Many Talents, Many Solutions: Climate Change Adaptation Strategies

Timothy Scarlett

2021 MML Breakout

Thursday, Sept 23, 2021

3:00 – 4:00 PM

Grand Rapids, MI

Alfred P. Sloan Foundation

Michigan Technological University

1885

Liabilities into Assets for Post-Mining Communities in Michigan

PUSH: Pumped Underground Storage Hydropower
Keweenaw Energy Transition Lab @ Michigan Technological University

Partners:

- Nate Heffron, the City of Negaunee
- Brett Niemi, WPPI
- WUPPDR

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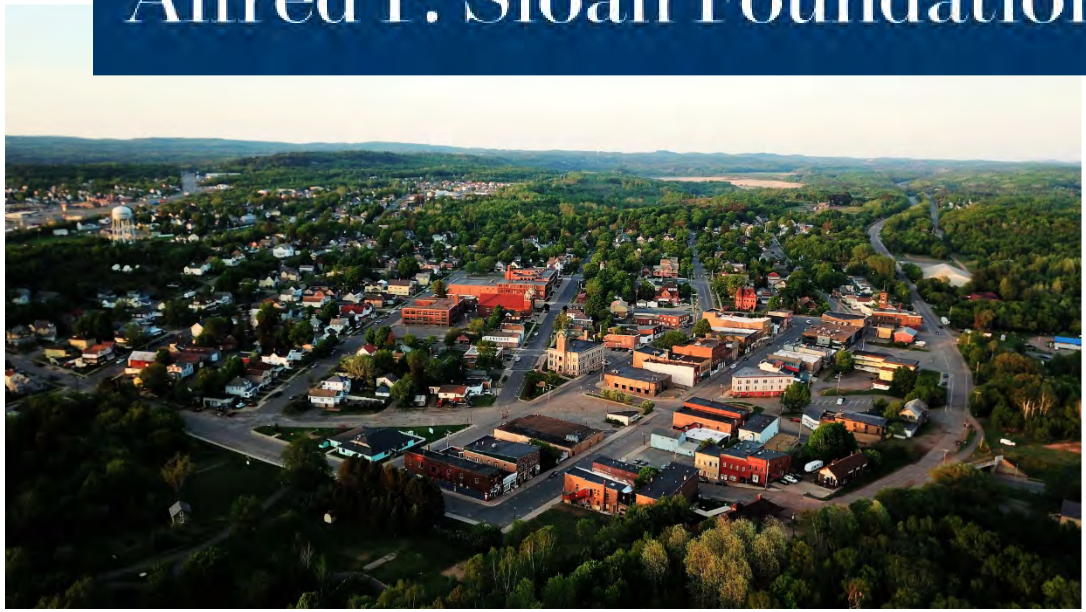

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WUPPDR of Michigan

NEGAUNEE · VILLAGE · 1865 · FOUNDED · 1846 · CITY · 1873

WPPI energy

Hancock City Hall
b. 1898

Old Marquette City Hall
b. 1895

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NEWS

Michigan's U.P. goes head-to-head with its energy future

WRITTEN BY
Andy Balaskovitz
October 6, 2014

PHOTO BY
Superior Watershed Partnership

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MICHIGAN

Michigan researchers say state's utilities 'manipulate' system to their advantage

WRITTEN BY
Andy Balaskovitz
March 26, 2019

...l University campus is located in Houghton, Michigan, in the state's Upper ...ne of the highest electric rates in the U.S.

...er says Michigan utilities use political ... distributed generation — and regulators

...t month by Michigan Tech researchers says utilities in the ...olitical power to put up barriers for customer-owned solar ...entially cost-saving distributed generation.

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UPPCO's customers need bold solutions for problems

COLUMNS | elise matz

ELISE MATZ

The fact that UPPCO's residential electricity rates are among the highest in the continental United States is old news to the people who pay the bills each month. As of June 1, the utility's household rates were 68% higher than the Michigan average, in a state that has the 12th highest rates rates in the country.

Detroit Free Press | HOME | NEWS | SPORTS | AUTOS | ENTERTAINMENT | RESTAURANTS | IMPACT | MORE

Power bills are whoppers for some in the U.P.

Keith Matheny, Detroit Free Press | Published 3:49 p.m. ET Sept. 7, 2016 | Updated 11:56 a.m. ET Sept. 8, 2016

(Photo: Courtesy of UPPCO.)

Opening an electric bill is no one's favorite moment of the month. But for some Upper Peninsula residents, it comes with a particular dread.

Ratepayers with Upper Peninsula Power. pay 23 cents-25 cents per kilowatt hour for their electricity — about 67% higher than the Michigan average. The utility, known as UPPCO, has about 54,000 electric retail customers in 10 of the U.P.'s 15 counties, mostly in the northwest and north-central parts of the peninsula.

► Related: Michigan DEQ favors approval for mine Up North
► Related: Researchers monitor crayfish in Upper Peninsula

That rate is higher — much higher — than the average kilowatt hour rate in 49 of the 50 states. Only residents in Hawaii pay more for power.

And UPPCO is asking the Michigan Public Service Commission, the state's utility regulator, for a further rate increase of 6%-12%.

For the utility's customers in an area with a struggling ...

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Monopolies and Demographics: Why Meeting UP Energy Needs is Both Challenging and Expensive

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SAY 'YAH' TO DA U.P.'S SUNSHINE, EH?

MTU scientist says high rates make rooftop solar a good Up North deal

Solar Power | September 29, 2014 | By Jim Dulzo

Michigan Technological University

MICHIGAN WORKS! business is UP The Job Force Board

MI-SBTDC MICHIGAN SMALL BUSINESS & TECHNOLOGY DEVELOPMENT CENTER

PTAC

AN ECONOMIC OPPORTUNITY STUDY
FOR THE
MICHIGAN UPPER PENINSULA/ WISCONSIN BORDER REGION

SEPTEMBER 2009

NorthStar Economics, Inc.

MSA PROFESSIONAL SERVICES

HOUGHTON COUNTY ENERGY PLAN

Vision Statement

Houghton County will be a model for rural communities in creating an affordable, sustainable, and community-driven energy landscape to support a vibrant regional economy and a high quality of life for all its members

A FRAMEWORK FOR ECONOMIC DEVELOPMENT IN MICHIGAN'S UPPER PENINSULA

by

Roger J. Vaughan
Roger Vaughan Associates

Including

IMPLEMENTING A DEVELOPMENT STRATEGY FOR THE UPPER PENINSULA

by

Alfred N. Joyal, Ph.D.
Robert Kulisheck, Ph.D.
Principal Investigators

with

Sarah M. Ekdahl
Project Assistant

Northern Michigan University

Prepared for the U.P. Plan Steering Committee, Michigan Department of Commerce
Final Report
December, 1989

COMPREHENSIVE ECONOMIC DEVELOPMENT STRATEGY

WESTERN UPPER PENINSULA, MI
ECONOMIC DEVELOPMENT DISTRICT
PLANNING & DEVELOPMENT REGION 13

WUPPDR of Michigan

2017-2022

The Energy Transition

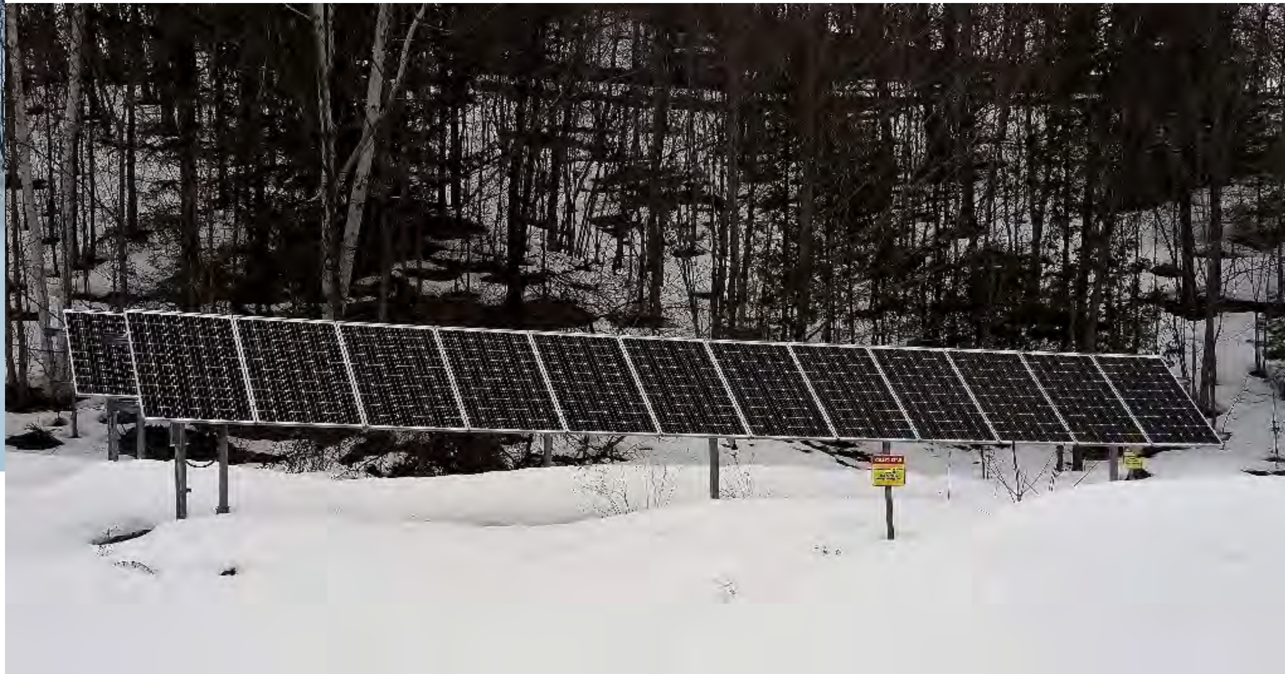


Photo credit: Roman Sidortsov, By Keweenaw National Historic Park, Dan Johnson - http://www.fhwa.dot.gov/byways/photos/61350, Public Domain, https://commons.wikimedia.org/w/index.php?curid=695316

The “Duck Curve”

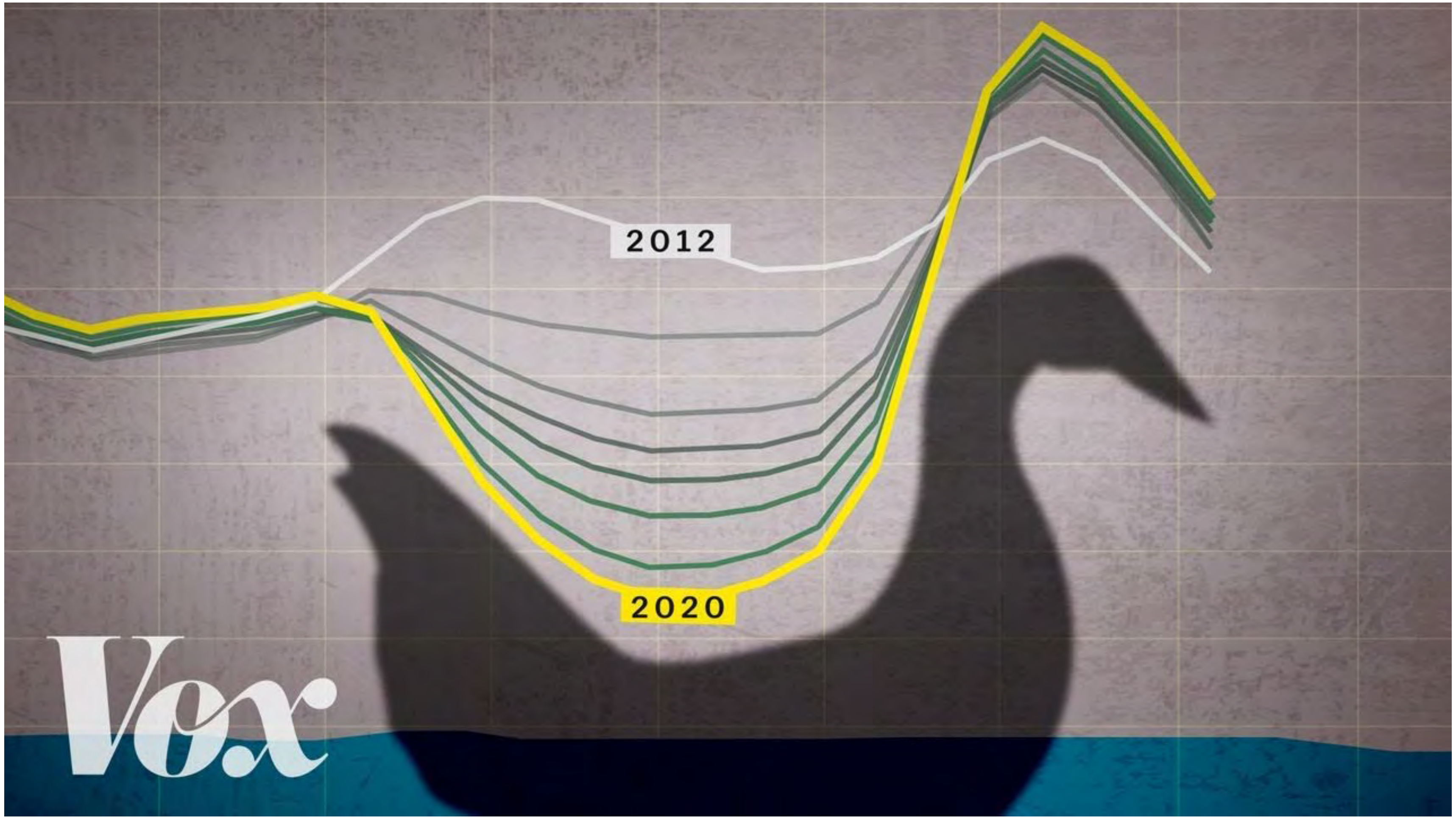


Photo credit: Vox on YouTube: https://i.ytimg.com/vi/YYLzss58CLs/maxresdefault.jpg

Energy Storage

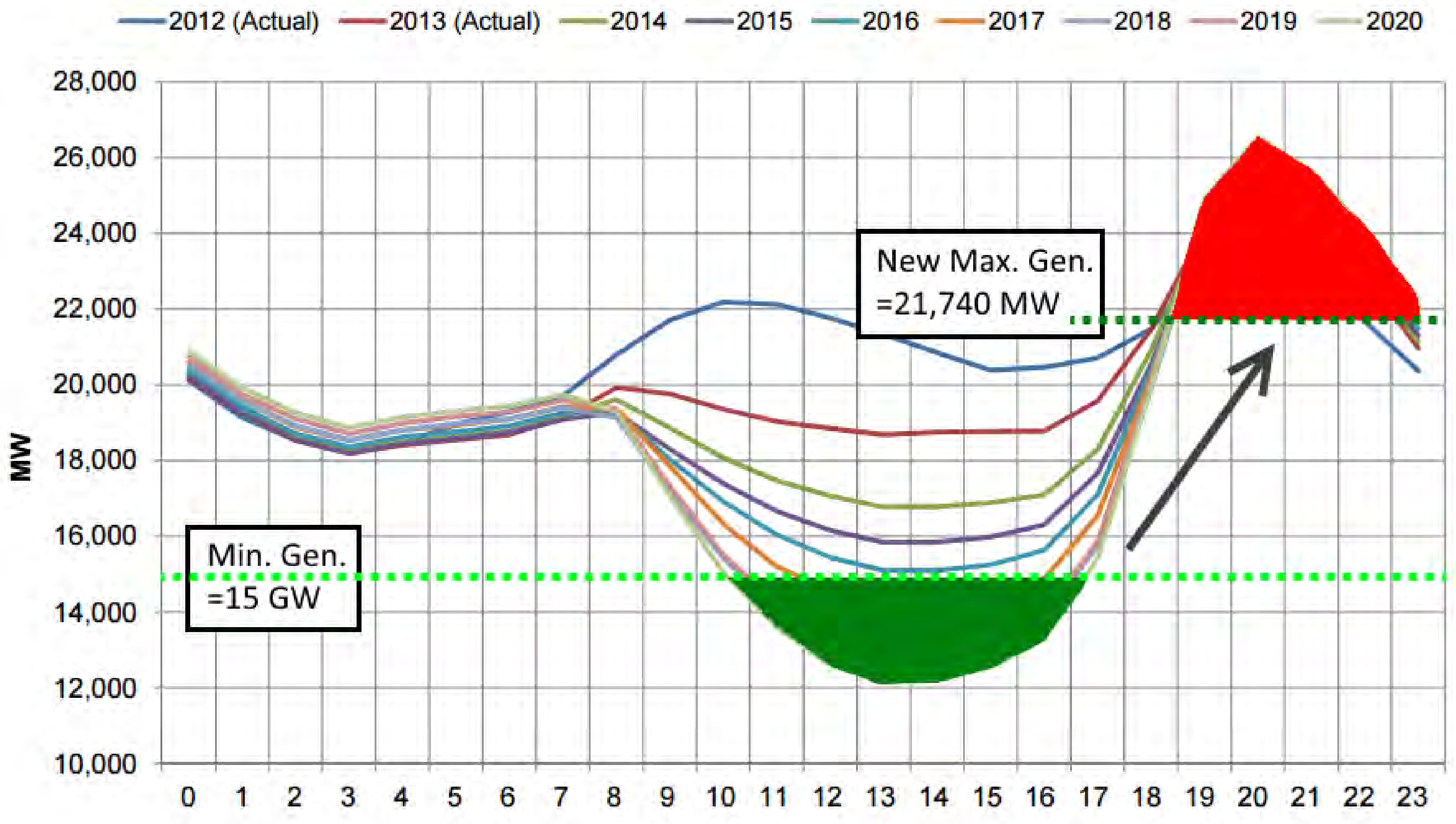


Photo credit: Michael Burnett, Stanford University.
http://large.stanford.edu/courses/2015/ph240/burnett2/images/f3big.png

Pump Storage Hydro: Ludington

Photo credit: Consumers Energy on Flikr:

Storage must grow:

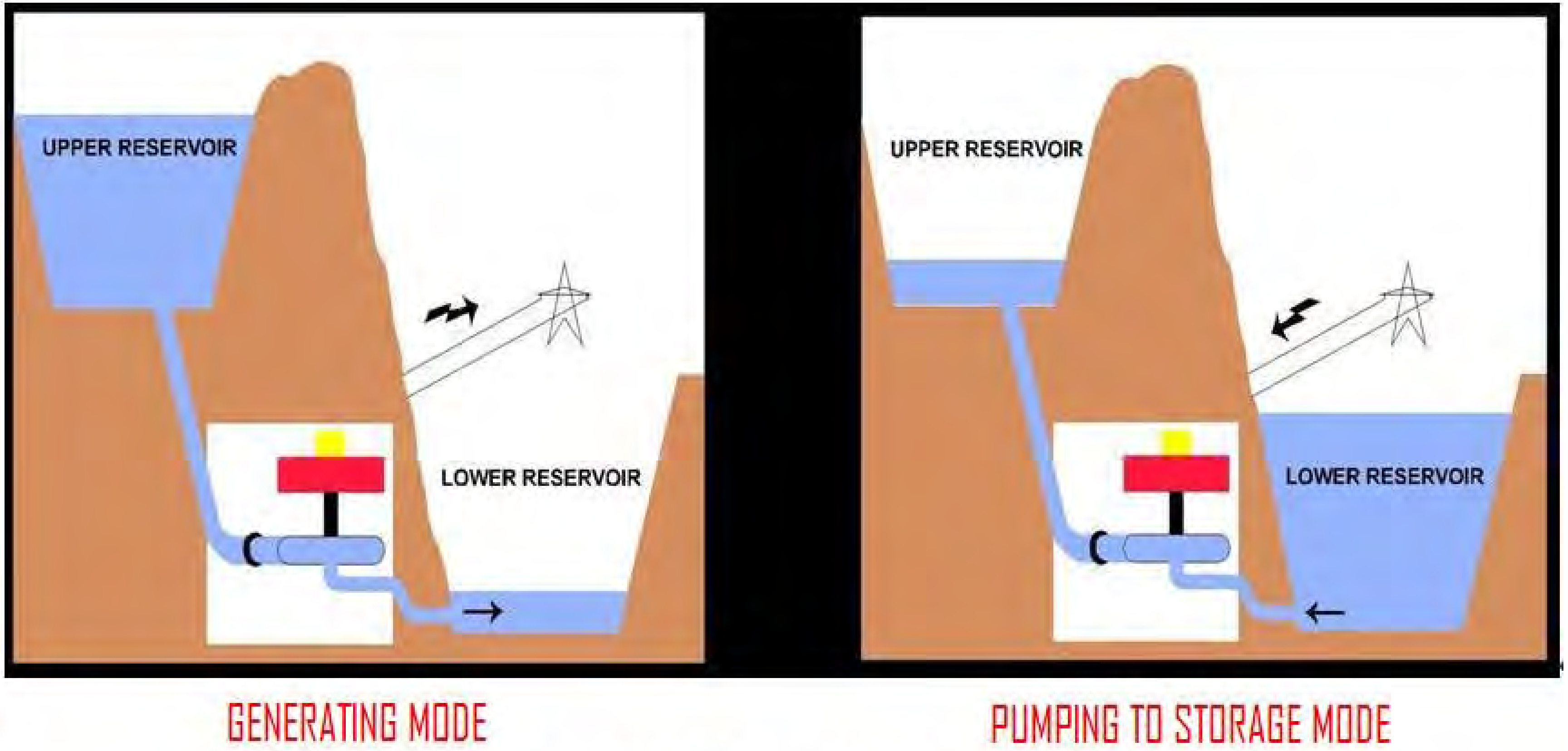
2020: 23.2 GW

2050: 120 GW

Photo credit: MagicBones, London. https://www.picfair.com/pics/09434662-london-england-feb-22-2019-large-pile-of-old-used-corroded-batteries-at-a-uk-recycling-centre

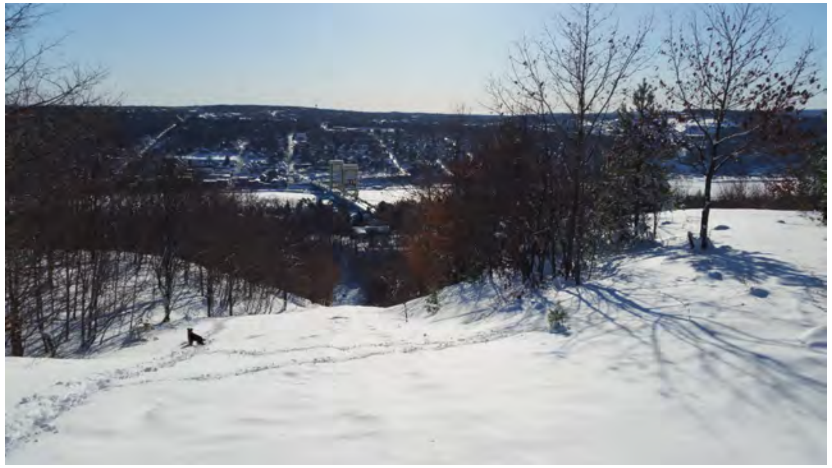
Batteries

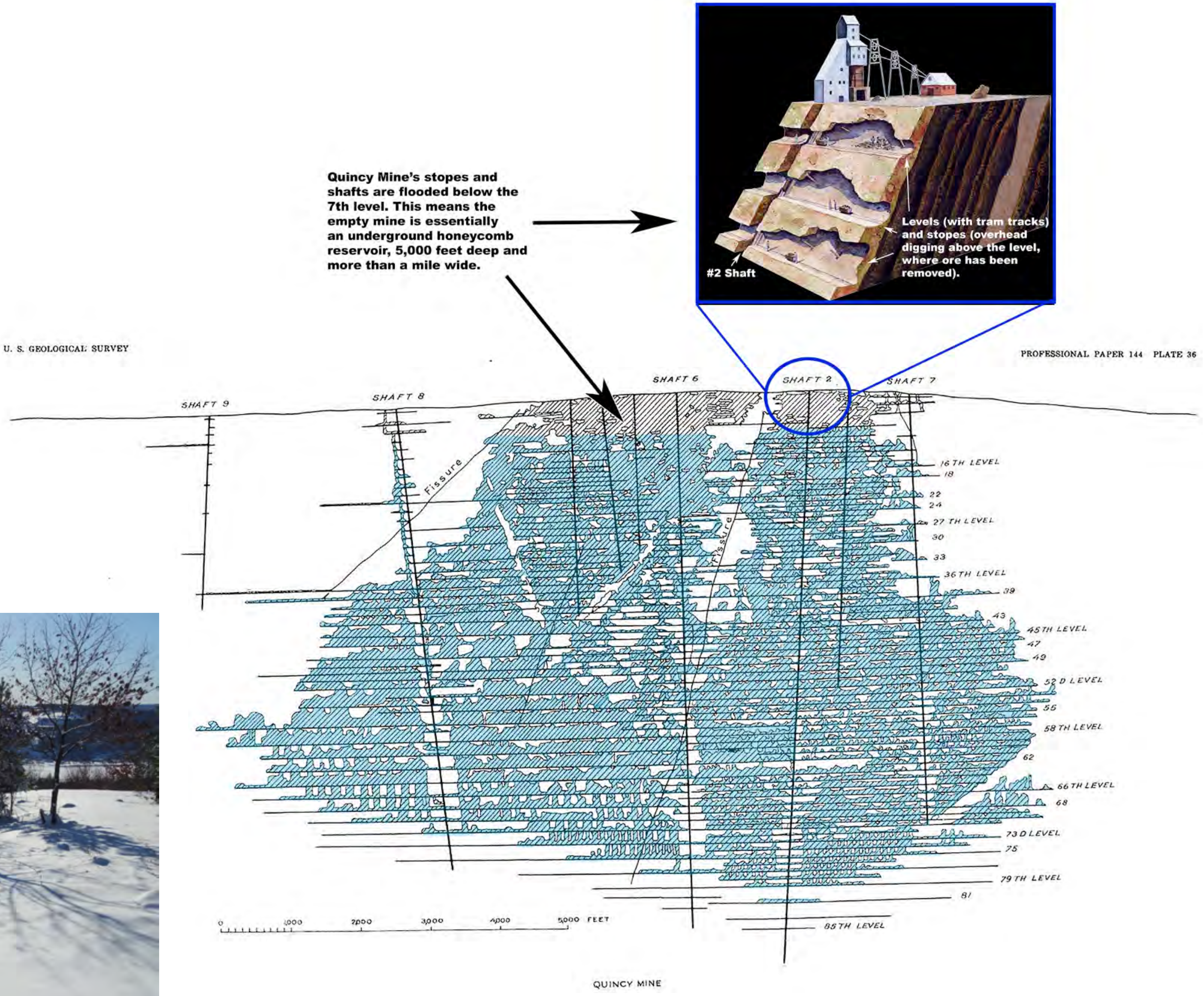
"Regular" Pump Storage Hydropower



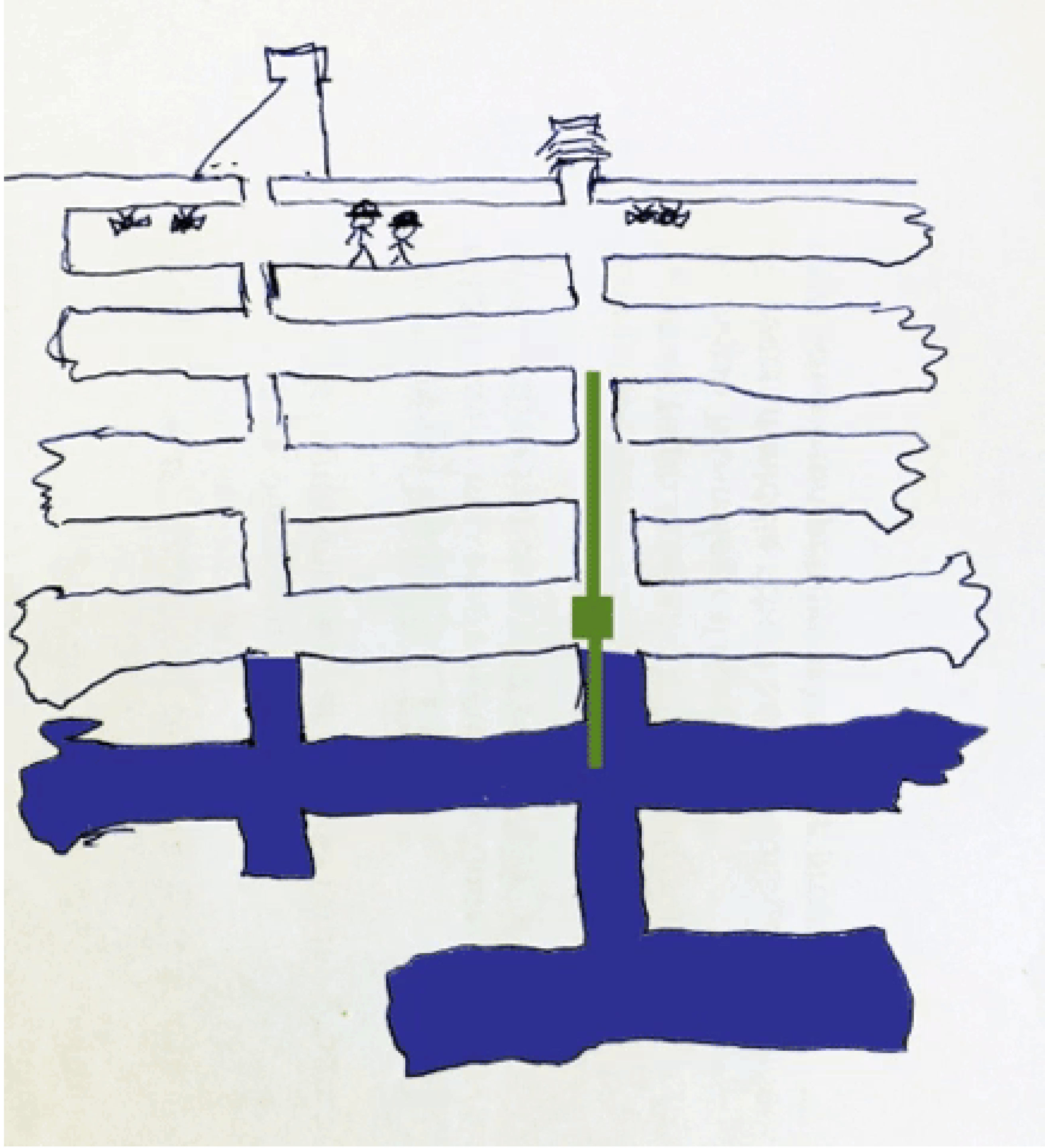
pumped hydro operating principals

PUSH in a nutshell





Credit: Timothy Scarlett, Keweenaw National Historic Park, Dan Johnson - http://www.fhwa.dot.gov/byways/photos/61350, Public Domain, https://commons.wikimedia.org/w/index.php?curid=695316



Liabilities into Assets for Post-Mining Communities in Michigan

COMMUNITY **BURDENED** BY ITS MINING POST-INDUSTRIAL PAST

Barriers/Liabilities	Opportunities/Assets
Environmental (e.g. mine water quality)	Environmental (e.g. mine water quality control)
Policy, Legal, and Regulatory (e.g. brownfield status)	Policy, Legal, and Regulatory (e.g. CERCLA liability exception)
Socio-economic & political (e.g. financial liability)	Socio-economic & political (e.g. tax revenue creation)
Geographic (e.g. remoteness)	Geographic (e.g. DER integration center)
Technological (e.g. lack of local generation)	Technological (e.g. reason to build DERs)

COMMUNITY **THRIVING** BECAUSE OF ITS MINING POST-INDUSTRIAL PAST

Photo credit: UP Panorama, Pasty.com

Research Core Team and project partners

Team members:

- Dr. Roman **Sidortsov** (energy law and policy)
- Ana **Dryson** (modeling, energy, ME-EM)
- Dr. Chelsea **Schelly** (sociology)
- Dr. Timothy Scarlett (archaeology and anthropology)
- Dr. David **Watkins** (water quality, civil and environmental engineering)

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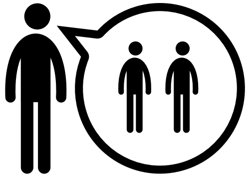

Created by corpus delicti from the Noun Project

Created by Gan Khoon Lay from the Noun Project

- Mr. Joe **Dancy** (energy law and policy)
- Dr. **Qingli** Dai (turbines, environmental engineering)
- Dr. Chee-Wooi **Ten** (grid integration, electrical and computer engineering)
- **Mr. Shardul Tiwari, KETL Fellow**

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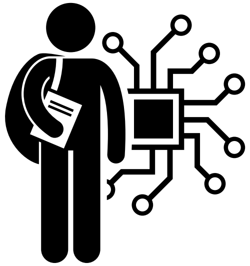

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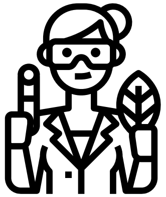

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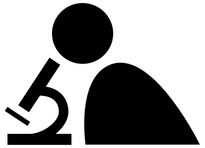

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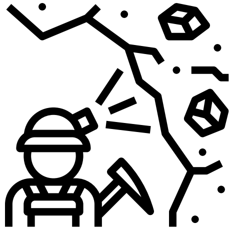

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KETL
Keweenaw Energy Transition Lab
at the Great Lakes Research Center
Michigan Technological University

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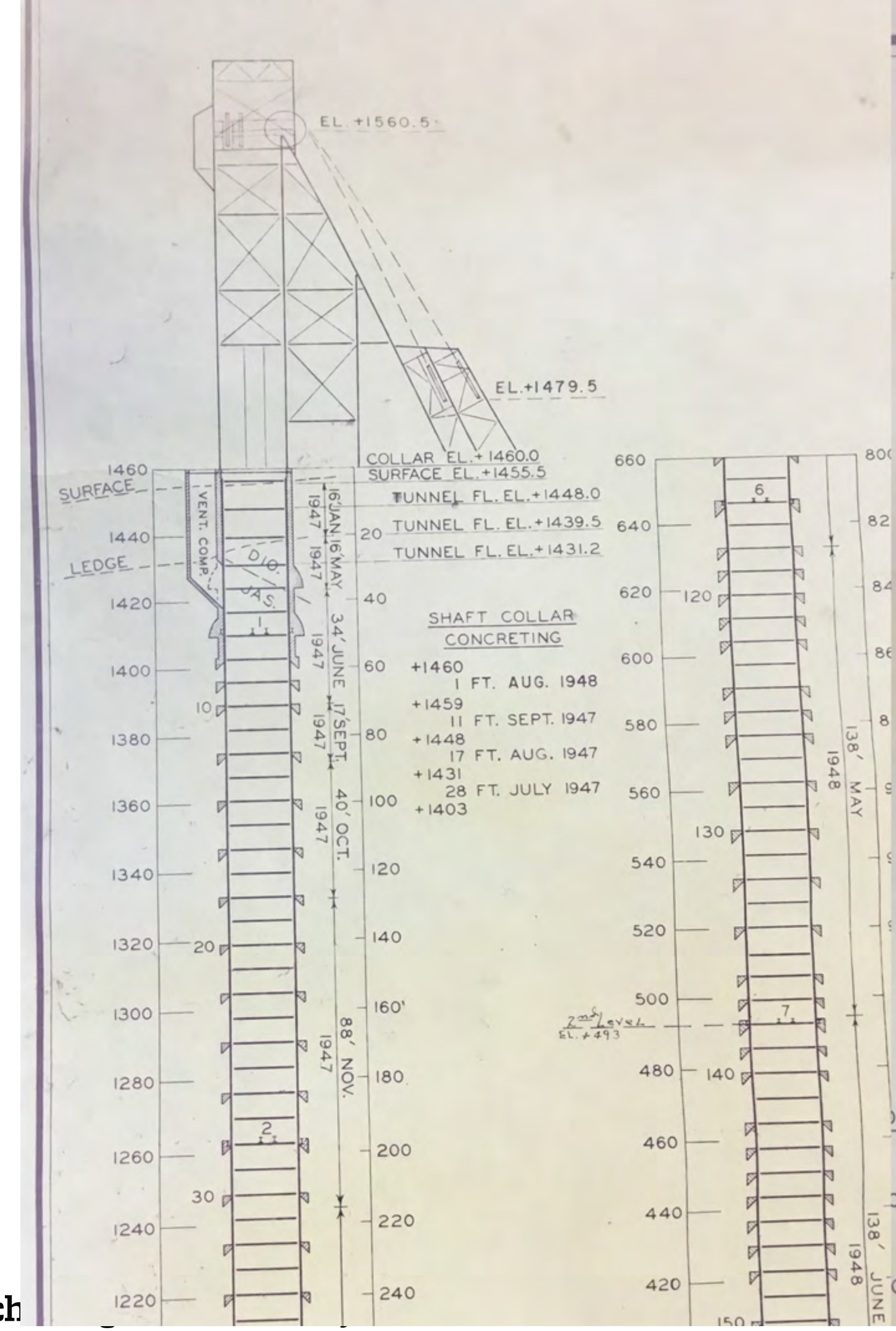
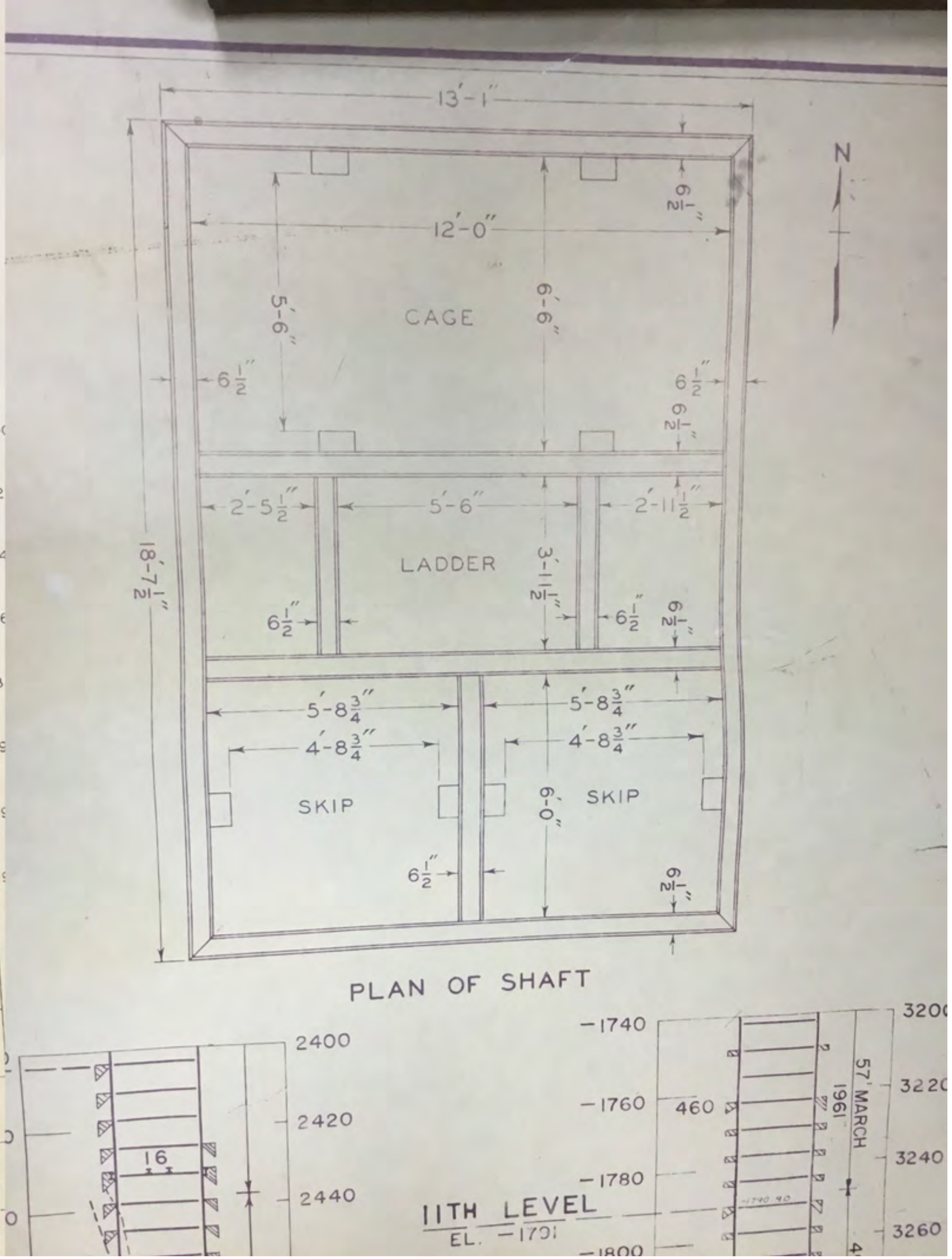
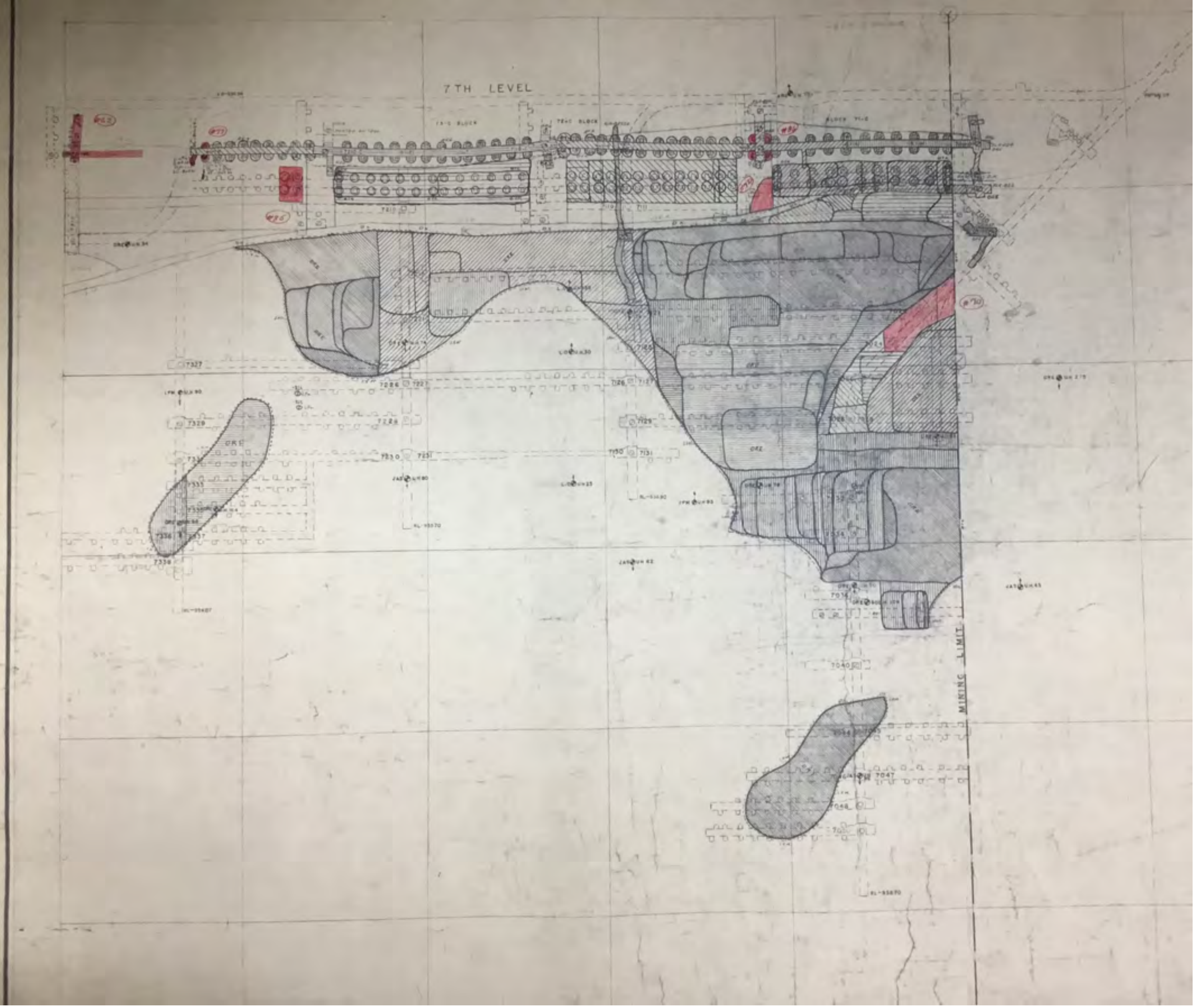
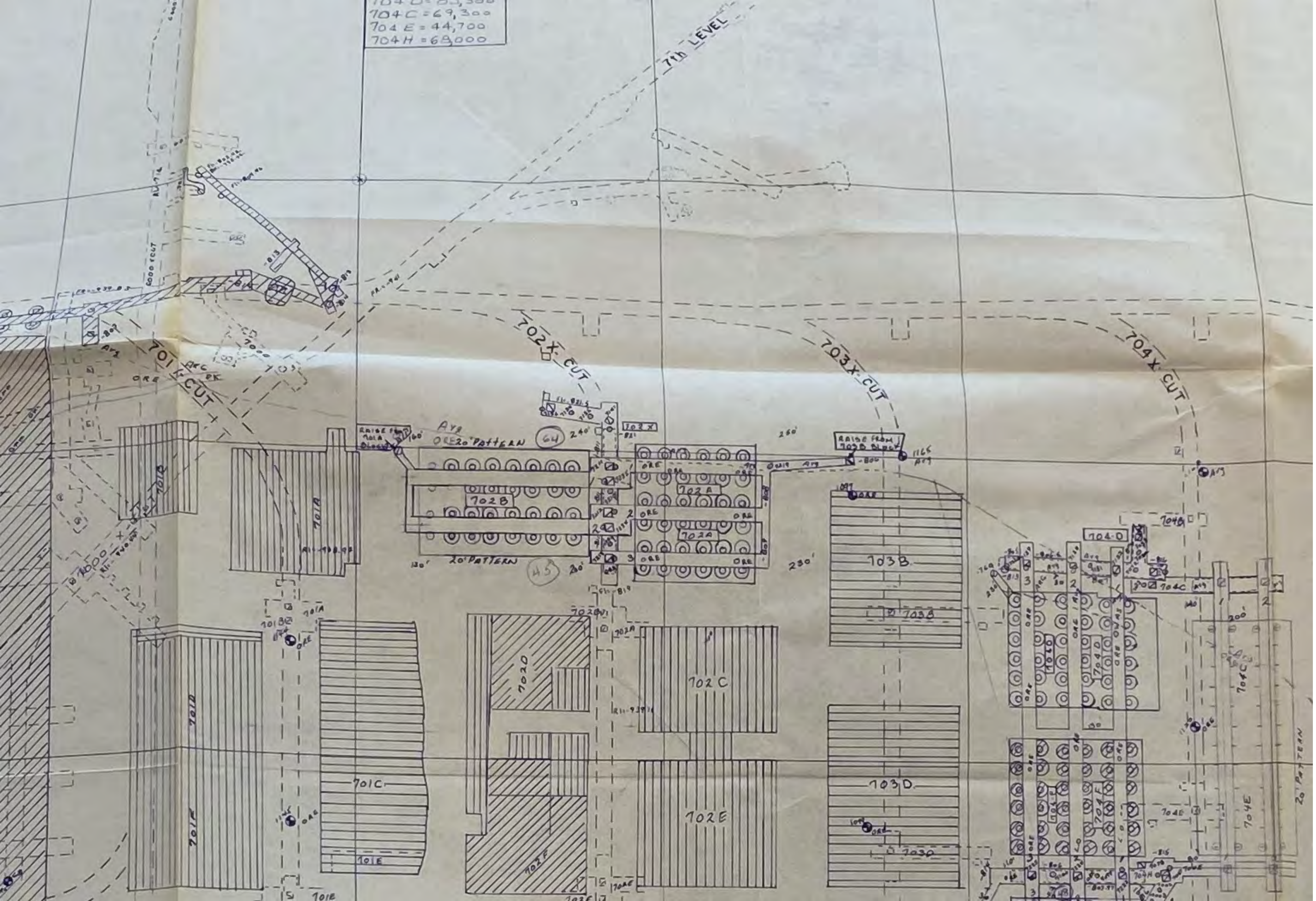
Micl

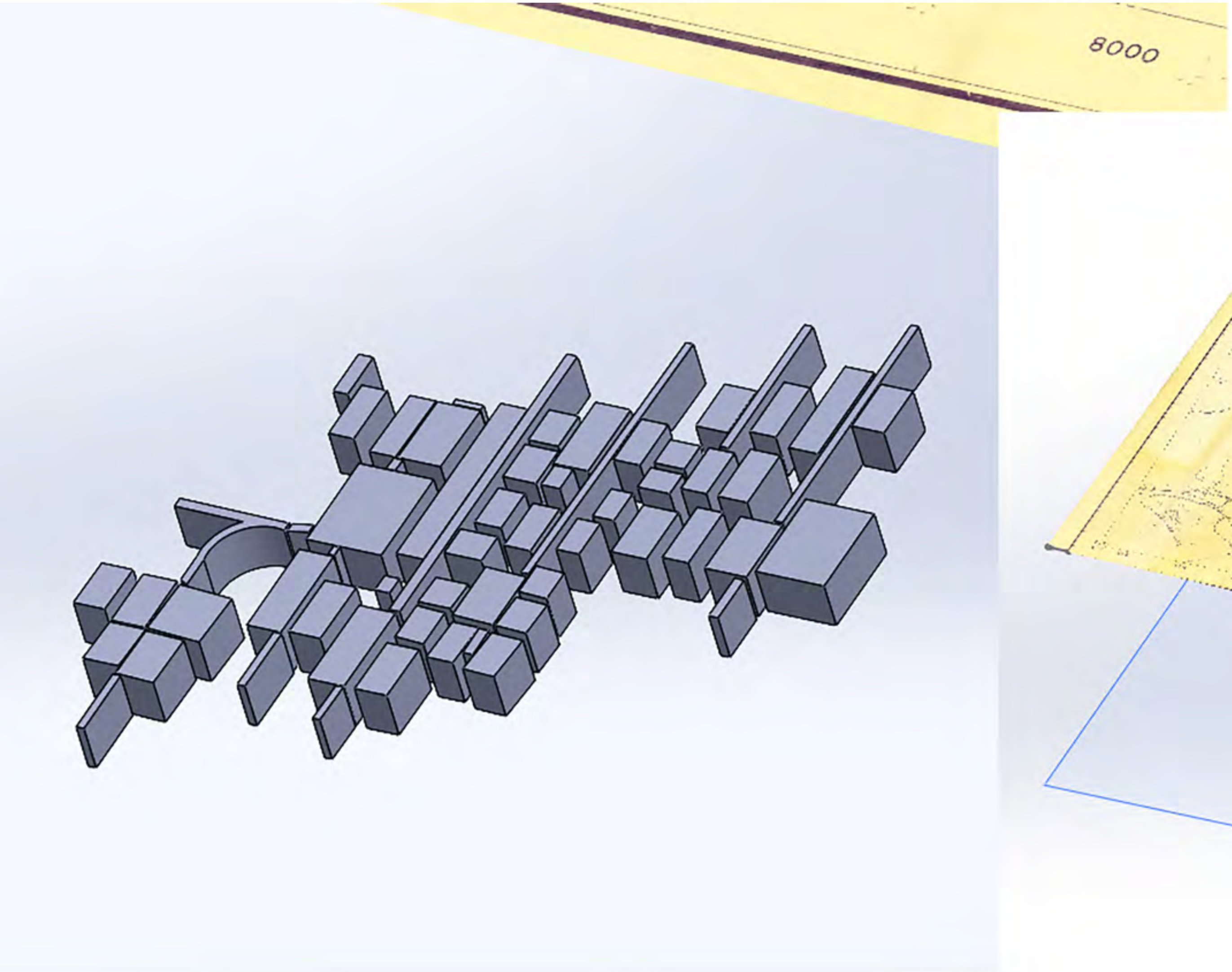
Photo credit: Paul Petosky, GeneologyTrails.com

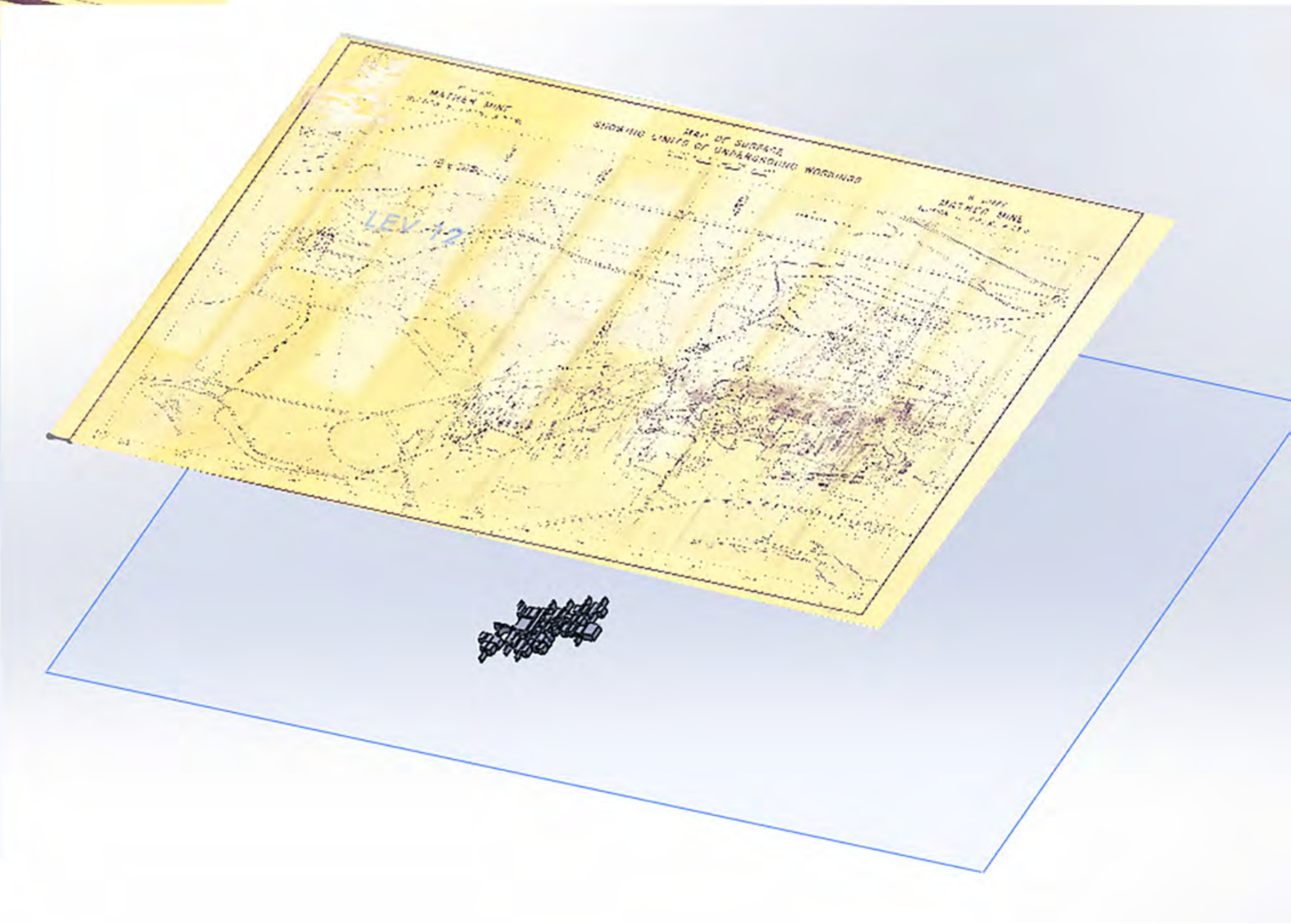

EL.+1560.5
EL.+1479.5
COLLAR EL.+1460.0
SURFACE EL.+1455.5
TUNNEL FL. EL.+1448.0
TUNNEL FL. EL.+1439.5
TUNNEL FL. EL.+1431.2
SURFACE
LEDGE
VENT. COMP.
SHAFT COLLAR
CONCRETING
+1460
1 FT. AUG. 1948
+1459
11 FT. SEPT. 1947
+1448
17 FT. AUG. 1947
+1431
28 FT. JULY 1947
+1403
16' JAN. 1947
16' MAY 1947
34' JUNE 1947
17' SEPT. 1947
40' OCT. 1947
88' NOV. 1947
138' MAY 1948
138' JUNE 1948
2nd Level
EL.+493

13'-1"
12'-0"
CAGE
5'-6"
6'-6"
LADDER
2'-5 1/2"
2'-11 1/2"
3'-11 1/2"
SKIP
SKIP
5'-8 3/4"
4'-8 3/4"
6'-0"
6 1/2"
18'-7 1/2"
N
PLAN OF SHAFT
11TH LEVEL
EL. -1791
57' MARCH 1961

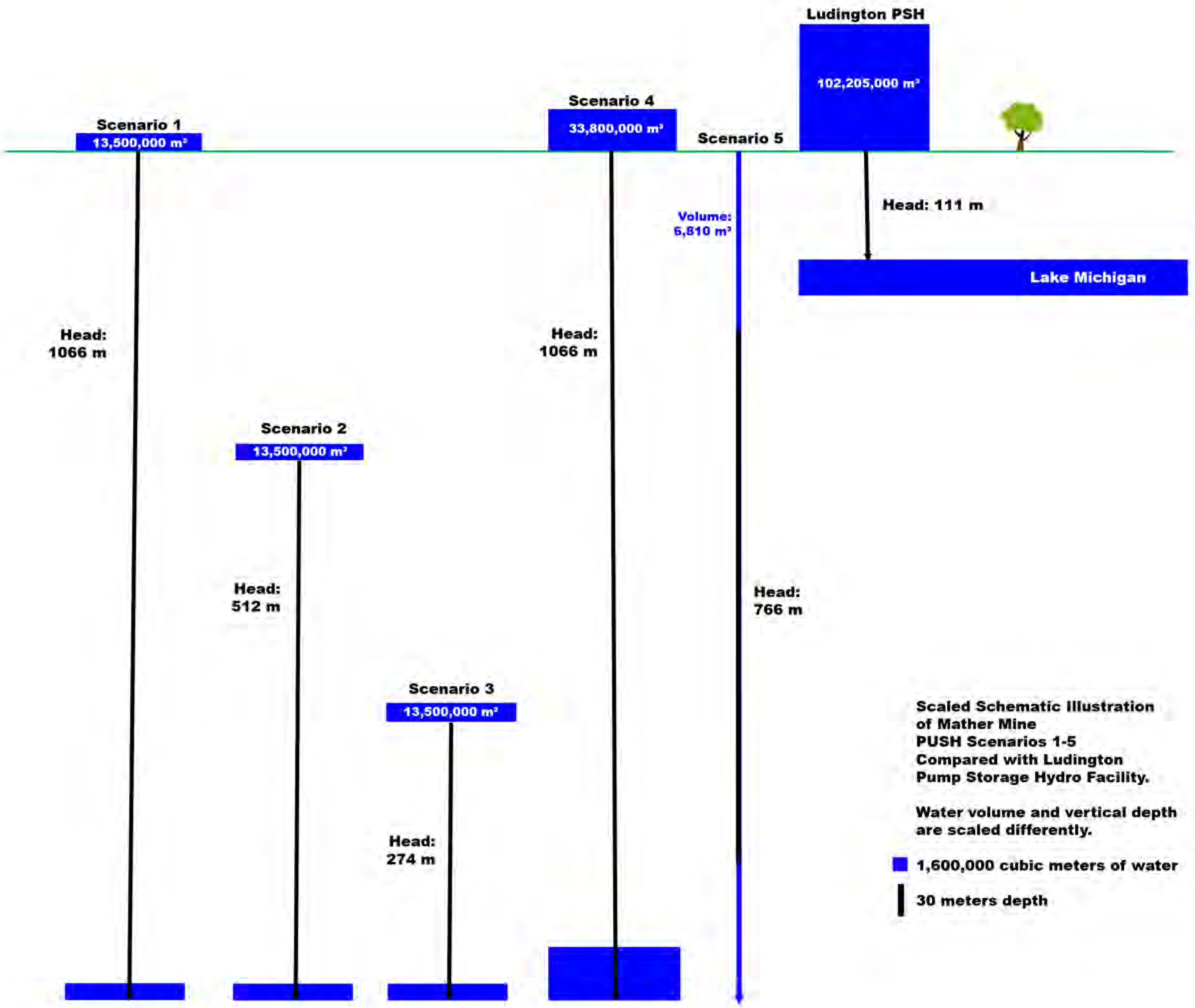

SEVENTH LEVEL
THE CLEVELAND-CLIFFS IRON CO.
MATHER MINE
B SHAFT
-825' SUB LEVEL-CENTER
MINING DEPT. SCALE 1" = 50FT. DATE
2000
2200
7200
7000
6800
MINING LIMIT


7TH LEVEL
MINING LIMIT


704 C = 69,300
704 E = 44,700
704 H = 68,000
7th LEVEL
702 X-CUT
703 X-CUT
704 X-CUT
701 X-CUT
20' PATTERN
702 B
702 A
703 B
704 D
704 C
701 A
701 B
701 C
701 D
701 E
701 F
702 C
702 D
702 E
702 F
703 D
704 E
RAISE FROM 703 B BLOCK
ORE


8000


LEV-12


Ludington PSH
102,205,000 m^3
Scenario 4
33,800,000 m^3
Scenario 1
13,500,000 m^3
Scenario 5
Head: 111 m
Volume: 6,810 m^3
Lake Michigan
Head: 1066 m
Head: 1066 m
Scenario 2
13,500,000 m^3
Head: 512 m
Head: 766 m
Scenario 3
13,500,000 m^3
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
Head: 274 m

Top Hydro Power plants in the World

Rank	Name of Power plant	Generation Capacity (MW)	Type
1	Three Gorges, China	22, 500	Not Pump storage
2	Itaipu, Brazil	14,000	Not Pump storage
3	Xiluodo, China	13,860	Not Pump storage
4	Belo Monte, Brazil	11, 233	Not Pump storage
5	Guri, Venezuela	10,235	Not Pump storage
	PUSH 1 (constrained by shaft size)	**9,824**	**Pump storage**
	PUSH 2 (constrained by shaft size)	**4,912**	**Pump Storage**
1	Bath county (USA)	3,003	Pump storage
5	Ludington Pumped Storage Plant	1,872	Pump storage

Technical Results

Volume: 75600 m^3; flow rate 10m^3/sec per shaft ; pumping time: 7hrs; overall efficiency: 80%						
Scenarios	Gross head (m)	Head Loss(Hf) m	Net head(m)	Penstock Dia (m)	Power (MW)	Energy Generated (MWh)
1.1	1,067	101.07	965.92	1.2*3	**283.98**	**1,605.20**
2.1	610	57.78	552.21	1.2*3	**162.35**	**917.69**
2.2	305	28.89	276.10	1.2*3	**81.18**	**458.84**
3b.1	762	72.18	689.81	1.2*3	**202.81**	**1,146.36**
4b.1	511	48.40	462.59	1.2*3	**136.00**	**768.75**

Table showing the feasibility of daily energy storage under different head scenarios

- Scenarios based on different heads that are possible in the mines
- These scenarios make use of existing shafts that are available with minimum modification

Comparison slide with Ludington

Ludington Power Plant				PUSH in Mather B mine Negaunee			
Total capacity (MW)	Head (m)	Energy Storage (MWh)	Volume of storage (m3)	Total capacity (name plate) (MW)	Head (m)	Energy Storage (MWh)	Available Volume of storage (m3)
2,172 (1,872)	111	752 GWh	102,206,118 (27 billions US gallons)	284	1,067	1,605	25,371,896

- In terms of name plate estimates PUSH in Mather B is around 1/7 in the capacity of Ludington
- We are not considering here the full volume that could be utilized in the mine
- We are only using less than 10% of the volume available in the mine

Technical Results

- 15,960 MWh is the average yearly household electricity consumption in Negaunee
- This is over 3.5 times and 1.5 times the energy storage available in high and low estimate scenario of PUSH
- Total Average yearly electricity consumption of people living in Negaunee city is 59,083 MWh*.
- This 59,083 MWh is roughly equivalent to long term energy storage based on high volume scenarios

Seasonal Storage	UR and LR vol (m3)	Net Head (m)	Flow rate (one pipe) m^3/sec	Gen time (hr)	Power (MW)	Total Power Generation
Scenario 1 (High volume estimate)	25,371,896.3	965.92	10	704.77	75.73	53,371 MWh
Scenario 1 (Low volume estimate)	12,685,948.15	965.92	10	352.38	75.73	26,685 MWh

Table showing the feasibility of seasonal energy storage

* The number is based on average per capita electricity consumption of the US

What would it cost to build?

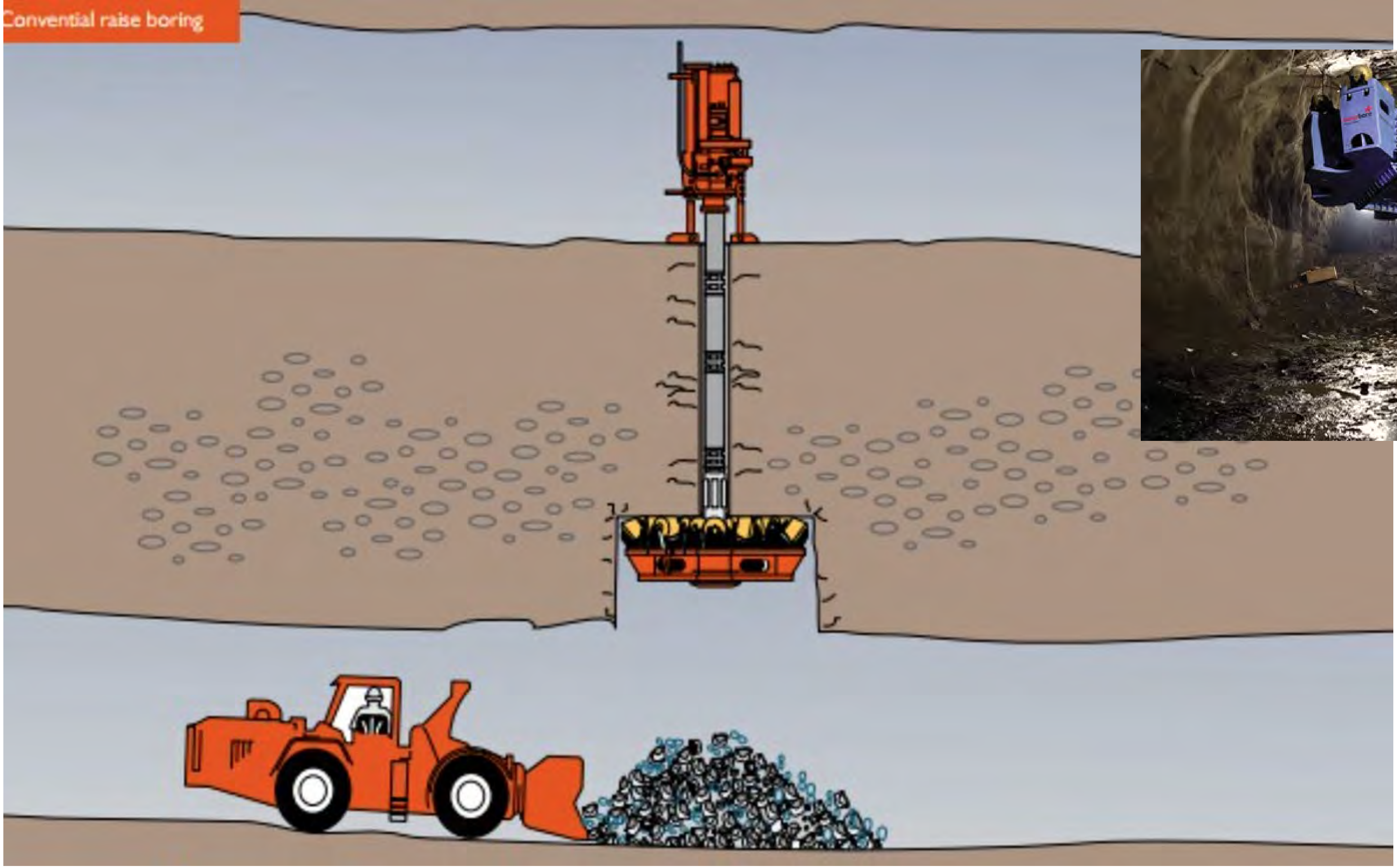


Photo credit: Stowell-Holding.com, Raisebore.com.au

Revenue with Capital Cost: Not promising?

Scenarios	Power (MW)	Energy Generation (MWh)	Annualized Capital Investment ($/yr)	Avg Off peak Price per Mwh	Avg On peak price per Mwh	Total Annual Cost ($)	Revenue Generation ($)	Profit/Loss ($)
1.1	284	561,858	29,783,052.51	17.61	25.74	41,380,778	14,462,237	-27,275,485
2.1	162	320,496	16,988,924.32	17.61	25.74	23,739,538	8,249,586	-15,693,561
2.2	81	160,248	$8,494,462.16	17.61	25.74	12,026,911	4,124,793	-8,003,923
3b.1	203	401,610	21,288,590.35	17.61	25.74	29,668,151	10,337,444	-19,585,847
4b.1	136	269,059	14,262,306.84	17.61	25.74	19,979,929	6,925,578	-13,225,282

Table: Revenue estimate while including the investment and maintenance cost

- We consider the initial incentives and tax credits for the renewable energy storage

Revenue with Capital Cost

- Impact of changing the difference between peak and off peak price
- The difference in peak and off peak price is likely to go up with influx of more renewable energy
- Comprehensive valuation can show us the real value of storage

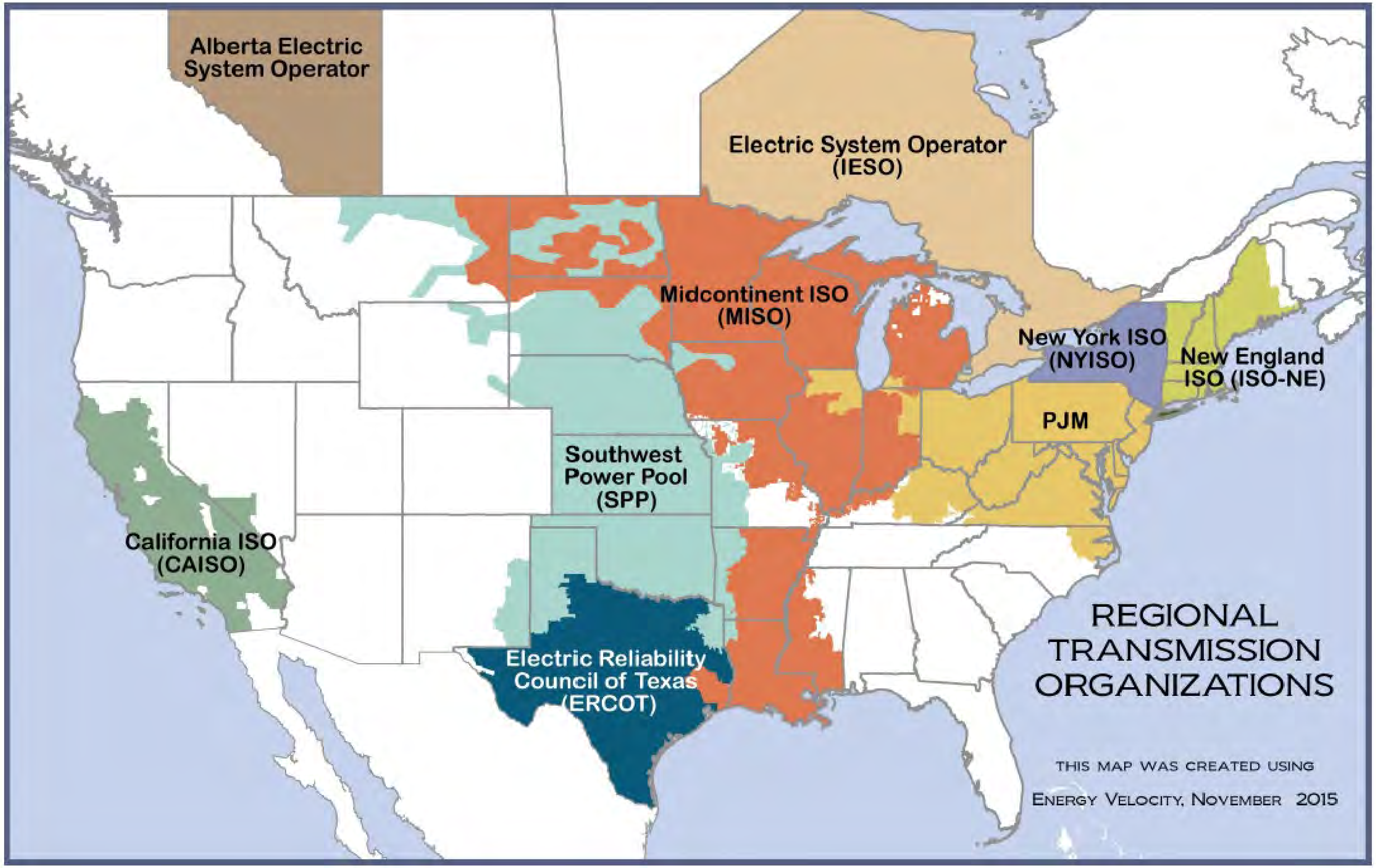
*PVPR is the peak value price ratio

Item	PVPR* 1:2	PVPR 1:3	PVPR 1:4	PVPR 1:5	Unit
Electricity Revenue	$19,788,724	$29,682,984	$39,577,312	$49,471,640	$/Yr
Annual profit	-$21,949,067	-$12,054,739	-$2,160,410	**$7,733,917**	$/Yr
Size of facility	284	284	284	284	MW
Annual stored (produced)	561,858	561,858	561,858	561,858	MWh

Item	PVPR* 1:2	PVPR 1:3	PVPR 1:4	PVPR 1:5	Unit
Electricity Revenue	$5,643,947	$8,465,921	$11,287,895	$14,109,869	$/Yr
Annual profit	-$6,484,768	-$3,662,794	-$840,820	**$1,981,152**	$/Yr
Size of facility	81	81	81	81	MW
Annual stored (produced)	160,248	160,248	160,248	160,248	MWh

Table 6: Annual Revenue estimates with effect of different pricing

RTO/ISO Map



Source: https://www.ferc.gov/industries/electric/indus-act/rto.asp

What are risks of Environmental Impacts? Water Quality?

Mine Water Quality Sampling

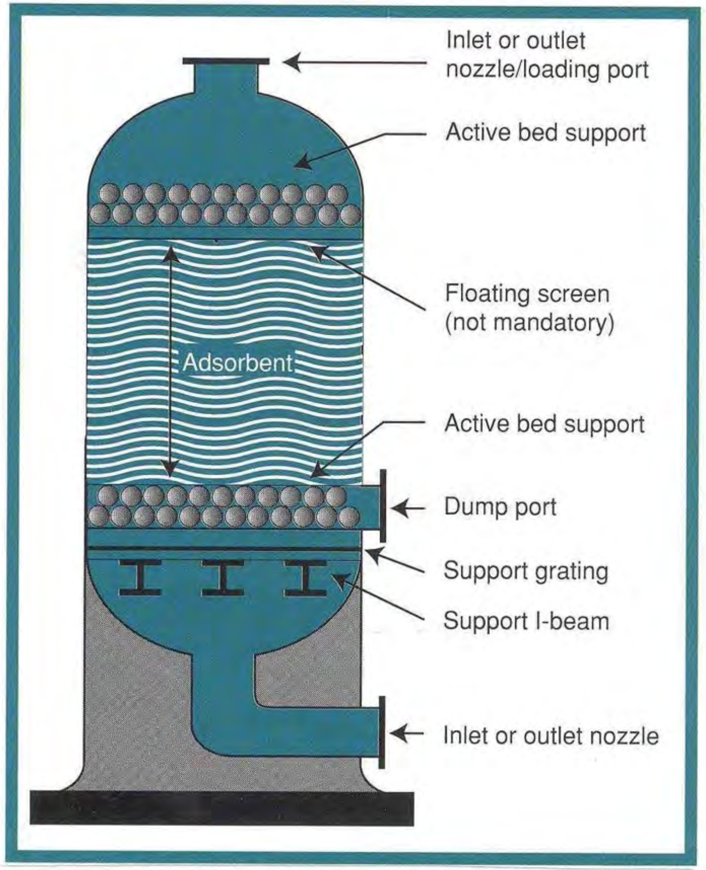
Contaminants of Concern

- Mercury
- Other metals
  - Arsenic
  - Cadmium
  - Copper
  - Lead
  - Lithium
- PCBs

Parameter	Units	Measured Concentration	MDL	
Alkalinity (as $CaCO_3$)	mg/L	110	9.1	
pH	pH units	6.9 - 7.0	0.10	
Arsenic	ug/L	ND	0.91	
Cadmium	ug/L	ND	0.27	
Copper	ug/L	ND	4.3	
Lead	ug/L	ND	0.41	
Lithium	ug/L	17	0.40	910
Mercury (LL)	ng/L	0.48 - 0.62	0.332	1.4
PCBs*	ug/L	ND	0.18 - 0.25	

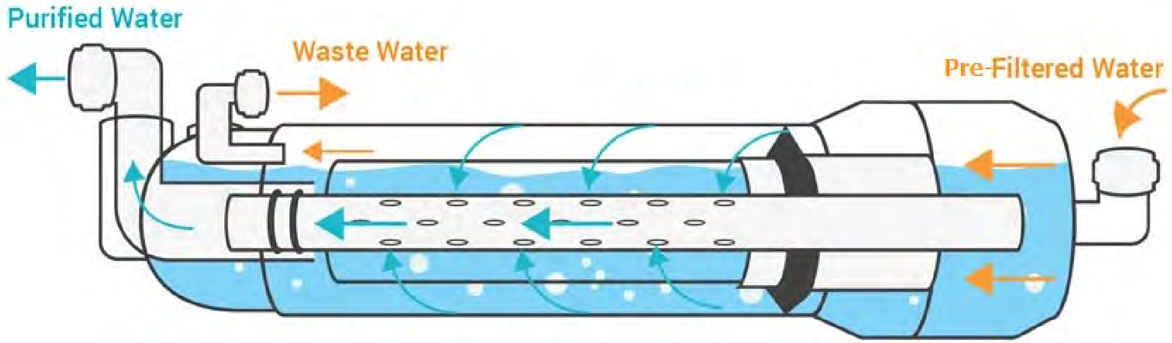
ND = Not Detected, **AMV** = Aquatic Maximum Value (EGLE), **MDL** = Method Detection Limit
*Multiple PCBs were analyzed: 1016, 1221, 1232, 1242, 1248, 1254, 1260

Treatment Methods



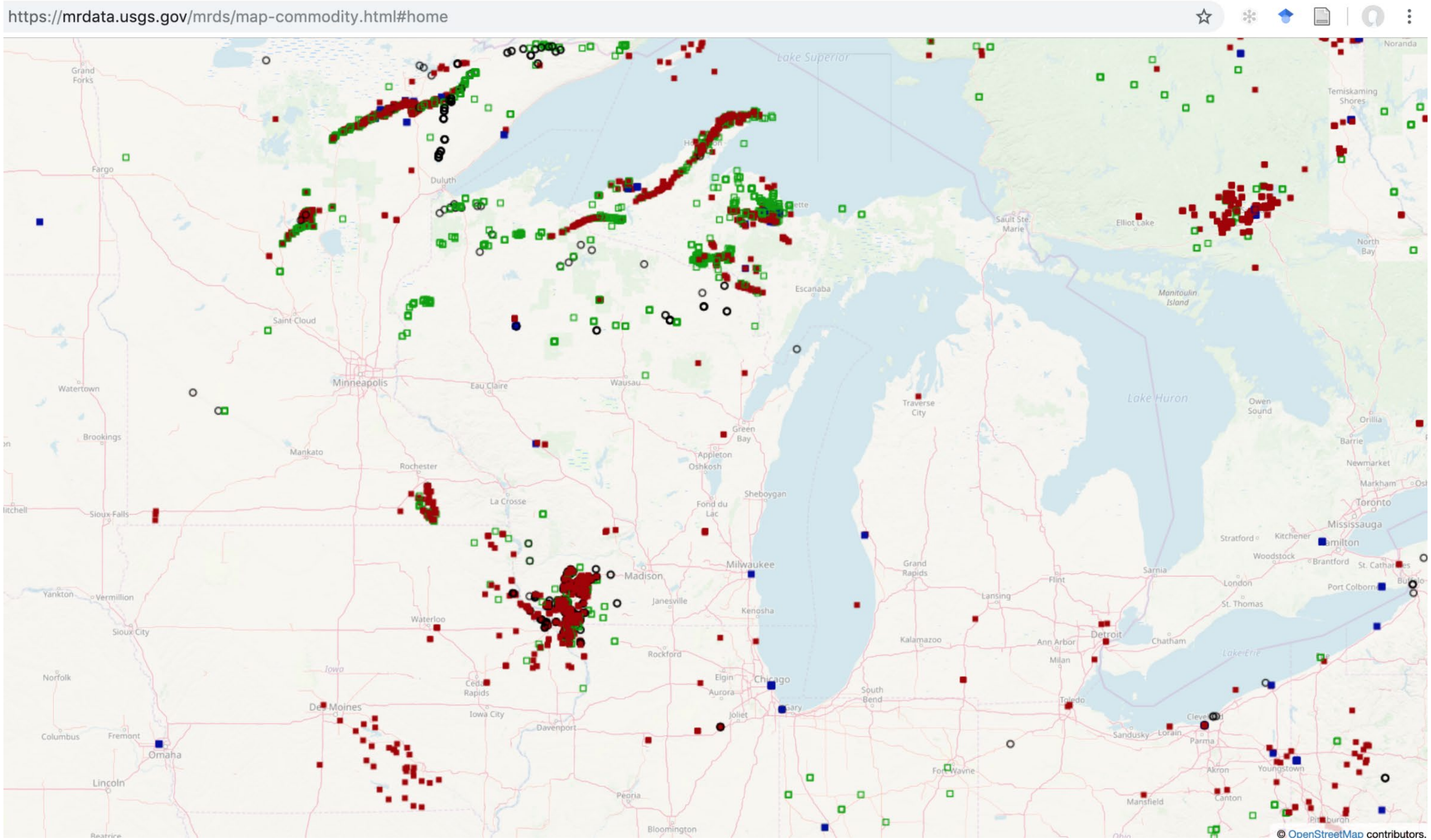
1) Adsorption
(Source: sme-llc.com)

2) Precipitation/co-precipitation (Source: USGS)



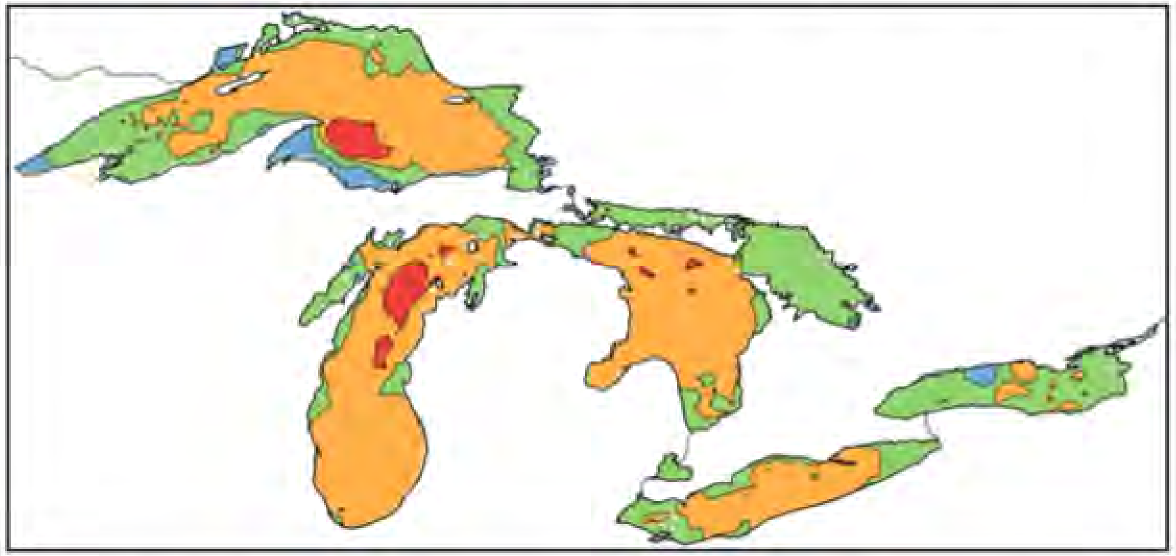
3) Membrane filtration
(Source: maxwaterwholesale.com)

What did the Mather and Negaunee teach us about the state and the national picture?



MSDS Metals Mines only

Wind atlas for the Great Lakes



	10 m		25 m		50 m		90 m		150 m	
	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}
(red)	< 7.5	< 258	< 8.1	< 326	< 8.6	< 390	< 9.0	< 447	< 9.4	< 509
(orange)	< 6.6	< 176	< 7.2	< 229	< 7.6	< 269	< 8.0	< 314	< 8.3	< 350
(green)	< 5.8	< 120	< 6.3	< 153	< 6.7	< 184	< 7.0	< 210	< 7.3	< 238
(blue)	< 5.0	< 077	< 5.4	< 096	< 5.7	< 113	< 6.0	< 132	< 6.2	< 146

Fig. 12. Observationally-derived wind atlas for the Great Lakes as obtained from QuikSCAT, SAR, coastal stations and buoys. Wind atlas is described both in terms of mean wind speed (ms^{-1}) and mean energy density ($0.5\,\rho u^3\ Wm^{-2}$) at five heights (10, 25, 50, 90, 150 m). The mean energy density was calculated assuming the given wind speed as constant. Note that nine-point local smoothing was applied to the plot. The classes and coloring conventions used are as in the European Wind Atlas (Troen & Petersen, 1989). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Doubrawa, P., Barthelmie, R.J. Hasager, C.B., Badger, M., Karagali, I. and Pryor, S.C. 2015: Satellite winds as a tool for offshore wind energy resource assessment: The Great Lakes Wind Atlas, *Remote Sensing of the Environment*, **168**, 349-359.



STEAM HOIST →

LIFE IN MICHIGAN

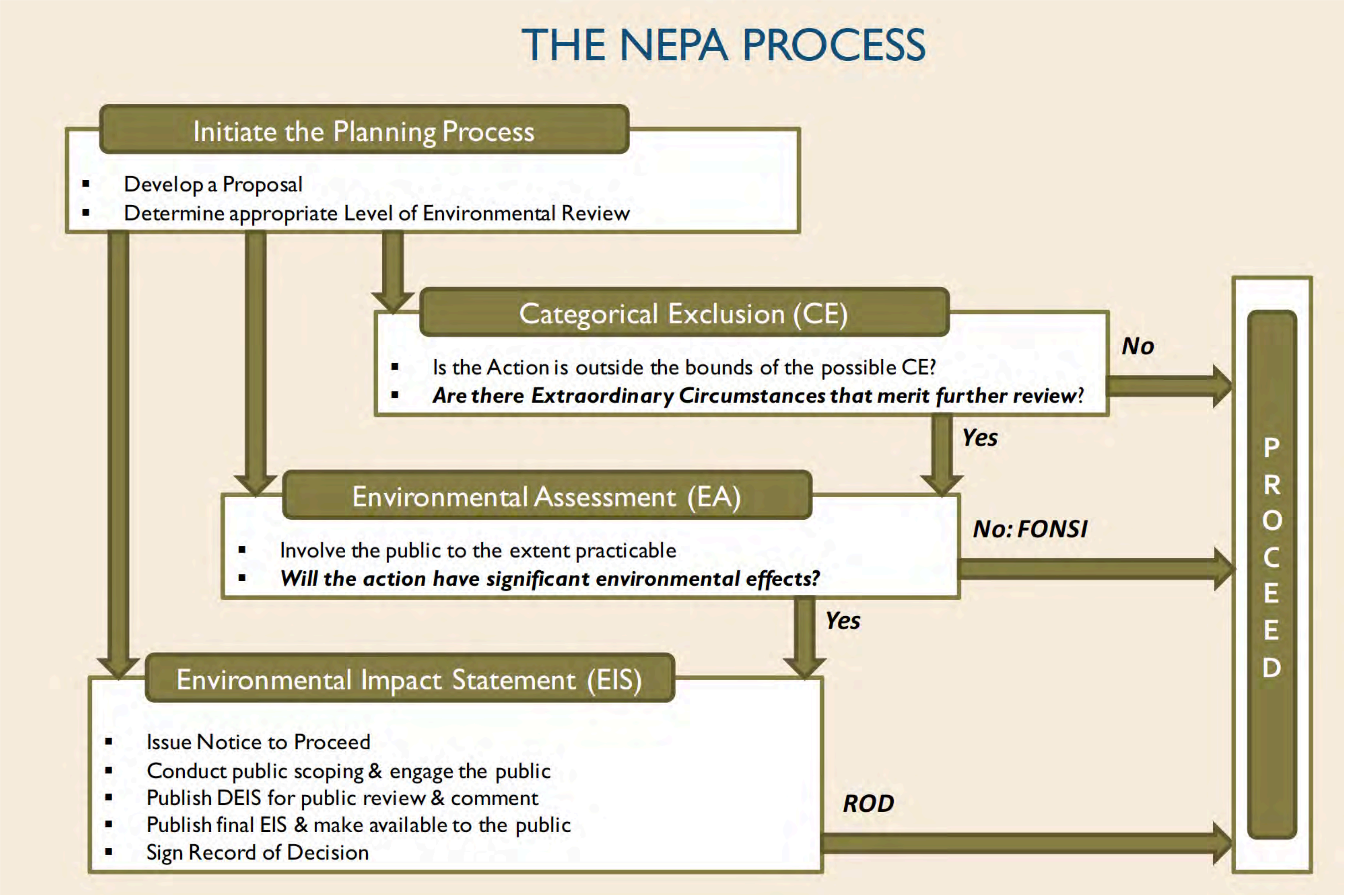

Keweenaw
Heritage Site

Photo credit: KNHP Web

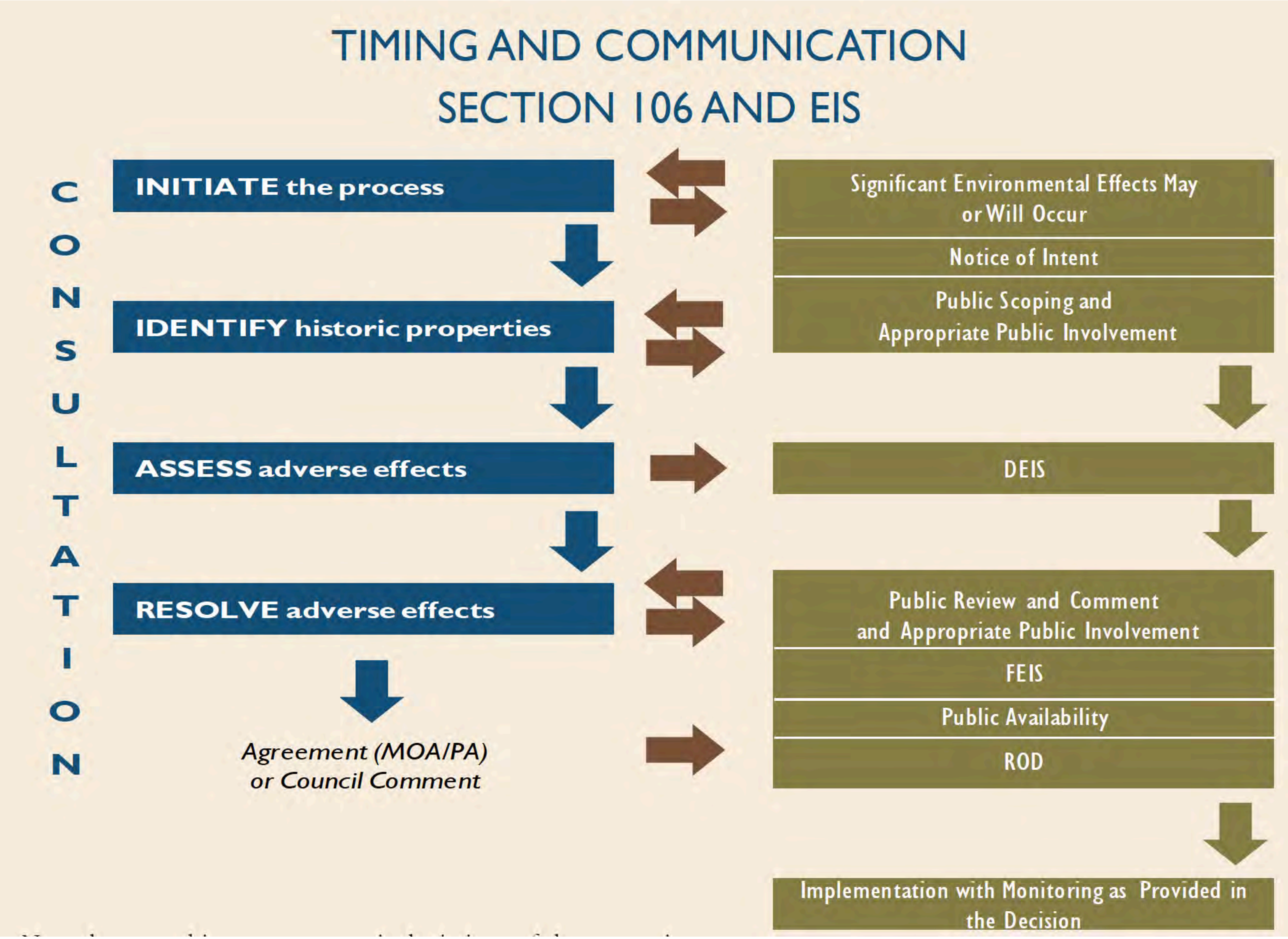
Calumet

Electronics Corporation

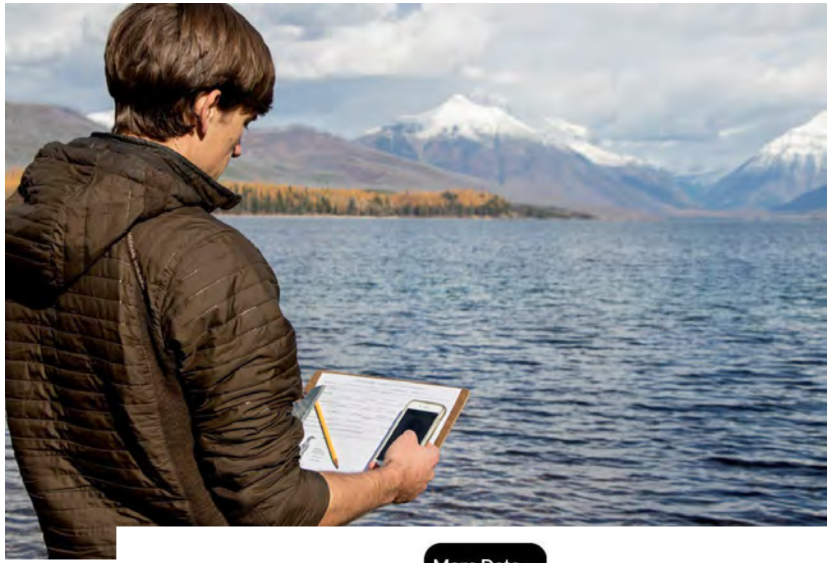
1885

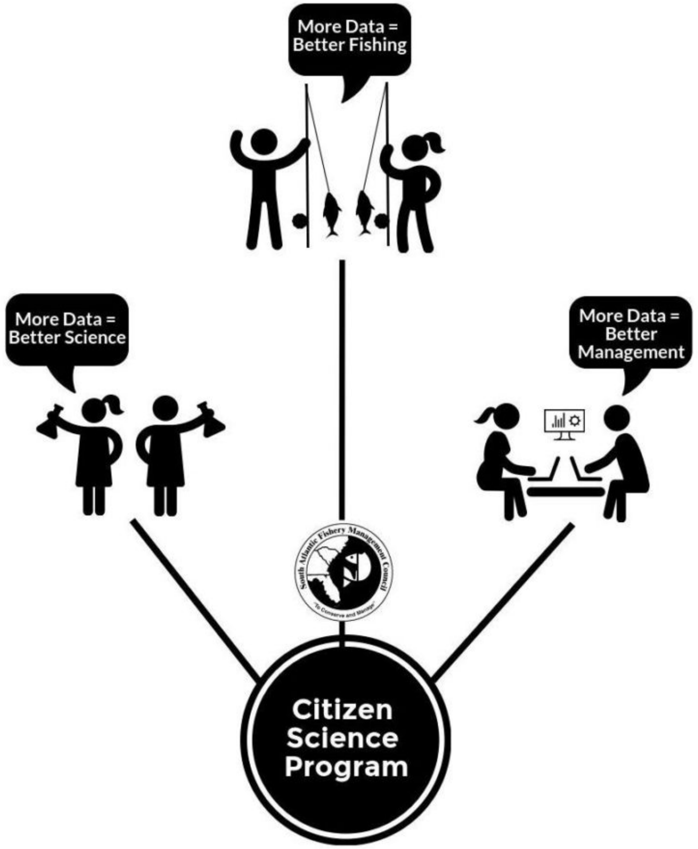


Credit: Council on Environmental Quality Executive Office of the President and Advisory Council on Historic Preservation (2013)



Credit: Council on Environmental Quality Executive Office of the President and Advisory Council on Historic Preservation (2013)




More Data = Better Fishing
More Data = Better Science
More Data = Better Management
Citizen Science Program


Verizon
10:23 PM
79 %
Blogger
BlogPress
PLoS
Citizen Science
Galaxy Zoo
Natur...ebook
CreekWatch
Project Noah
Counter
Observer
Roadkill
WildLab Bird
Redwoods
Tempe...Blast
Instant Wild
Starmap

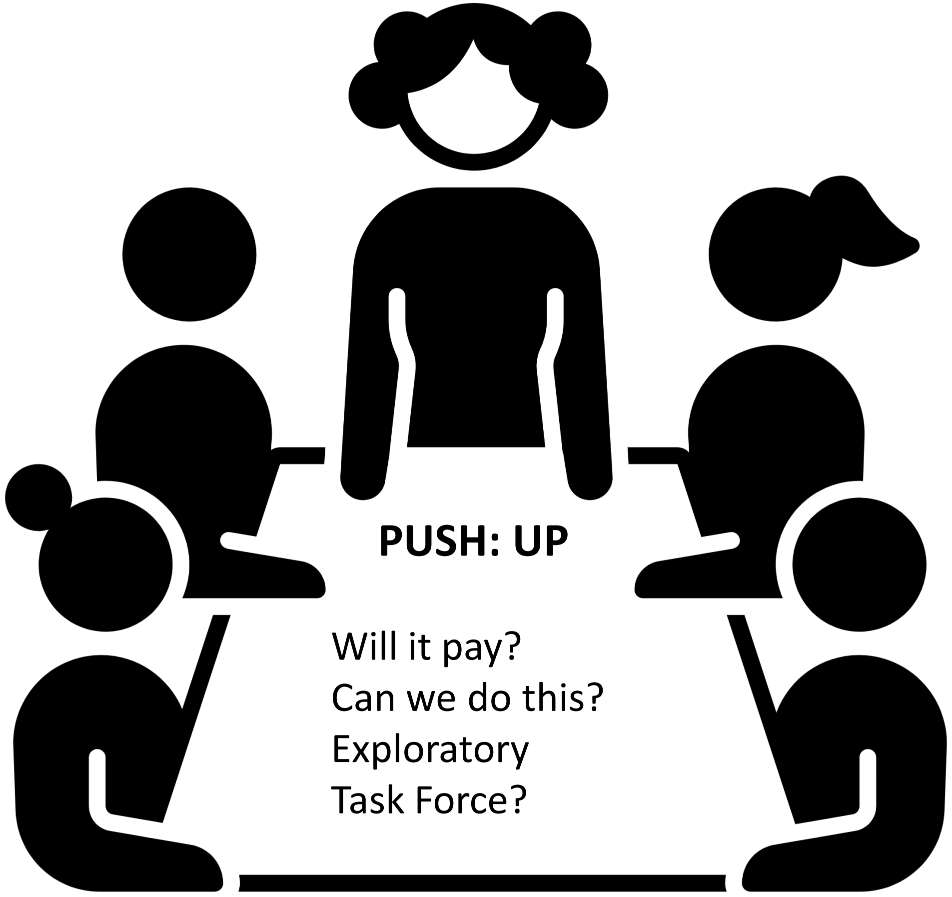

crowd water
WATER LEVEL
STATISTICS
WEEK
MONTH
QUATER
YEAR
currently open Spot
Tabs for Comments and Update Grid
Statistics panel tab
Time range switch
Observation data points
various time ranges
active time range

__Secure and Resilient Energy Grid__
Homeland Security

CERCLA
Brownfields
Clean Water Act
__Environmental Remediation__

__Historic Preservation__
Tax Credits
Transferable Development Rights
Block Grants
Cultural Programs
Media

__Economic Development__
Rural Development
Grants and Loans
Small Business Startup



__Education and Job Training__
Vocational/Artisanal Skills
STEM Jobs

TheNounProject.com/

Secure and Resilient Energy Grid
Homeland Security
Defense

CERCLA
Brownfields
Clean Water Act
Environmental Remediation

Historic Preservation
Tax Credits
Transferable Development Rights
Block Grants
Cultural Programs
Media

Economic Development
Rural Development
Grants and Loans
Small Business Startup

PUSH: UP

Will it pay?
Can we do this?
Exploratory Task Force?

Education and Job Training
Vocational/Artisanal Skills
STEM Jobs

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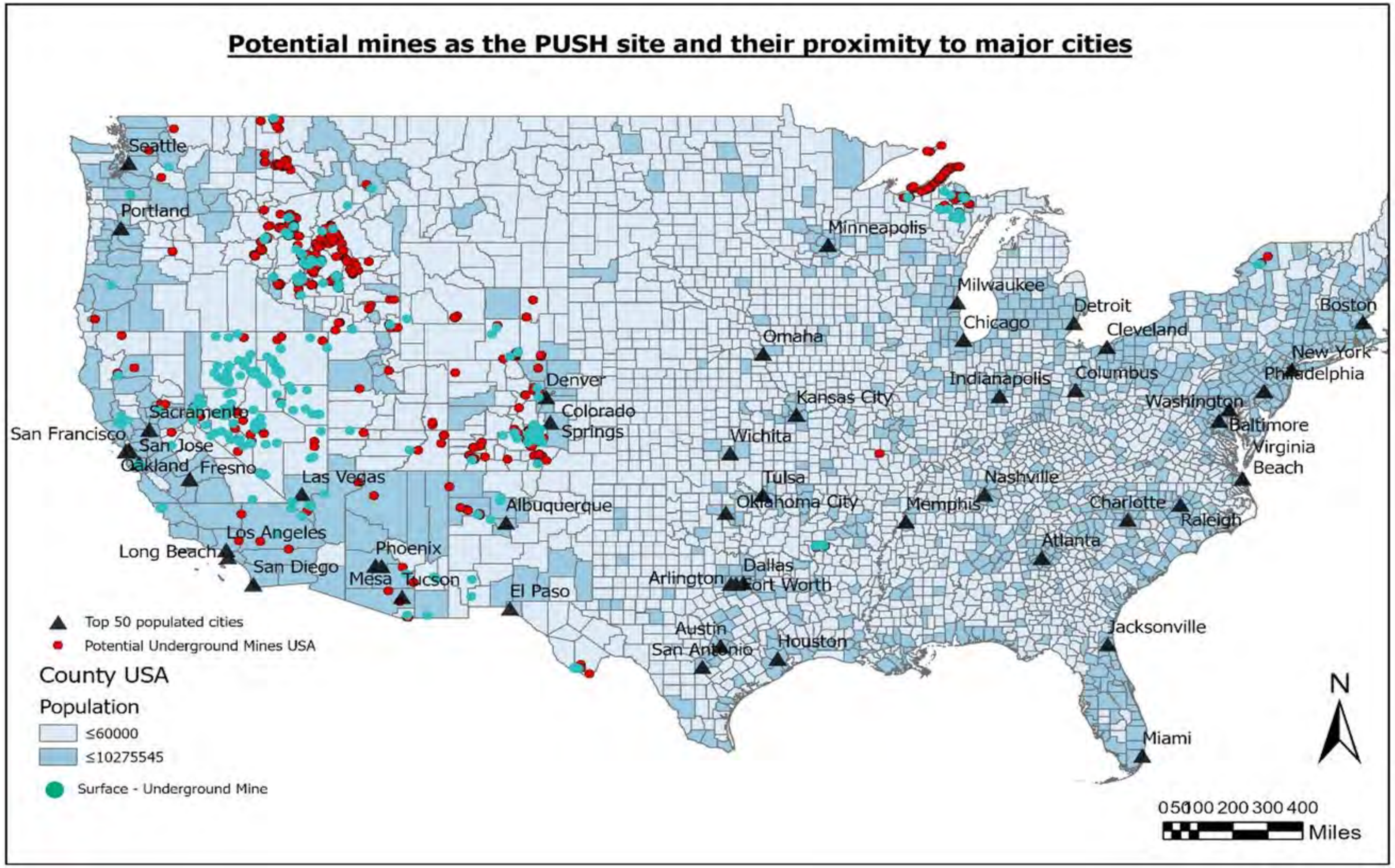
Potential PUSH site location with solar map

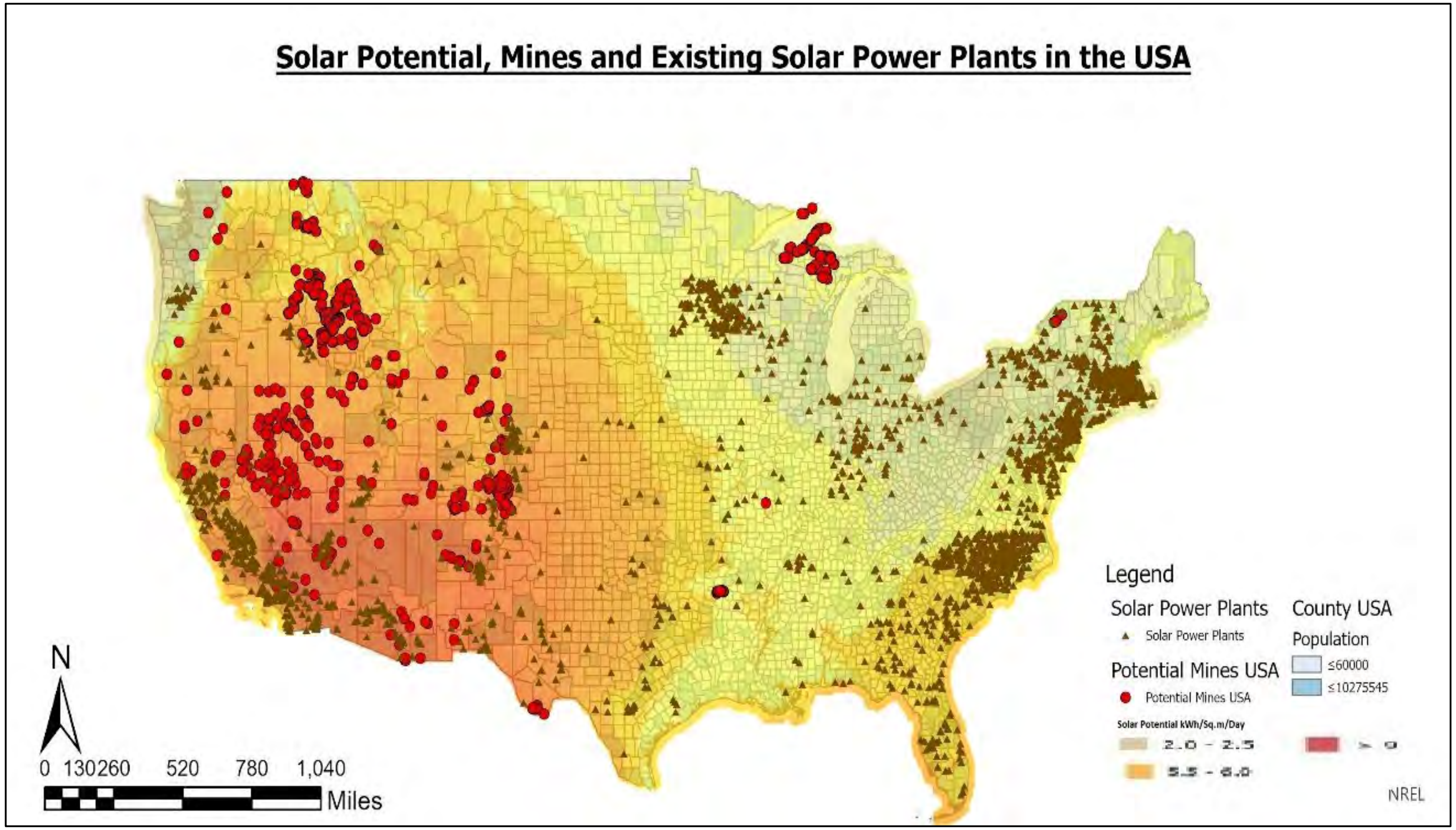
- Total 968 mines identified as feasible mines for PUSH development
- 873 mines are past producing mines and 95 are currently operational
- 706 mines are completely underground and 262 are semi – underground mines
- Marquette county have the most mines feasible for PUSH in a county with over 60,000 people



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

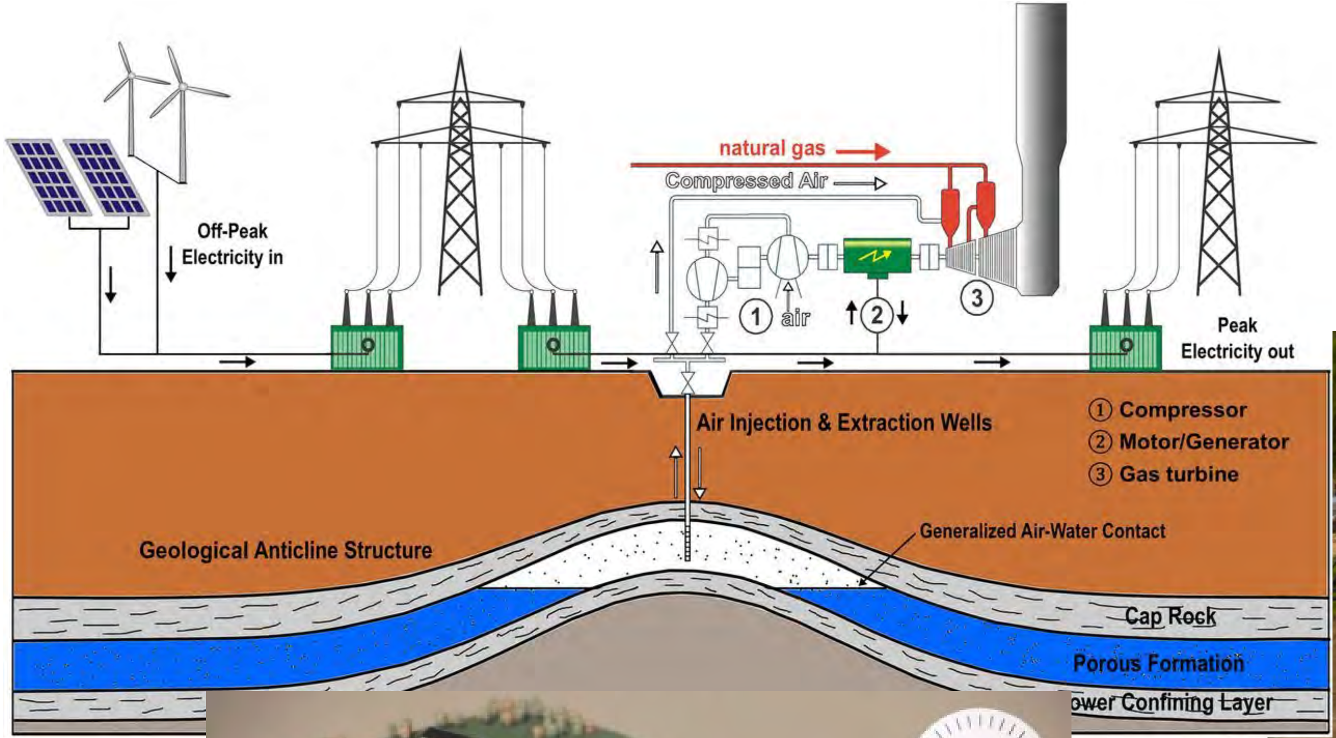
Potential PUSH site location

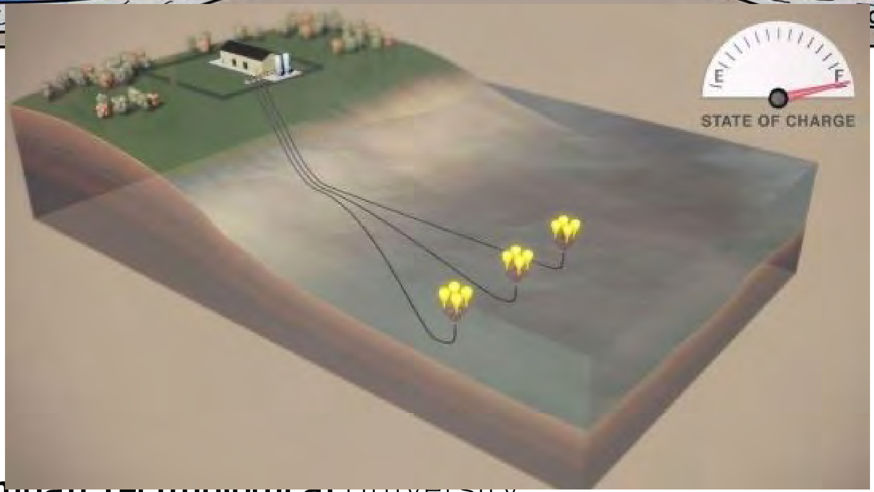
- The base map is the solar potential map of the USA
- Most mines are located in UP, west coast of the US and western United States
- There are potential mines in 15 state of the US
- Up does not have solar potential however limited solar power plants



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

Not only PUSH: Other maturing tech systems:





Compressed air storage

Photo credit: Hydrostor , diagram, Wikipedia.

Not only PUSH: Other maturing tech systems:

Binary cycle geothermal generation
("low-differential thermal")

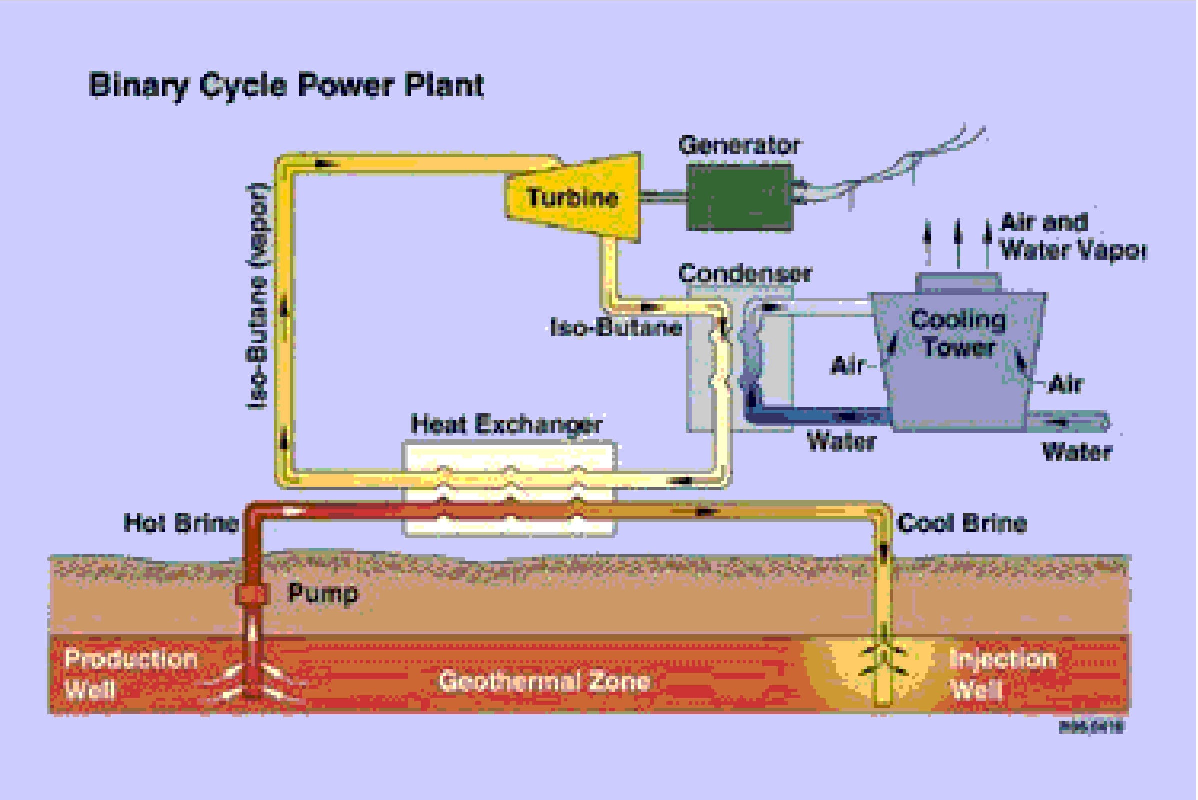
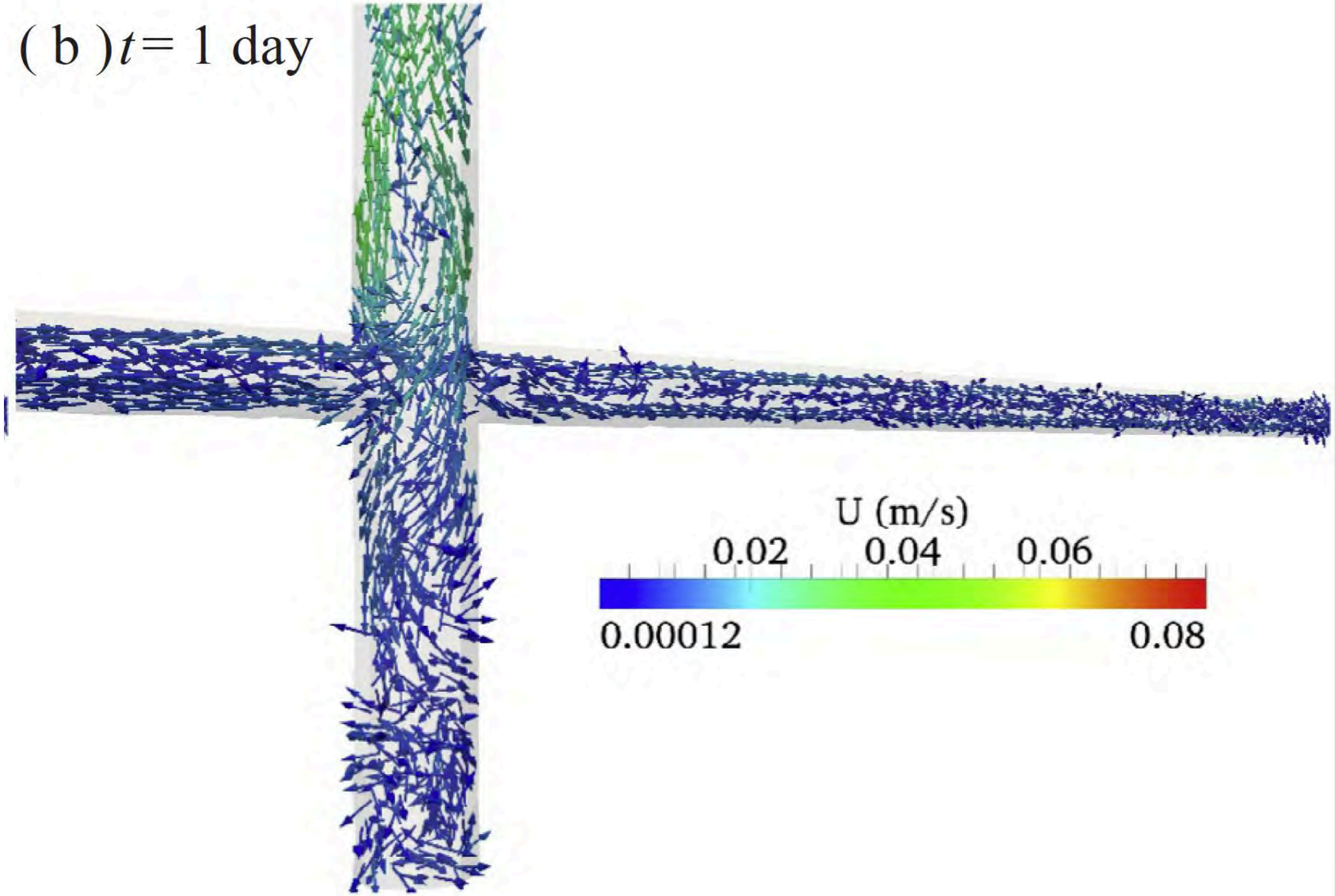


Photo credit: Enel's Salts Wells Geothermal Plant, NV ,

Not only PUSH: Other maturing tech systems:



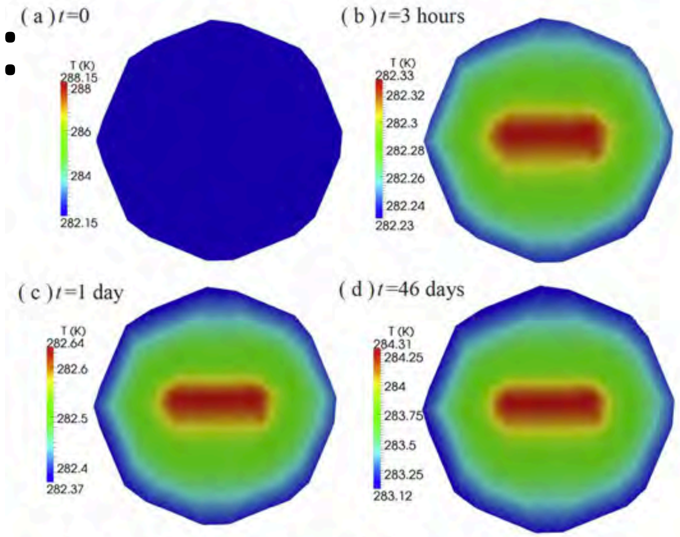
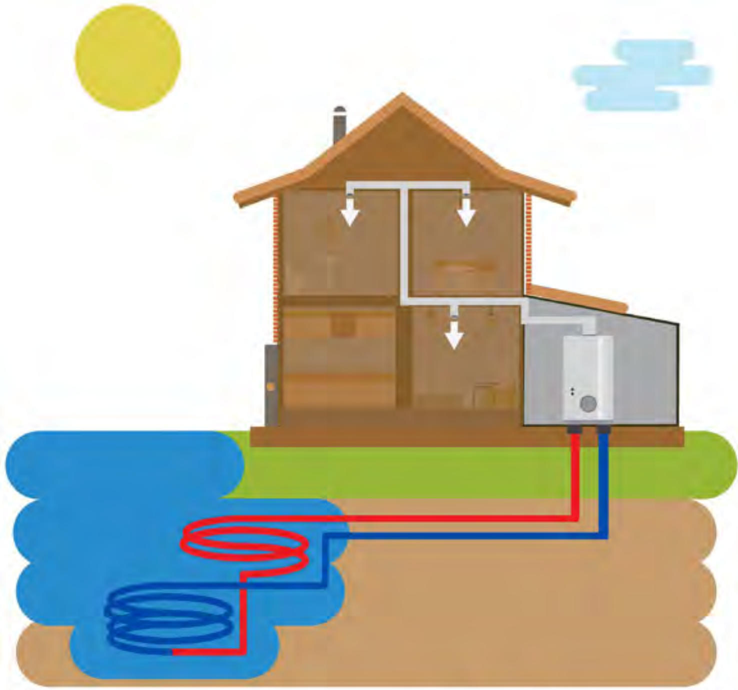


Fig. 10. Temperature contours in cross-sections at the top of the water body at different times.



Geothermal HVAC, Michigan Tech Research

Thank you!

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