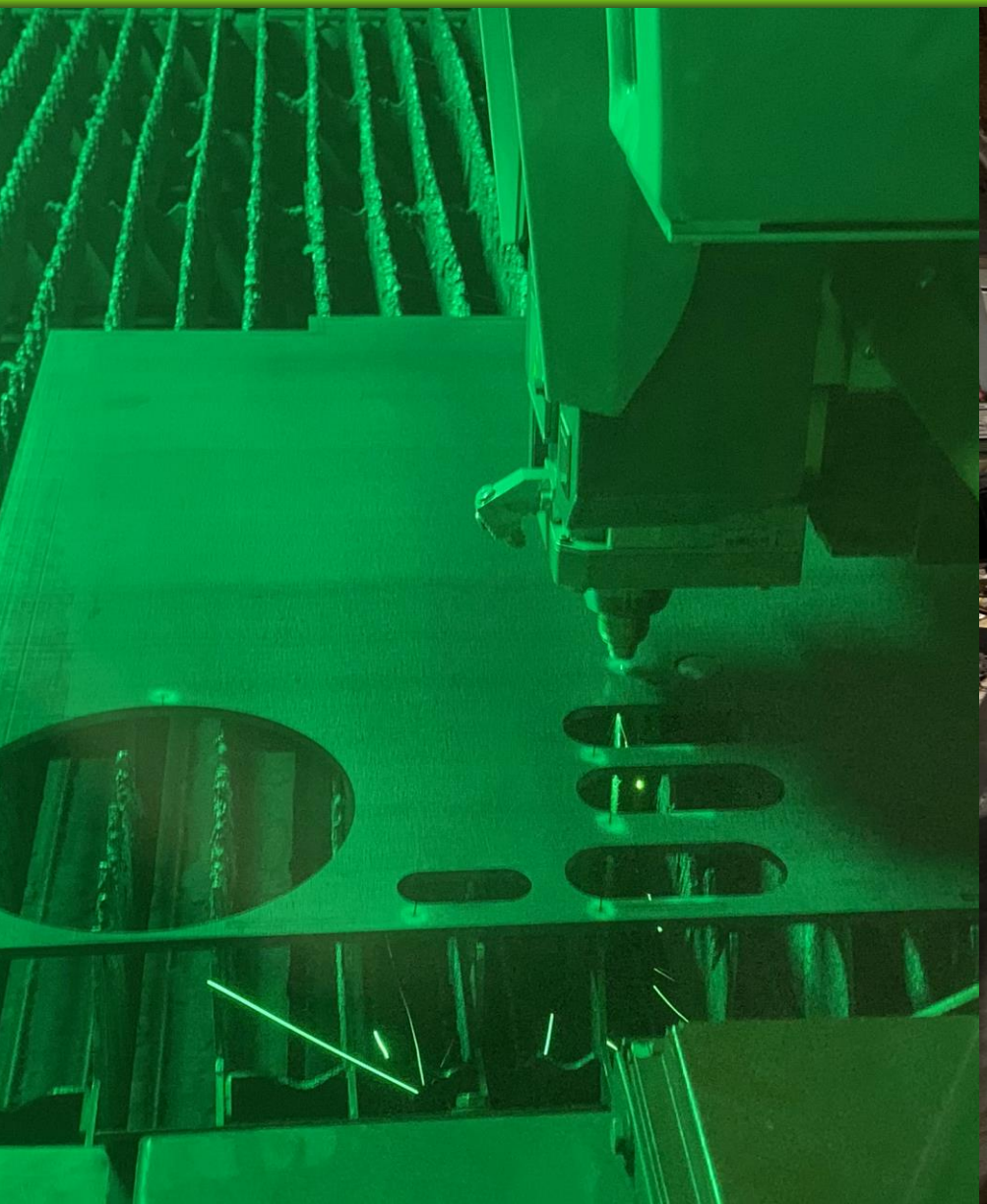



Laser fabrication




Urethane Production

# ARES Manufacturing



# ARES Issued Patents

| PAT. NO. | TITLE |
|---|---|
| 11,738,781 | Gravitational potential energy storage systems and methods |
| 10,069,333 | Ridgeline cable drive electric energy storage system |
| 9,096,144 | Combined synchronous and asynchronous power supply for electrically powered shuttle trains |
| 8,952,563 | Utility scale electric energy storage for utility grid ancillary services |
| 8,674,541 | Rail based potential energy storage for utility grid ancillary services |
| 8,593,012 | Utility scale electric energy storage system |

# A Carbon Conscious Company


Recycled Steel – US Made

Aggregate Sourced On-site

Roller Compacted Concrete – Light Water – Light Cement


Local Manufacturing

# Thank You

# Pumped Storage Using Abandoned Mines

Tim Scarlett, Associate Professor, Michigan Technological University

# Pumped Storage in Abandoned Mines


## Timothy Scarlett

**Keweenaw Energy Transitions Lab**
**Michigan Technological University**



WASHINGTON STATE UNIVERSITY
Energy Program

Pumped Storage Hydropower (PSH) Siting Study

Washington State University Energy Program

Thursday, January 23rd, 2025

WSU PSH Website

Michigan Technological University

“Michigan Technological University sits on the beautiful shore of Portage Lake in Houghton County, Michigan.

*Gakiiwe-onigamiing* in Ojibwe:

"the place where they go straight across a point by portage."

Our campus lands are located within Ojibwa (Chippewa) homelands and ceded-territory established by the Treaty of 1842.

These are lands and waters we share with the Native American nations in Gakiiwe’onaning (Keweenaw Bay), Gete-gitgaaning (Lac Vieux Desert), Mashkii-ziibing (Bad River), Odaawaa-zaaga’iganing (Lac Courte Oreilles), Waaswaaganing (Lac Du Flambeau), Miskwaabikong (Red Cliff), Wezaawaagami-ziibiing (St. Croix), Zaka’aaganing (Sokaogon Mole Lake), Nagaajiwanaag (Fond du Lac), Misi-zaaga’iganiing (Mille Lacs), and Gaa-mitaawangaagamaag-ininiwag (Sandy Lake).”

KETL Keweenaw Energy Transition Lab at the Great Lakes Research Center | Michigan Technological University

# Pump Storage Hydropower: Ludington, Michigan

102,000,000 $m^3$
111 m head
6 turbines
1,872 MW total
9 hrs.
19,548 MWh



Photo credit: Consumers Energy on Flikr:
https://www.flickr.com/photos/consumersenergy/28497624290

# Dinorwig Power Station

Mynydd Gwefru

“Electric Mountain”

Gwynedd, north Wales.

maximum power of 1,728 MW storage capacity +/- 9 GWh


**PARC CENEDLAETHOL**

# ERYRI Snowdonia

**National Park**

National Slate Museum World Heritage Site

The Slate Landscape of Northwest Wales

# Underground Pumped Storage Hydropower (UPSH, or PUSH):

What are specific concerns about *underground* PSH facilities?

a. How does it work?
b. Where is it feasible?

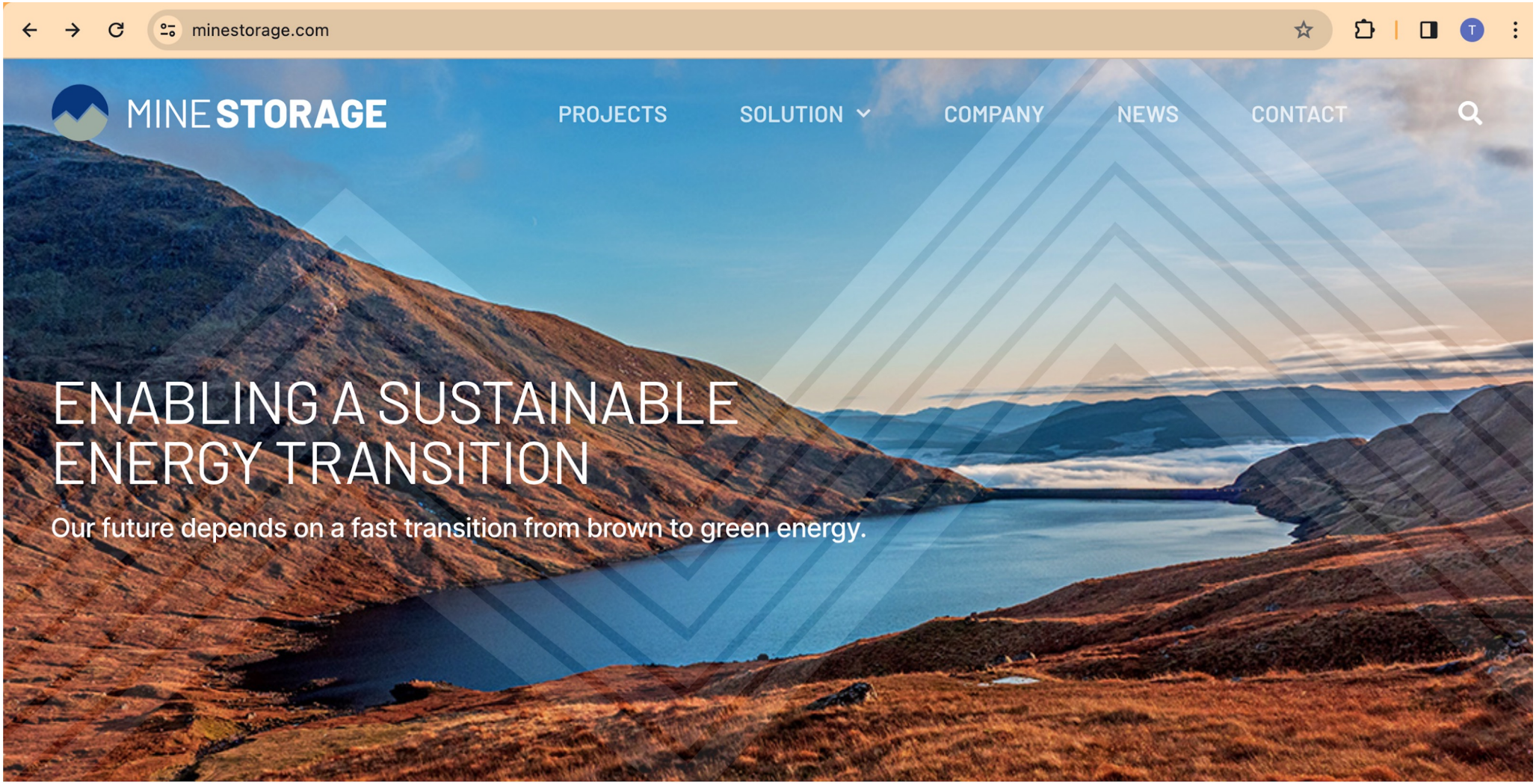
What are potential benefits vs. adverse impacts?

# Some Companies in the Energy Space in Abandoned Mines

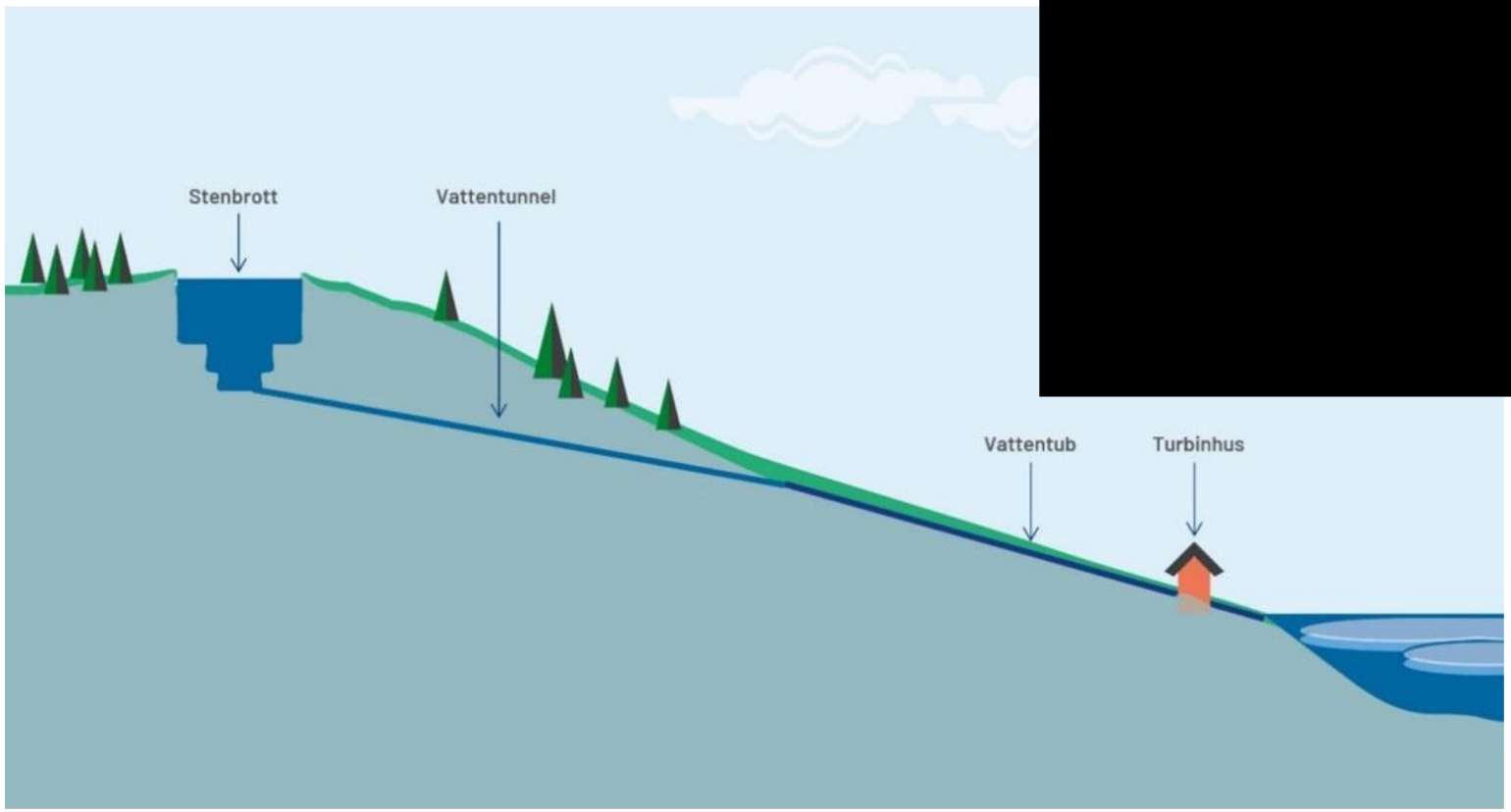
Minestorage International AB (PUSH) https://www.minestorage.com/
Hydrostor (A-CAES) https://hydrostor.ca/
Ontario Power https://www.opg.com/projects-services/projects/energy-storage/marmora
Rhe Energise (High Density hydro PUSH) https://www.rheenergise.com/
Gravitricity (Gravity) https://gravitricity.com/
SENS Sustainable Energy Solutions Sweden Holding AB (PUSH), https://www.sens.se/en/
Cavern Energy Storage (A-CAES) https://cavernenergy.com/
Enel Green Power (Binary Cycle Geothermal), https://www.enelgreenpower.com/countries/north-america
Energy Vault (Gravity), https://www.energyvault.com/
Gravitricity (gravity): https://gravitricity.com/
EuroHeat & Power (Geothermal), https://www.euroheat.org/
Ormat Technologies (Geothermal), https://www.ormat.com/en/renewables/geothermal/main/
Mälarenergi (PUSH, working with MineStorage) https://www.malarenergi.se/om-malarenergi/miljo-och-hallbar-utveckling/ekologisk2/minestorage/
Quidnet Energy (Geomechanical PSH) https://www.quidnetenergy.com/
Sperra Technologies (Underwater PSH) https://sperra.com/

Example projects:
Minestorage just won a EUR 22 Mil award for their Norberg Project:
https://www.minestorage.com/projects/
Rye Development: https://www.ryedevelopment.com/
Their Lewis Ridge Project (Coal Mine land): https://lewisridgeproject.com/
Ontario Power
Their Marmora Clean Energy Hub (Iron Mine): https://marmorapumpedstorage.com/
Dairyland (PUSH, working with MineStorage)

Other companies perhaps involved:
Exceed Geoenergy (well-based underground geothermal energy and carbon sequestration) https://exceedgeoenergy.com/
Hatch (underground mining and energy storage) https://www.hatch.com/en
EPC Solar (South Africa, exploring grid-scale underground) https://www.solarepc.co.za/
Hydromine (Australia, but maybe closed) https://www.hydromine.com.au/


minestorage.com
MINE STORAGE
PROJECTS
SOLUTION
COMPANY
NEWS
CONTACT
ENABLING A SUSTAINABLE ENERGY TRANSITION
Our future depends on a fast transition from brown to green energy.

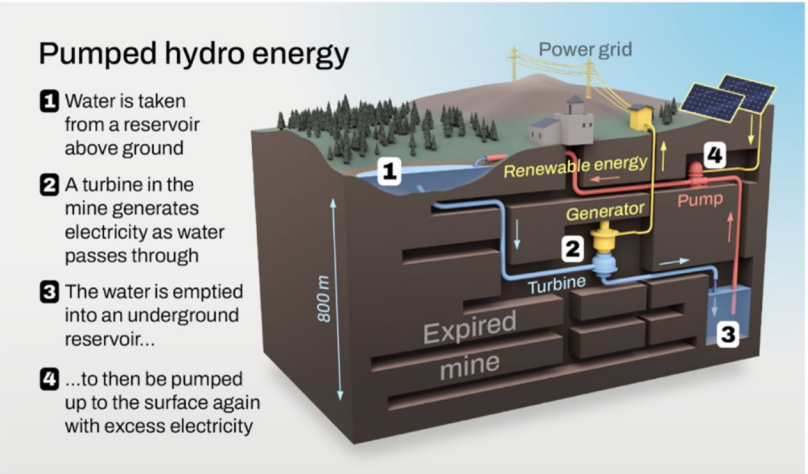
Minestorage AB project in Vånga, Skåne, Sweden.
50-70 MWh per cycle
20,000 - 30,000 households



# Pumped Hydro Storage

sens.se/en/17/65/pumped-hydro-storage/

SENS Energy Solutions Investors Career Information About us Contact us EN




## Our solution

SENS's solution is based on an understanding of the electricity market and future revenue streams for pumped storage plants. We have translated this into a software to simulate revenue streams from electricity trading and balancing services for the electricity grid. We use the knowledge to design and optimise facilities. These are easily adapted to local market and operating conditions.

Each facility has a unique and customised operating schedule. This maximises the utilisation of the energy storage to the benefit of its owner. The technology itself is proven and consists of pumps, generators and turbines in a synchronised system. With the help of this, water is moved in a closed system through corrosion-resistant pipes between an upper and a lower reservoir. By constructing the reservoirs in underground mines, the cost of these fires and the environmental impact are minimal.

MENU

MINE FOR BUSINESS
CALLIO
PYHÄJÄRVI, FINLAND


tureMINE

eMINE

MINE project develops the Pyhäsalmi mine's infrastructure into a digital test mine of hich can influence the electrification and digitalization of the entire mining industry d internationally.

ndustry is moving towards a more digital and electronic era. In the future, genuine mining test environment are required, where the cluster members involved plan ng models and develop their testing services in close cooperation with ODM's and logy vendors, and where the mining industry products and solutions are studied, nd tested in both real and simulated digital development environment.

y target groups of the FutureMINE innovation cluster project is manufacturers and the battery-powered technology (e.g., batteries, charging points, battery-powered es, vehicles and equipment, servers, and backup power services) whose activities esting new technology and ensuring end to end operational safety. Such safety

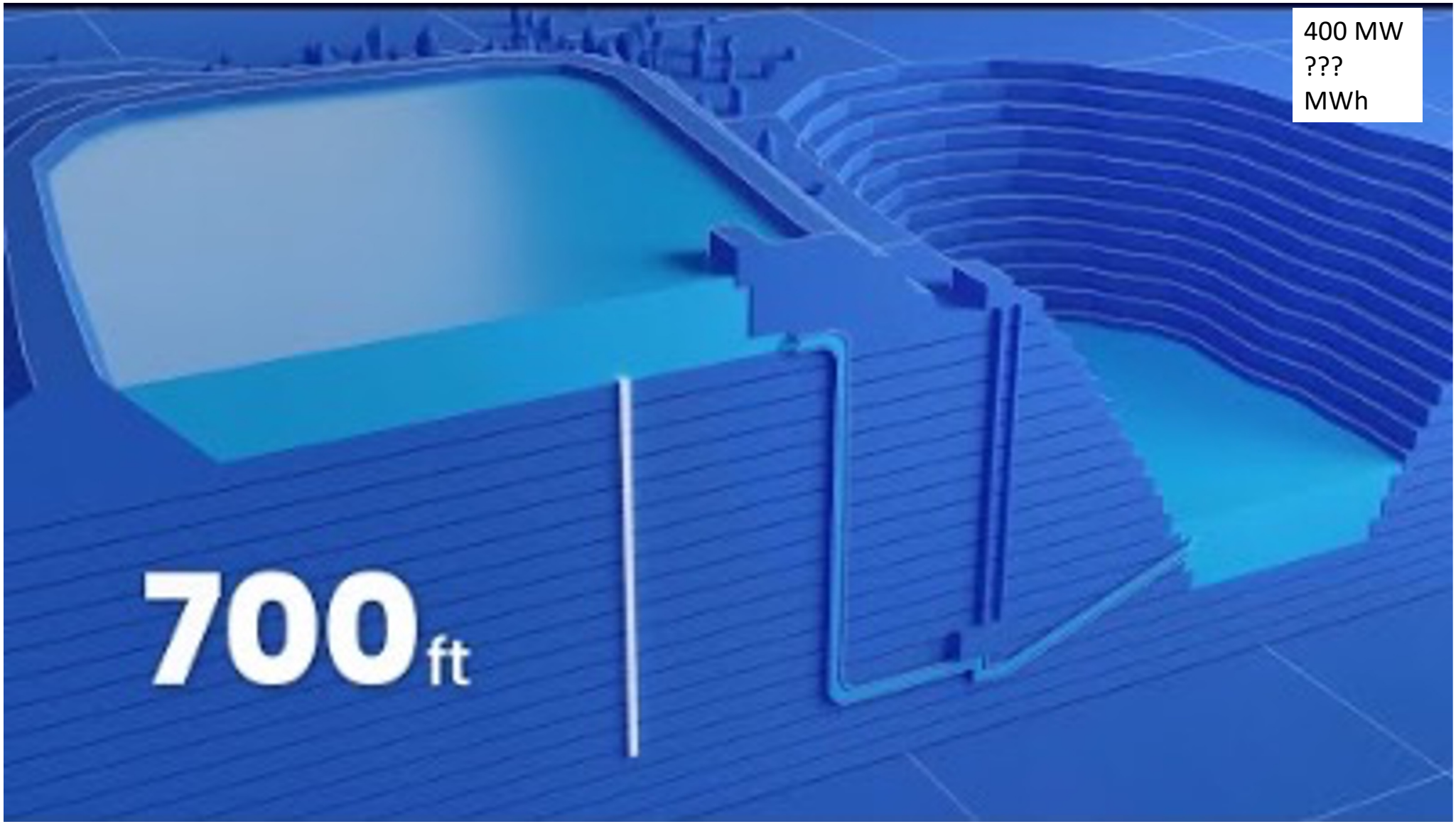
BUSINESS RESEARCH, DEVELOPMENT AND INNOVATION OPPORTUNITIES

# Marmora clean energy hub project

From a long inactive, open-pit iron ore mine to an innovative clean energy asset, we're planning on building a cleaner tomorrow, together.

ONTARIO POWER GENERATION

NORTHLAND POWER


400 MW
???
MWh
700 ft

ryedevelopment.com/rye-development-doe-grant-lewis-ridge-pumped-storage.html

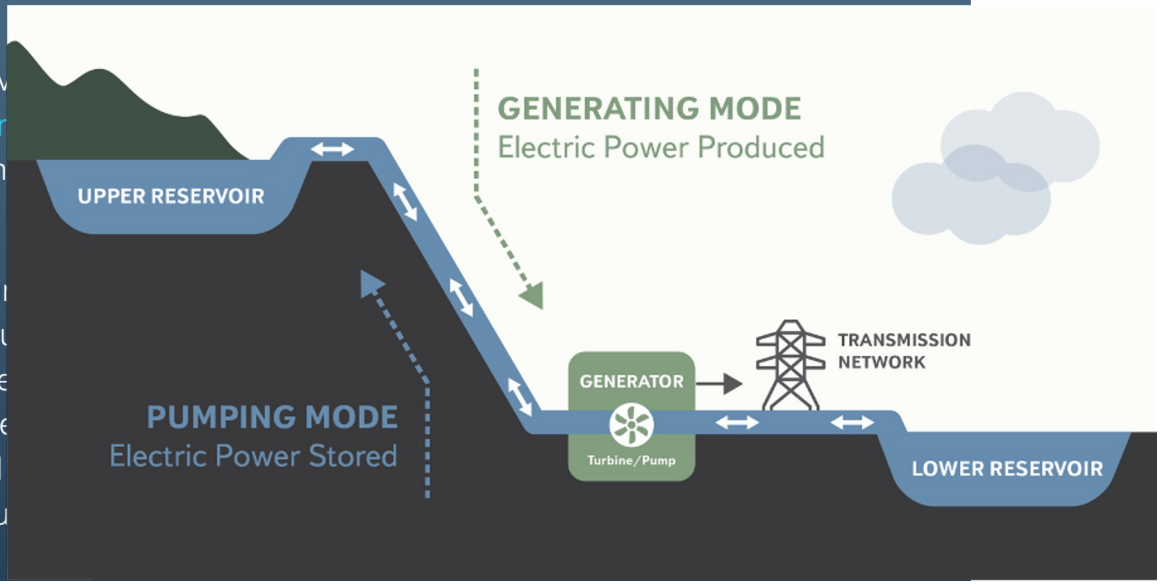
50-250 MW
600 MWh

Rye Development

# Rye Development Selected by U.S. Department of Energy to Receive $81 Million for Lewis Ridge Pumped Storage Project

Rye Development is one of five organizations that receiv
Energy Demonstration Program on Current and Former
pumped storage hydropower facilities constructed in th
on former mine land.

Lewis Ridge is a closed-loop pumped storage facility usi
undisturbed. When energy demand is low, electricity is u
more energy, such as during times of peak demand or e
In the United States, pumped storage hydropower curre
the most dependable energy storage solution. Pumped
are the most climate-friendly long-duration storage solu
released in 2023.



HYDROSTOR

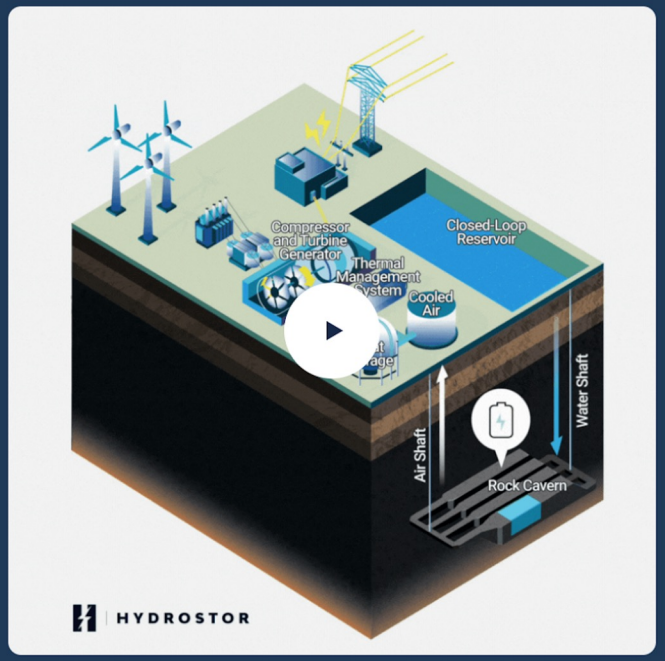
CONTACT US

## Long duration energy storage is the missing link to support carbon free electricity

Hydrostor's Advanced Compressed Air Energy Storage (A-CAES) technology provides a proven solution for delivering long duration energy storage of eight hours or more to power grids around the world, shifting clean energy to distribute when it is most needed, during peak usage points or when other energy sources fail.

DRAG TO DISCOVER

1/4

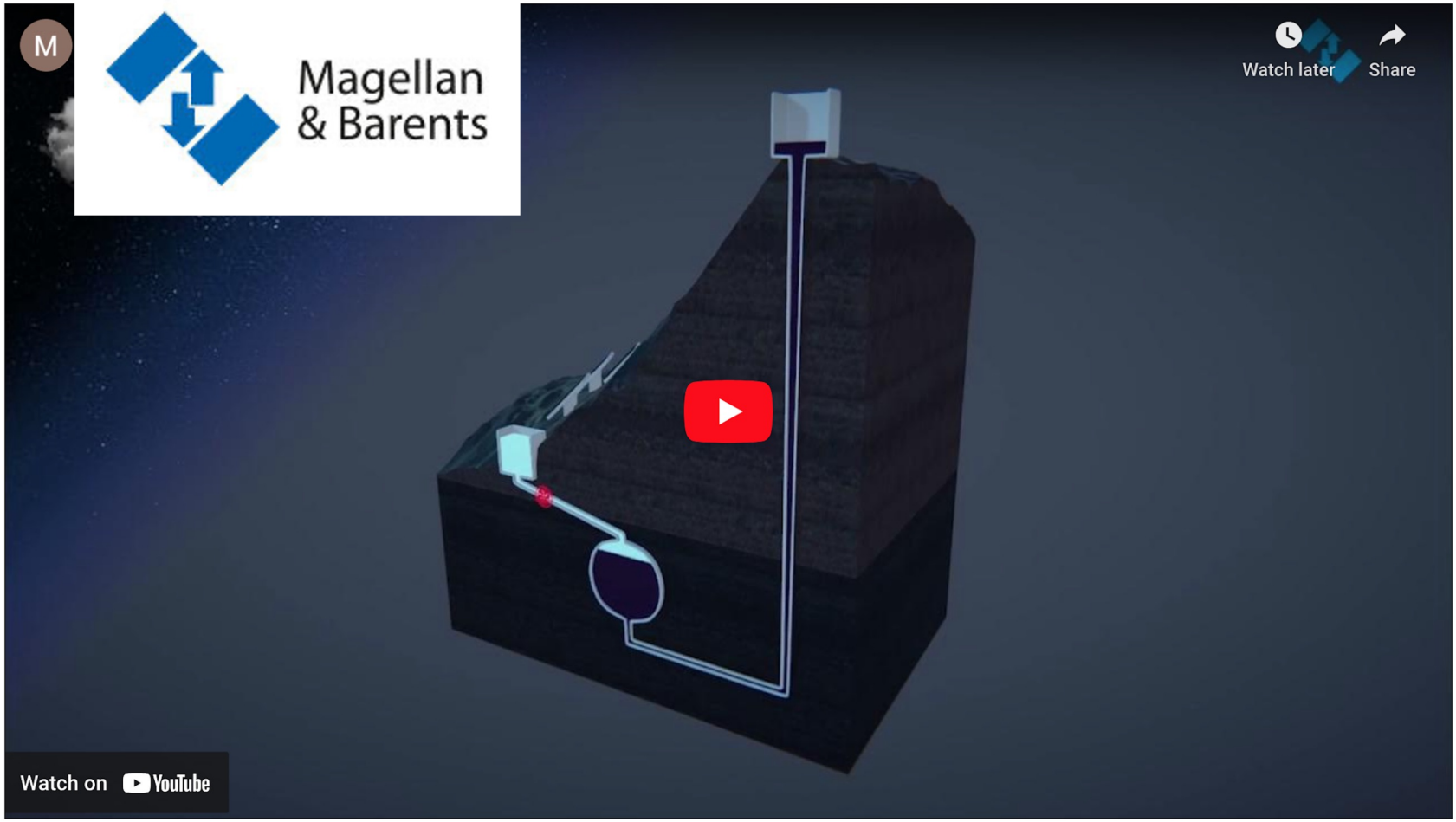



Using compressed air and water to stor energy, A-CAES allows grid operators t on clean energy, even when there is no fuel solar panels and no wind to genera energy from turbines.

DRAG TO DISCOVER

DRAG TO DISCOVER

**400MW/3,200MWh** Pechos Energy Storage Center in San Luis Obispo County; Willow Rock Energy Storage Center in Kern County in **200MW/1,600MWh**; ***4GWh TBA***




“Superdense” Fluid PSH, a.k.a. “High-Density Hydro”

LKAB Minerals

Dark mode

Menu

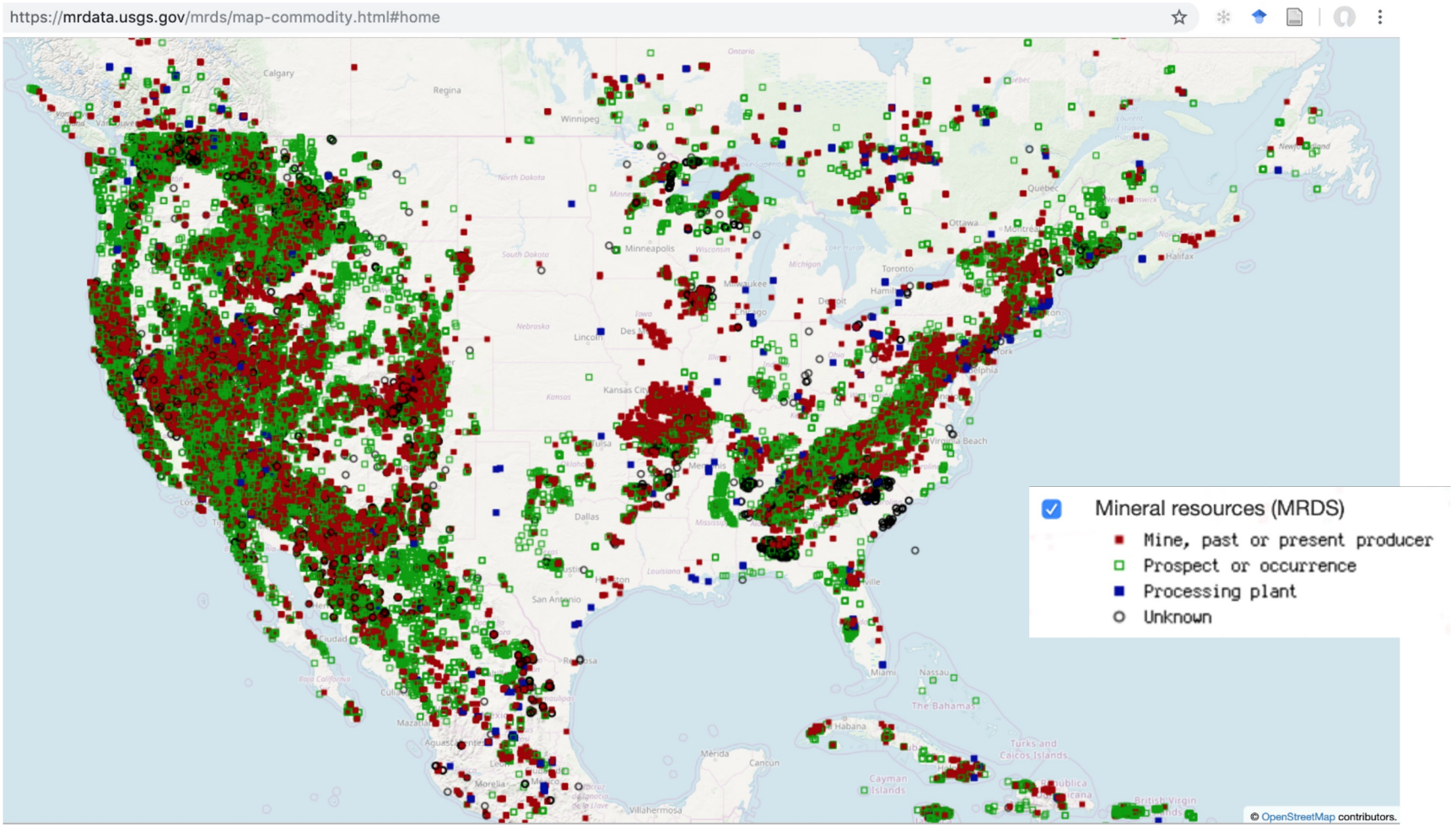
MagnaDense

# MagnaDense

MagnaDense is a natural Magnetite used for loose ballast and high density concrete.

- Certified according to EN standards
- High density
- High submerged/saturated density
- Reduced heat of hydration
- Space-saving
- Consistent quality
- High radiation shielding characteristics
- Noise and vibration dampening
- Reduced volume
- Thermal energy storage

1. What are specific concerns about underground PSH facilities?
   ~~a. How does it work?~~
   b. Where is it feasible?
2. What are potential benefits vs. adverse impacts?



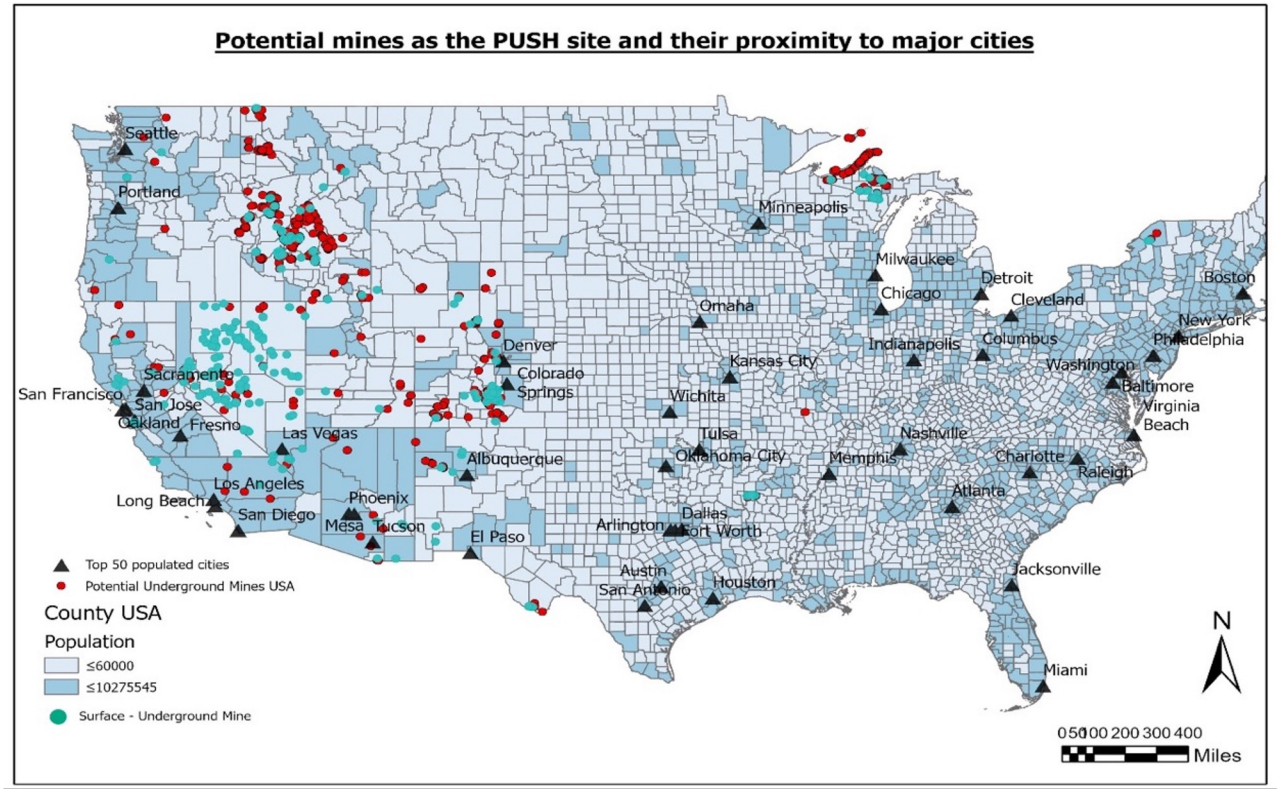



MSDS Metals Mines only

KETL Keweenaw Energy Transition Lab at the Great Lakes Research Center | Michigan Technological University

# Potential PUSH site location with solar map

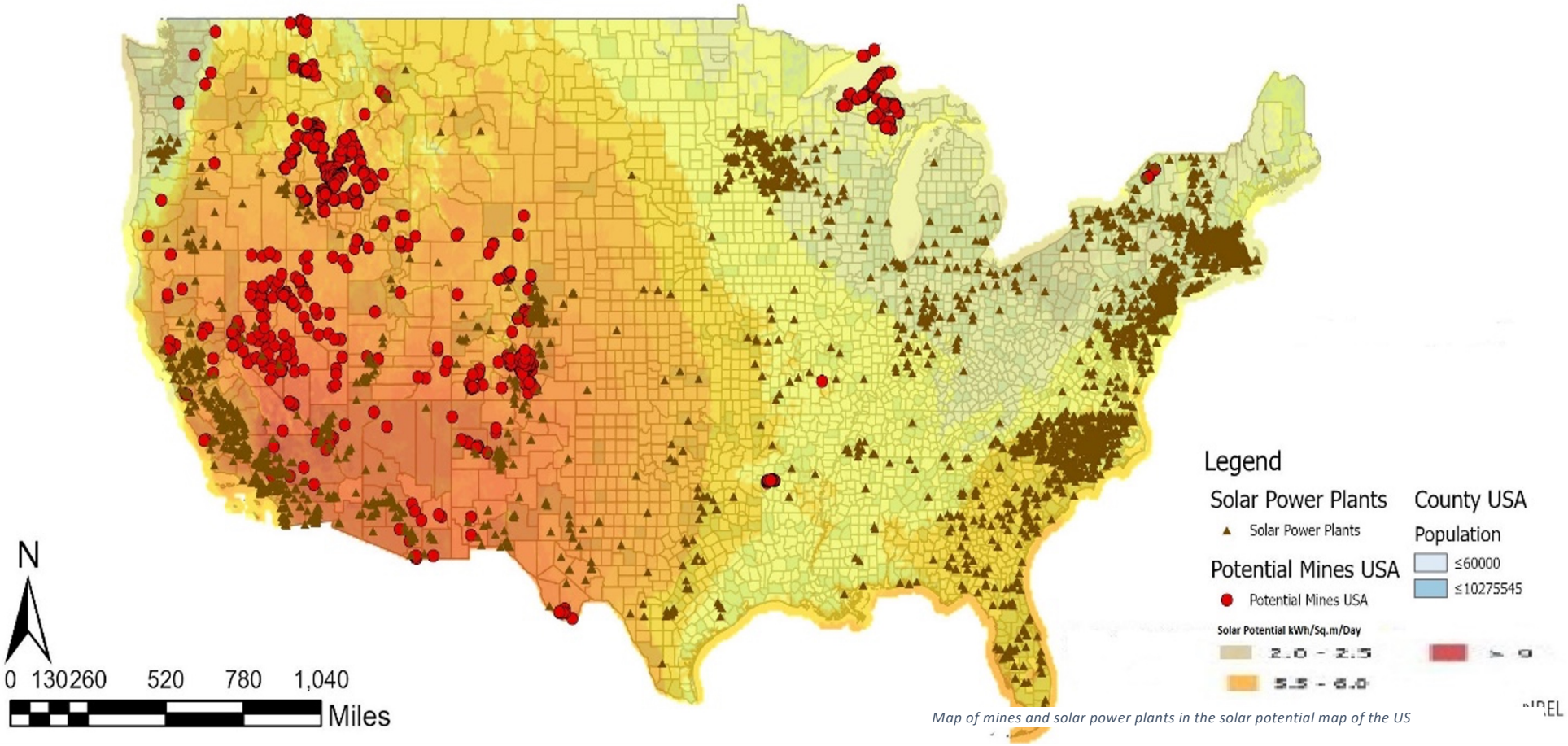
- Total 968 mines identified as feasible mines for PUSH development
- 873 mines are past producing mines and 95 are currently operational
- 706 mines are completely underground and 262 are semi – underground mines




*Map showing load centers (cities and counties) with mine location*

KE
Keweenaw

# Solar Potential, Mines and Existing Solar Power Plants in the USA




*Map of mines and solar power plants in the solar potential map of the US*

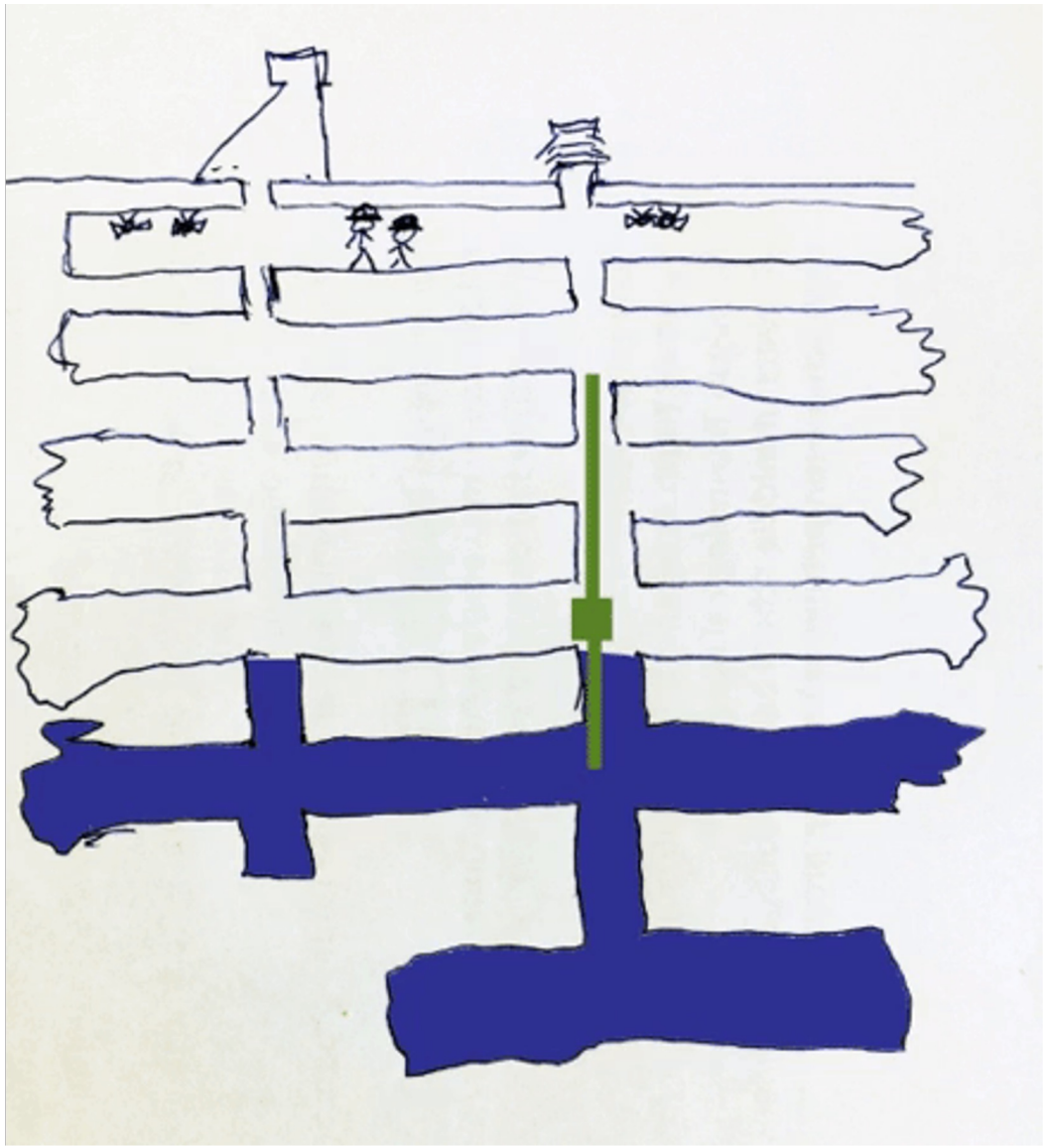
1. What are specific concerns about underground PSH facilities?
   ~~a. How does it work?~~
   ~~b. Where is it feasible?~~
2. What are potential benefits vs. adverse impacts?

Closed loop (or not)?

Underground (or not)?

Old Mine?
End-of-life?
In Development?

Facility's purpose?
Daily storage/Arbitrage?
Seasonal?
grid services?
security? Islanding?
transmission/congestion?




KETL
Keweenaw Energy Transition Lab
at the Great Lakes Research Center
Michigan Technological University
Ethics
People
Research
News
Partners
Blog
Contact
Top of Page
Keweenaw Energy Transition Lab
"It is becoming increasingly clear that routine energy analyses do not offer suitable answers to these sorts of issues. The enduring questions they provoke involve aspects of equity and morality that are seldom explicit in contemporary energy planning and analysis."
(Sovacool and Dworkin 2015)

Hancock City Hall
b. 1898


Old Marquette City Hall
b. 1895

# Liabilities into Assets for Post-Mining Communities in Michigan

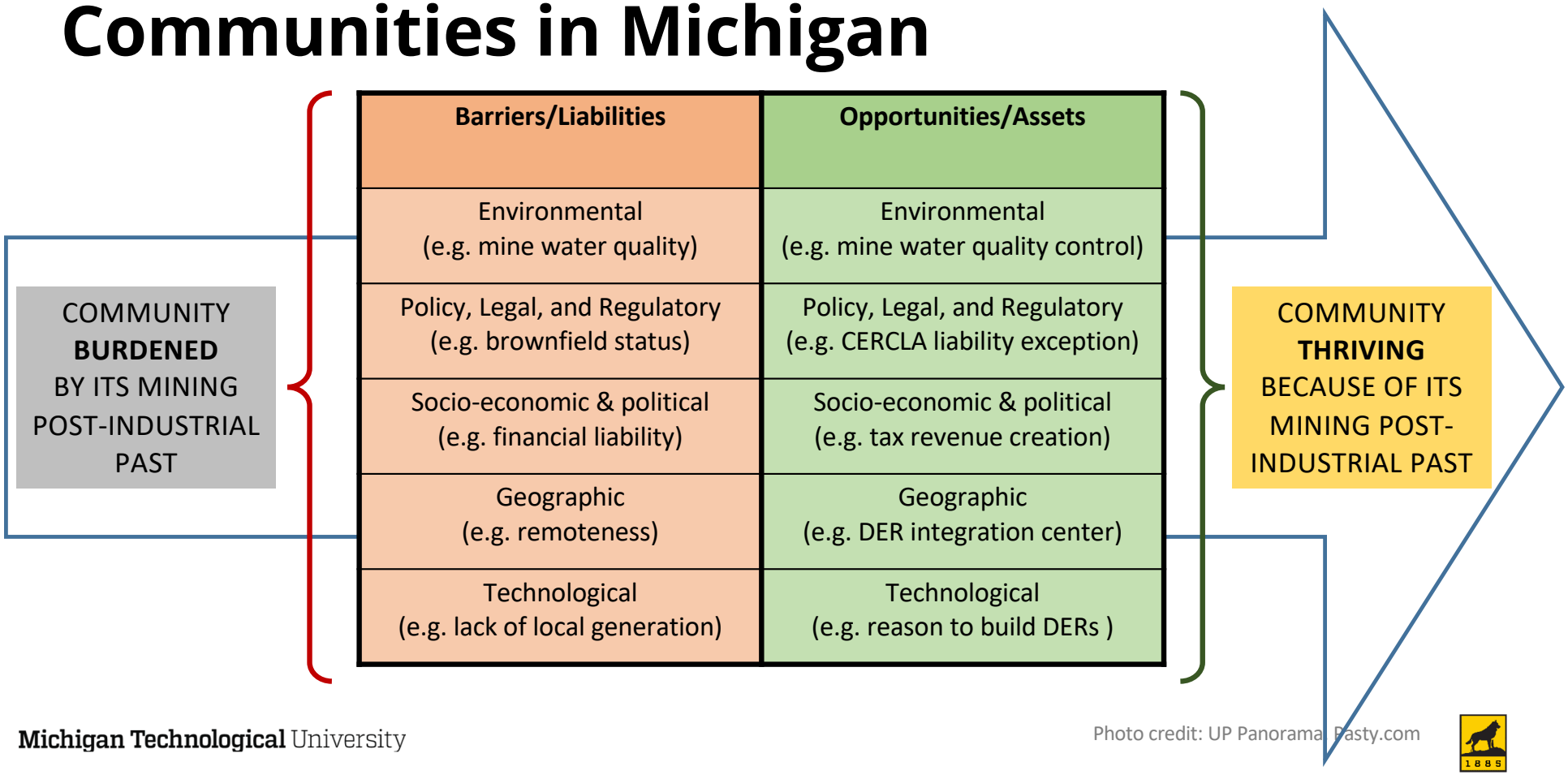





Photo credit: UP Panorama, Pasty.com

# Mather B: Liabilities into Assets for Post-Mining Communities

Alfred P. Sloan Foundation

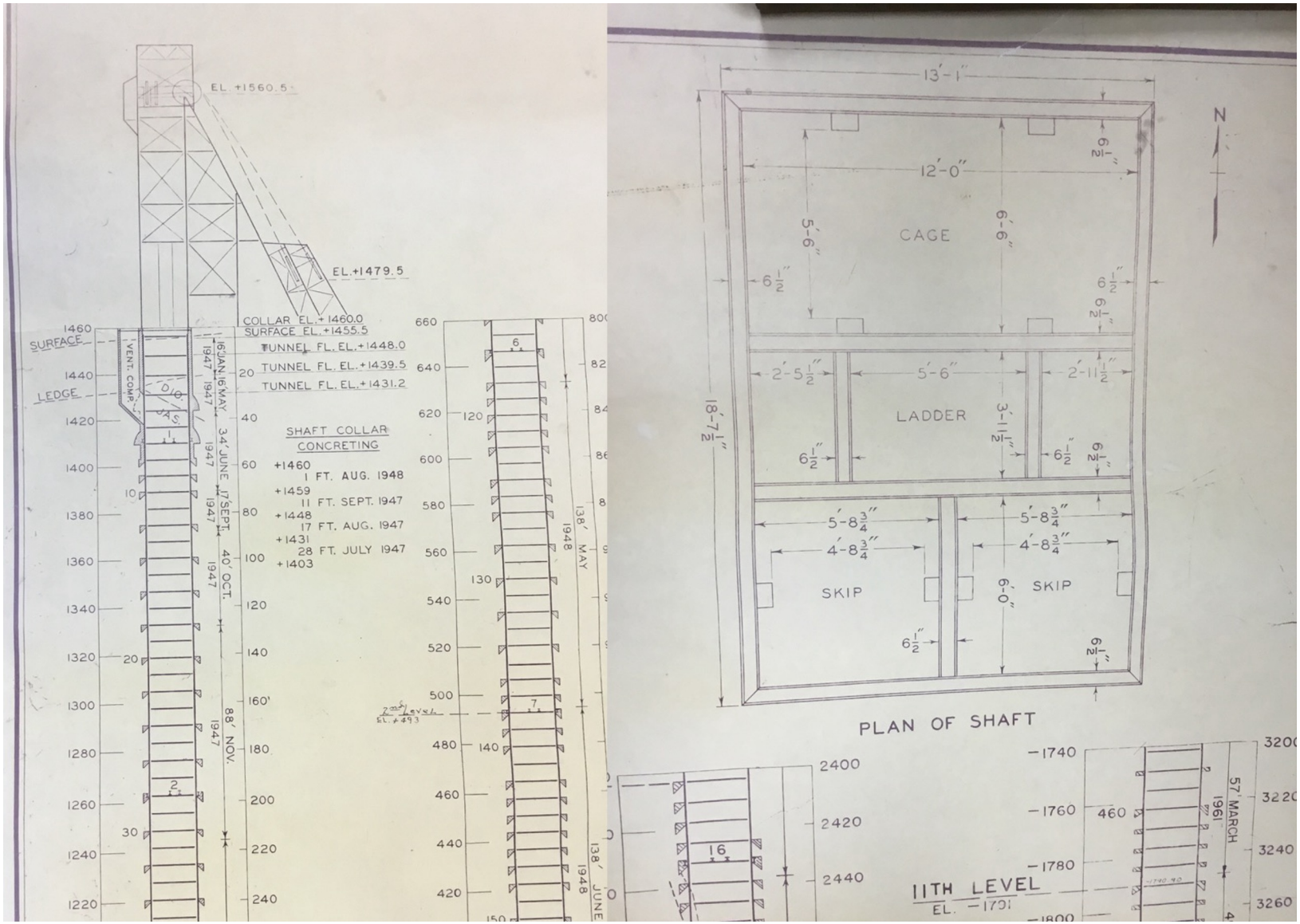
Photo credit: By Rklawton - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=69521341

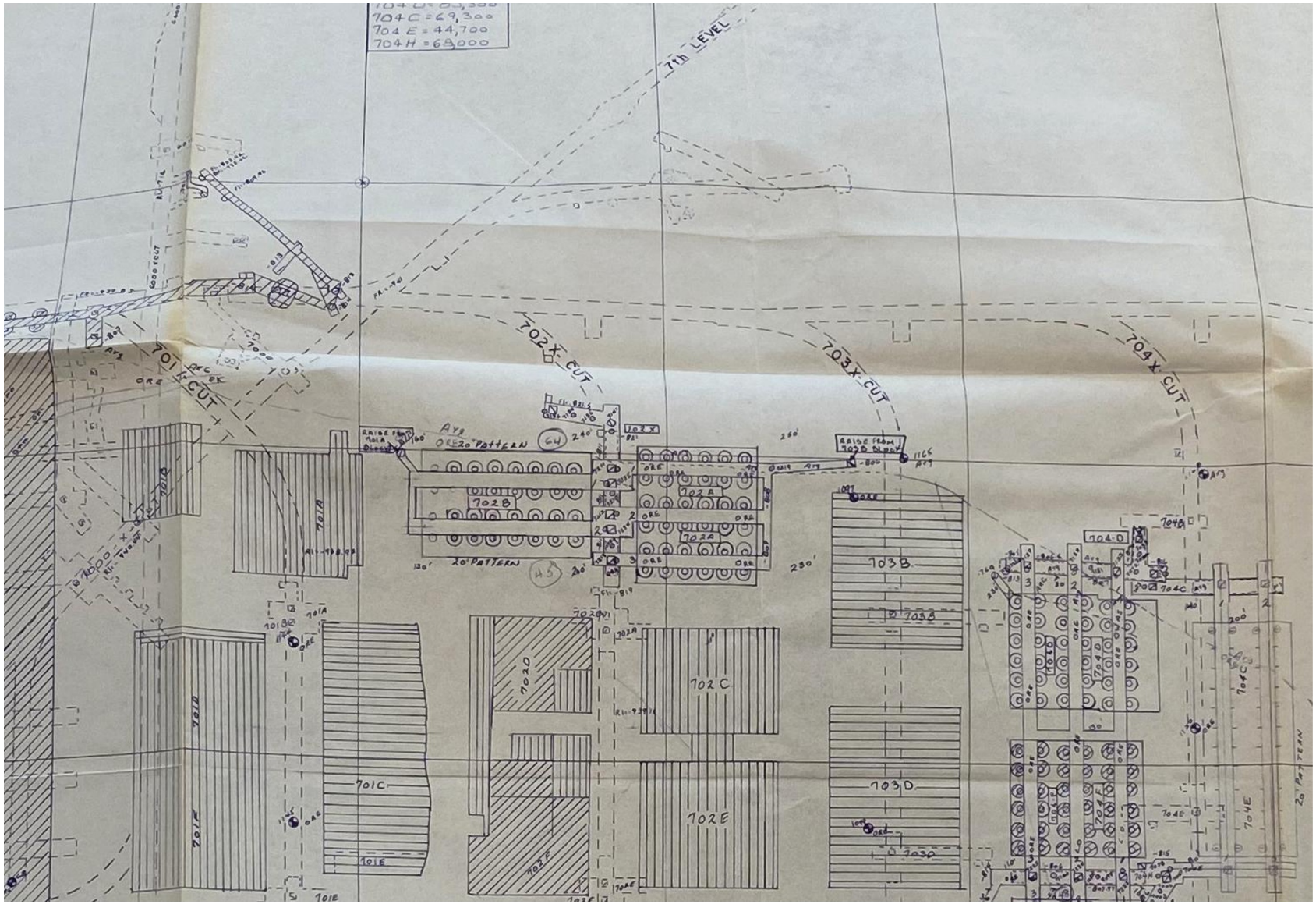
Michigan Technological University




Photo credit: Paul Petosky, GeneologyTrails.com


Mich


EL. +1560.5
EL.+1479.5
COLLAR EL. +1460.0
SURFACE EL. +1455.5
TUNNEL FL. EL. +1448.0
TUNNEL FL. EL. +1439.5
TUNNEL FL. EL. +1431.2
SURFACE
LEDGE
VENT. COMP.
SHAFT COLLAR CONCRETING
+1460 1 FT. AUG. 1948
+1459 11 FT. SEPT. 1947
+1448 17 FT. AUG. 1947
+1431 28 FT. JULY 1947
+1403
16 JAN. 1947
16 MAY 1947
3-4' JUNE 1947
17 SEPT. 1947
40' OCT. 1947
88' NOV. 1947
138' MAY 1948
138' JUNE 1948
13'-1"
12'-0"
5'-6"
6'-6"
CAGE
LADDER
2'-5½"
5'-6"
2'-11½"
3'-11½"
18'-7½"
5'-8¾"
4'-8¾"
SKIP
SKIP
6'-0"
6½"
N
PLAN OF SHAFT
11TH LEVEL
EL. -1791
57' MARCH 1961


704C = 69,300
704E = 44,700
704H = 69,000
7th LEVEL
702X CUT
703X CUT
704X CUT
701X CUT
ORE20 PATTERN
20' PATTERN
702B
702A
703B
703A
704D
704C
702C
702E
703D
703C
701C
701E
704E
20' PATTERN

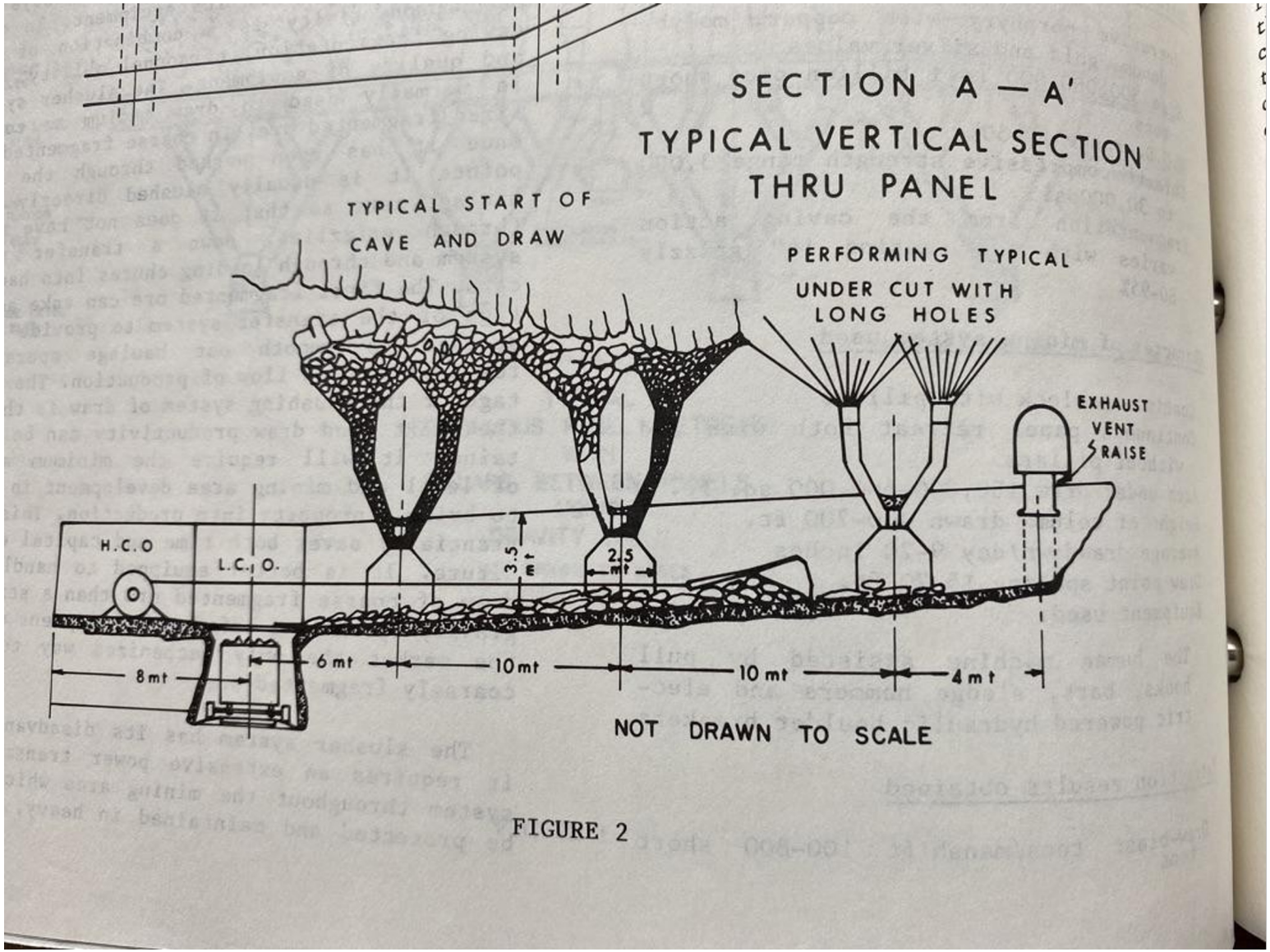

SECTION A — A'
TYPICAL VERTICAL SECTION
THRU PANEL
TYPICAL START OF
CAVE AND DRAW
PERFORMING TYPICAL
UNDER CUT WITH
LONG HOLES
EXHAUST
VENT
RAISE
H.C.O
L.C.O.
3.5 mt
2.5 mt
8 mt
6 mt
10 mt
10 mt
4 mt
NOT DRAWN TO SCALE

FIGURE 2

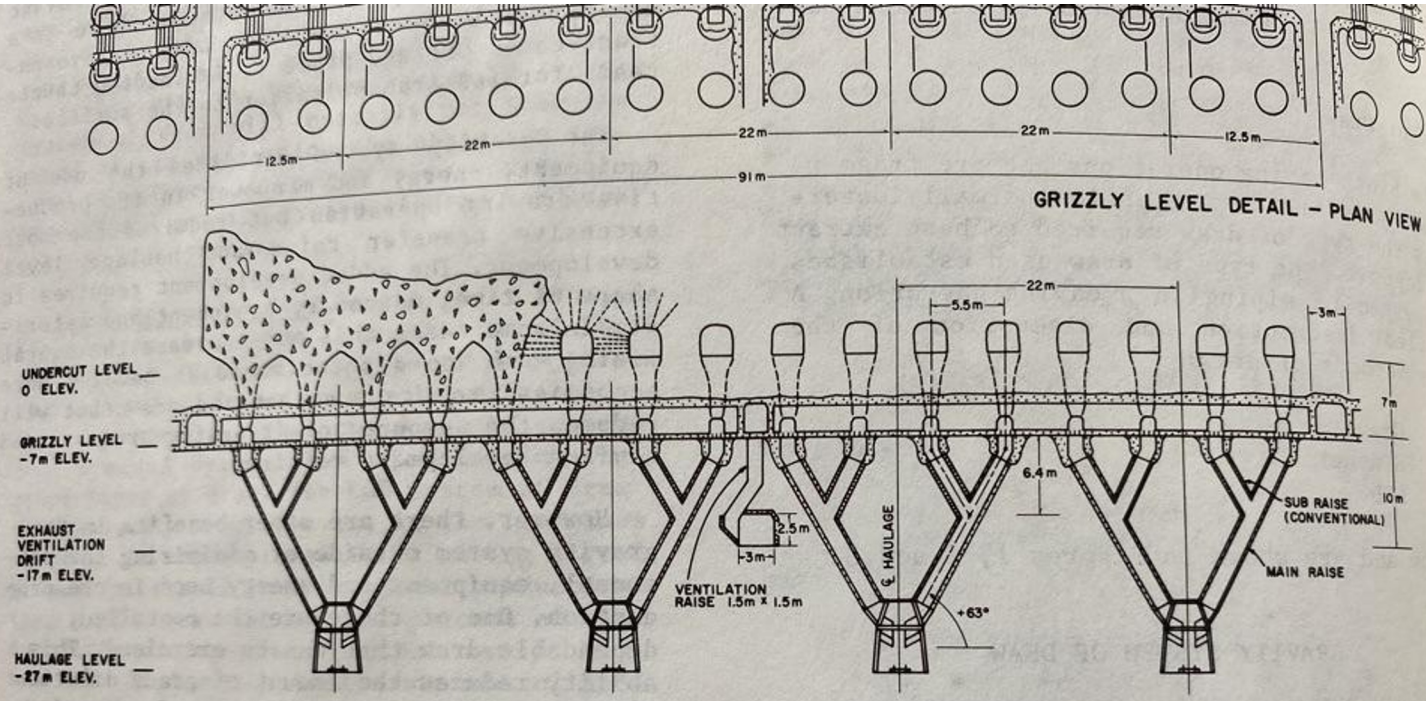
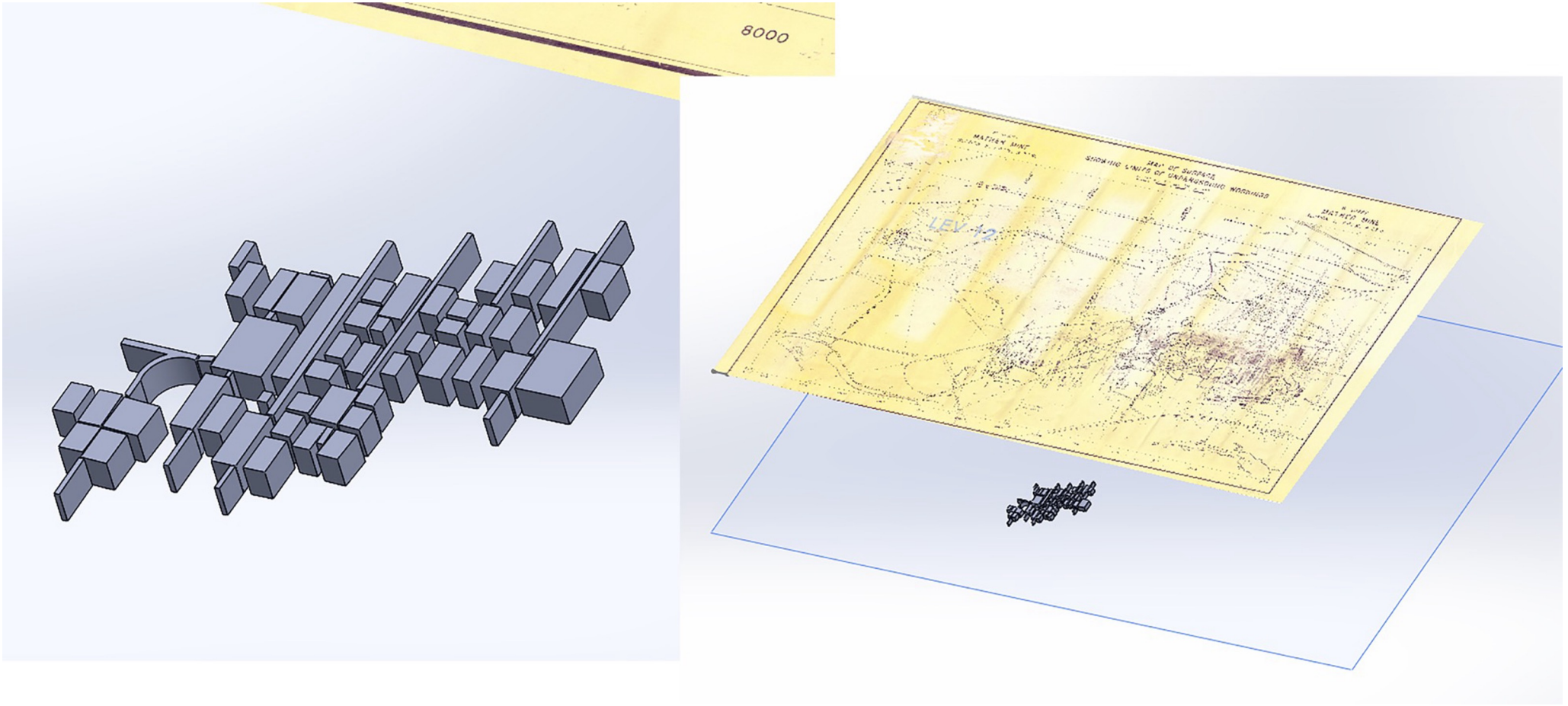
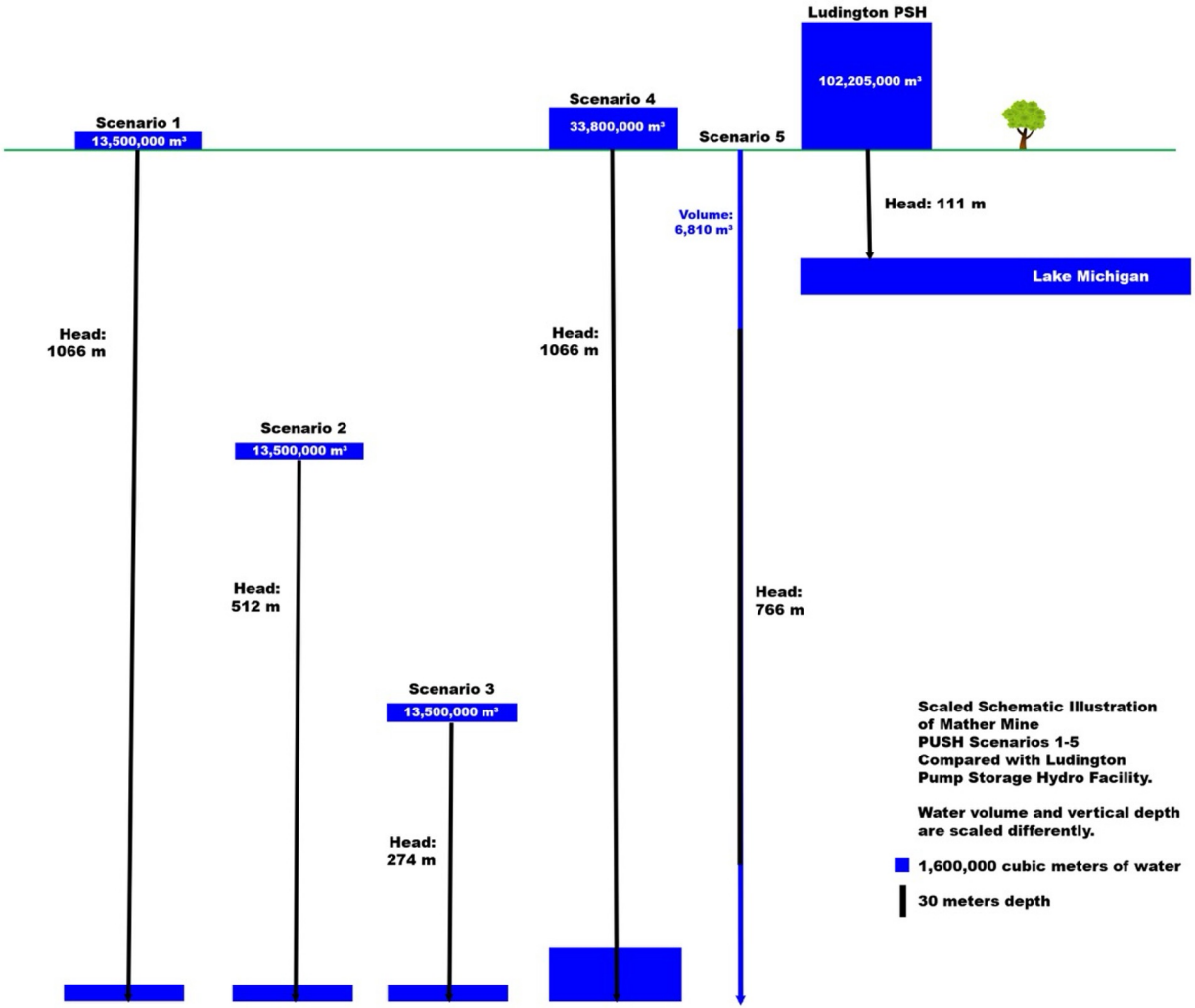



FIGURE 1

TYPICAL
CONTINUOUS PANEL RETREAT
WITH
PILLARS BETWEEN PANELS
USING
GRAVITY DRAW

NOT DRAWN TO SCALE


8000
LEV-12



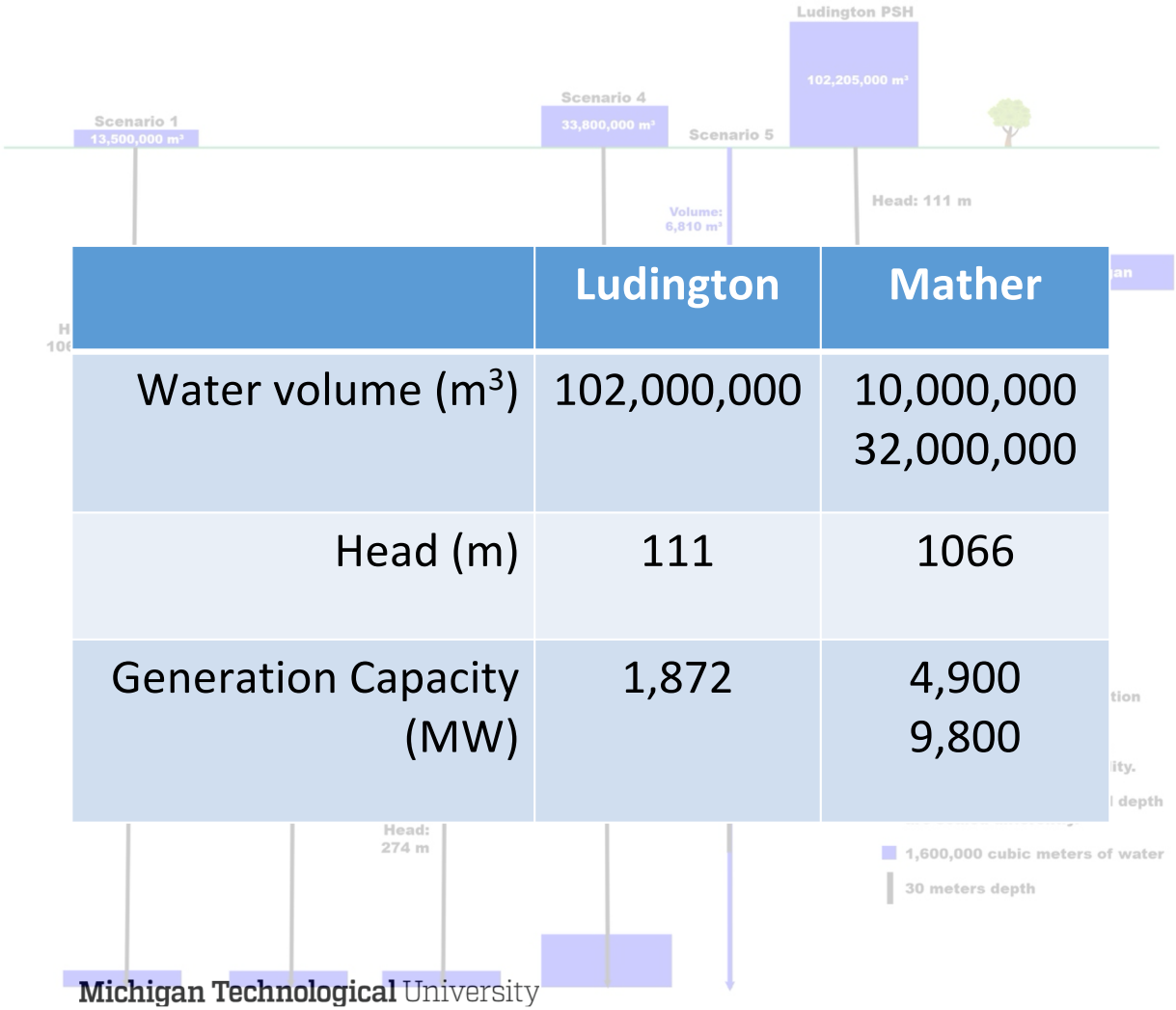

**Scaled Schematic Illustration of Mather Mine PUSH Scenarios 1-5 Compared with Ludington Pump Storage Hydro Facility.**

**Water volume and vertical depth are scaled differently.**

- **1,600,000 cubic meters of water**
- **30 meters depth**

*Table 1: High and Low Water Volume and Maximum Head estimates for five different PUSH design scenarios in the Mather Mine.*

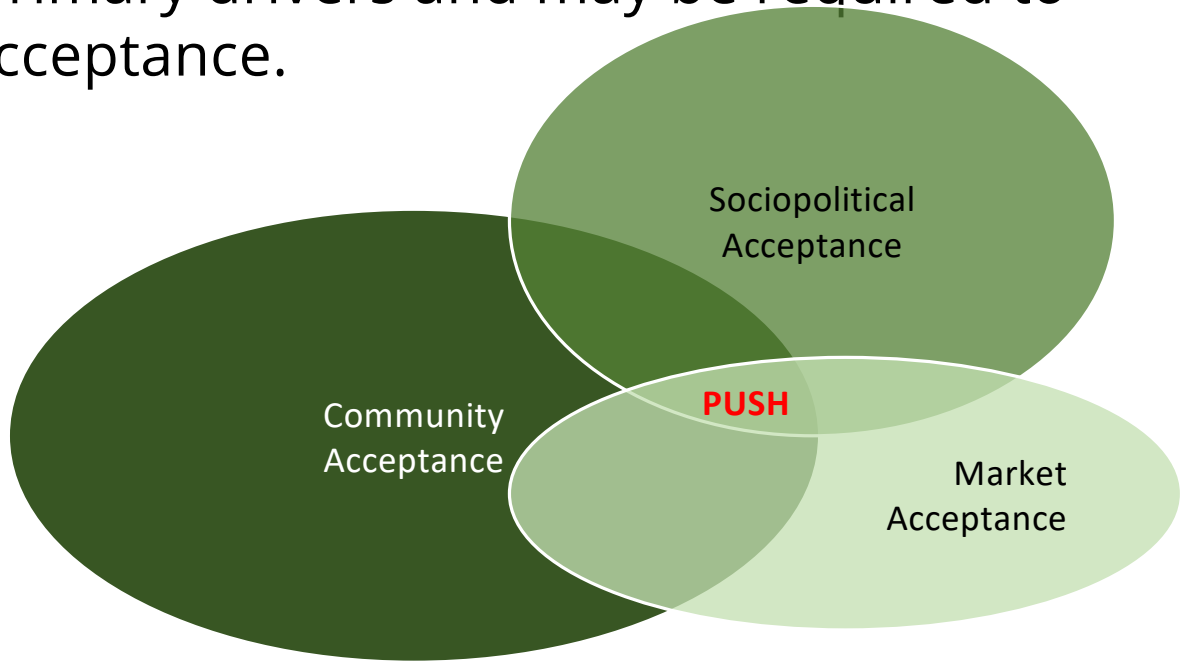
| Scenario | High Volume Estimate ($m^3$) | Low Volume Estimate ($m^3$) | Maximum Head (m) | Scenario designation in 2020 interim report |
|---|---|---|---|---|
| Scenario 1: Surface pond to Levels 11-12 | 13,536,062 | 13,536,062 | 1066 | Similar to 1 |
| Scenario 2: Levels 2-4 to Levels 11-12 | 13,536,062 | 13,536,062 | 512 | Similar to 3a |
| Scenario 3: Level 6-8 to Levels 11-12 | 13,536,062 | 13,536,062 | 274 | new |
| Scenario 4: Surface to levels 7-12 | 33,800,000 | 18,551,208 | 792 | new |
| Scenario 5: Shaft only | 6,810 | 6,810 | 766 | 2 |




| | Ludington | Mather |
|---|---|---|
| Water volume ($m^3$) | 102,000,000 | 10,000,000<br>32,000,000 |
| Head (m) | 111 | 1066 |
| Generation Capacity (MW) | 1,872 | 4,900<br>9,800 |

Michigan Technological University

- Meeting energy transition needs at Brownfield instead of Greenfield sites.
- *Community input* into design considerations and *economic participation* are the primary drivers and may be required to achieve community acceptance.

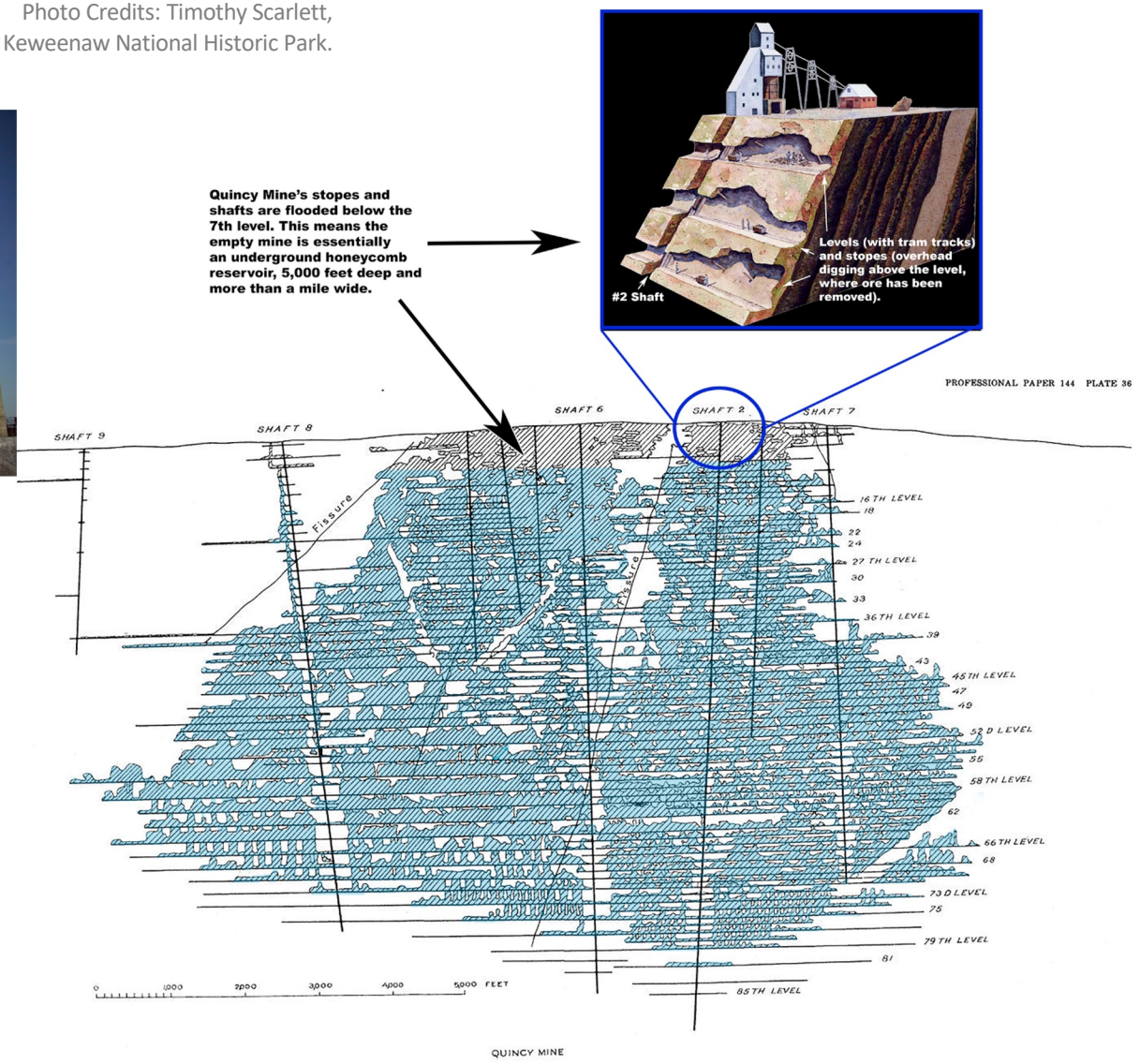



Tiwari, S., Schelly, C., & Sidortsov, R. (2023). Legacies Matter: Exploring Social Acceptance of Pumped Storage Hydro in Michigan's Upper Peninsula. *Case Studies in the Environment*, *7*(1).

# Key Questions

Photo Credits: Timothy Scarlett, Keweenaw National Historic Park.

Improve water quality.
Improve habitat (bats).
Improve energy access.
Educational Opportunities.
Land access/Greenspace.
Improve Heritage value.



# Thank you!

Timothy Scarlett, scarlett@mtu.edu
https://ketl.info

# Break

Returning at 11:15 am

# Group Polling and Discussion

# Polling and Discussion Questions

- *What are your overall impressions of the other mechanical storage systems you heard about today?*
- *If you've attended multiple meetings and your views of PSH siting have changed, how have they changed?*
- *In a word, what criteria should be emphasized when siting PSH?*
- *What have you found most useful from these meetings?*

# Online polling reminder

- When prompted, please use a phone or browser screen to access the polls using the QR code or website address: PollEv.com/lavishnature521
- For short "word cloud" responses, you can join_words using an underscore

Join by Web
PollEv.com/lavishnature521

Join by scanning the QR code

# PSH Kick-off Meeting Question (June 2024)

*"In a word, what criteria… do you think should be considered when siting PSH?"*

# Next Steps and Wrap up

*Karen Janowitz, WSU Energy Program*

# Next Steps

- Continued meetings with individuals and groups, as requested
- Draft report review (estimated April 2025)
- Final webinar (TBD)
- Final report – June 30, 2025

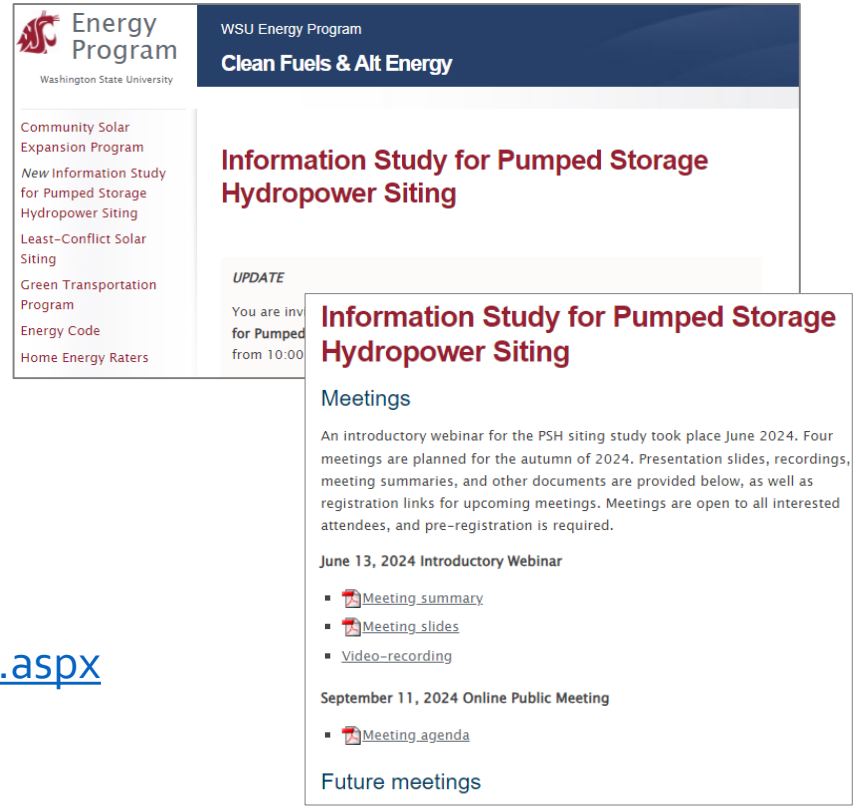
# WSU PSH Website and Email List

WSU Energy Program PSH Siting Study Webpages:
https://www.energy.wsu.edu/CleanFuelsAltEnergy/PSHSiting.aspx

PSH Siting Study Meeting Webpage:

- Meeting summary
- Meeting video-recording
- Meeting slides

https://www.energy.wsu.edu/CleanFuelsAltEnergy/PSHSiting/Meetings.aspx




Sign up for the email distribution list:
https://www.energy.wsu.edu/CleanFuelsAltEnergy/PSHSiting/PHSSitingEmailRegistration.aspx

Karen Janowitz
janowitzk@energy.wsu.edu

# THANK YOU!

Study lead:

Karen Janowitz
360-956-2096
janowitzk@energy.wsu.edu