ECONOMIC EVALUATION OF GEOMECHANICAL-BASED LONG-DURATION ENERGY STORAGE: A CASE STUDY IN PERMIAN BASIN

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LONG DURATION ENERGY STORAGE (LDES)

- DOE defines LDES as storage systems capable of delivering electricity for 10 or more hours in duration, which enables renewable energy to power our grids and accelerate carbon neutrality.
- Traditional energy storage systems are often limited to short durations (hours). LDES technologies are designed to store energy over much longer periods - making them especially useful for seasonal energy storage.
- The US grid may need 225-460 Gigawatts LDES capacity by 2060 to achieve a carbon net-zero economy, representing $330B cumulative capital, per DOE report in 2023.
- Key benefits: Renewable Energy Integration, Grid Stability and Energy Security (2021 Texas Freeze)

https://liftoff.energy.gov/wp-content/uploads/2023/03/20230320-Liftoff-LDES-vPUB.pdf

ECONOMIC YARDSTICK AND FEASIBILITY FOR LDES

- Levelized cost of storage (LCOS)—Cost of the LDES system measured in $ per MWh.
- Derived by accounting for all costs incurred and the total energy discharged throughout the storage system’s lifetime, ***accounting for charging costs** as they are related to grid prices and efficiency.
- LCOS is a **metric to benchmark** the relative price of energy storage technologies over useful lives.

https://liftoff.energy.gov/wp-content/uploads/2023/05/Pathways-to-Commercial-Liftoff-LDES-May-5_UPDATED.pdf

INVESTMENT TAX CREDIT (ITC)

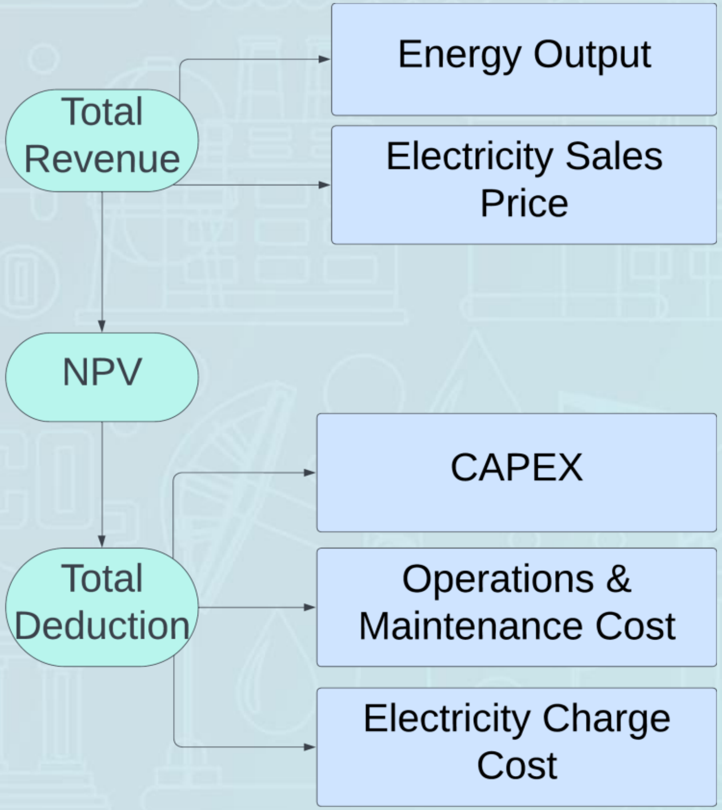
- The Inflation Reduction Act (IRA) significantly improves the economics for large-scale energy storage projects in the U.S.
- Standalone storage systems will be eligible for a 30% Investment Tax Credit (ITC) — and up to 70% with additional incentives.
- Full 30% rate for wide range of energy storage technologies, with certain exceptions.
- New Section 48E applies ITC to Energy Storage Technology through at least 2033.

https://www.epa.gov/green-power-markets/summary-inflation-reduction-act-provisions-related-renewable-energy

HOW TO CALCULATE LCOS

LCOS can be calculated when sum of future net income (NPV) is 0:

$$\text{NPV} = \text{Total Revenue} - \text{Total Deduction} = 0$$



$$\text{Total Revenue} = \text{Energy Output} * \text{Electricity Sales Price}$$

$$\text{Total Deduction} = \text{CAPEX} + \text{O\&M} + \text{ECC}$$

https://www.pnnl.gov/lcos-estimates

ECONOMICS MODEL-LCOS

We assume constant annual energy output and electricity sale price:

$$\text{NPV} = \text{Total Revenue} - \text{Total Deduction} = 0$$

$$\text{NPV} = \sum_{k=0}^{n} (\text{Energy Output} * \text{Sales Price}) - \sum_{k=0}^{n} (\text{CAPEX} + \text{O\&M} + \text{ECC})$$

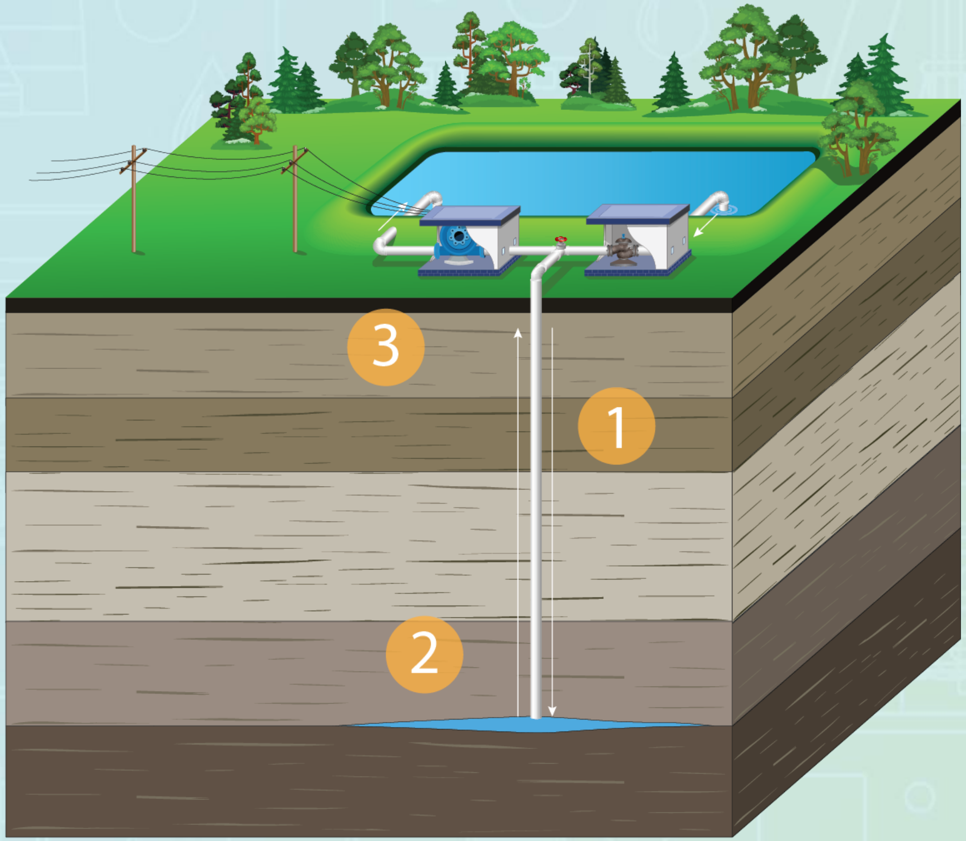
$$\text{LCOS} = \frac{\text{Total Deduction}}{\text{Total energy output}} = \frac{\sum_{k=0}^{n} (\text{CAPEX} + \text{O\&M} + \text{ECC})}{\text{Annual energy output} * \text{project life}}$$

- Project life *n* is assumed to be 20 years.
- Discount factor (~10%) is usually accounted in economics model.
- Inflation factor (~3%, commonly used in utility industry) is usually accounted in cost estimation.
- Note that this model doesn't include financing issues, tax payment, future replacement or degradation costs, etc.

https://www.pnnl.gov/lcos-estimates

CASE STUDY - “TOM” ENERGY

- This case study is based on an energy storage project evaluated in 2022 with synthetic data and economic inputs.
- We assumed the operator is an operator and produce massive flare gas.
- Geomechanical Pumped Storage by “Tom” Energy



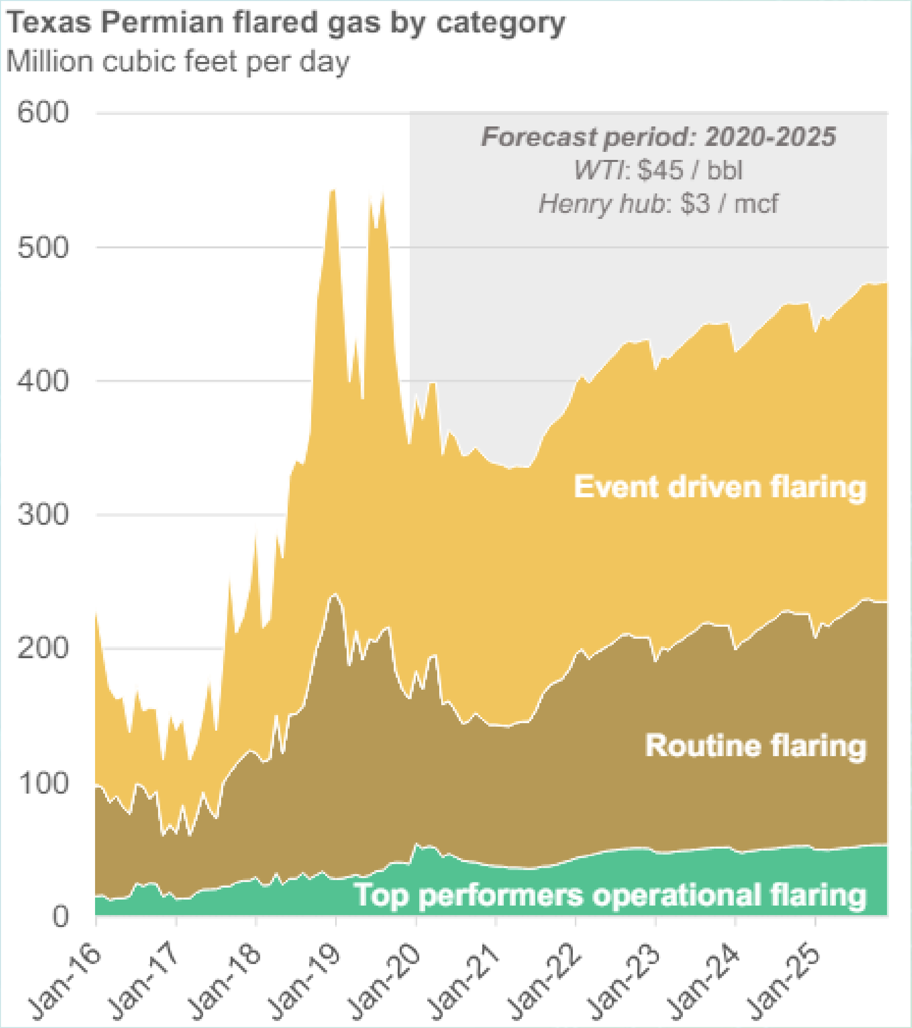
APPLICATION POTENTIAL IN PERMIAN BASIN

Wastewater:

- Largest volume of oilfield water produced among all US onshore regions, Permian Basin wastewater production at ~11 million barrels per day.
- Rising cost of injecting wastewater underground, ~5 billion barrels of water to inject underground per year.
- Disposal and treatment costs for wastewater over $1.00/barrel.

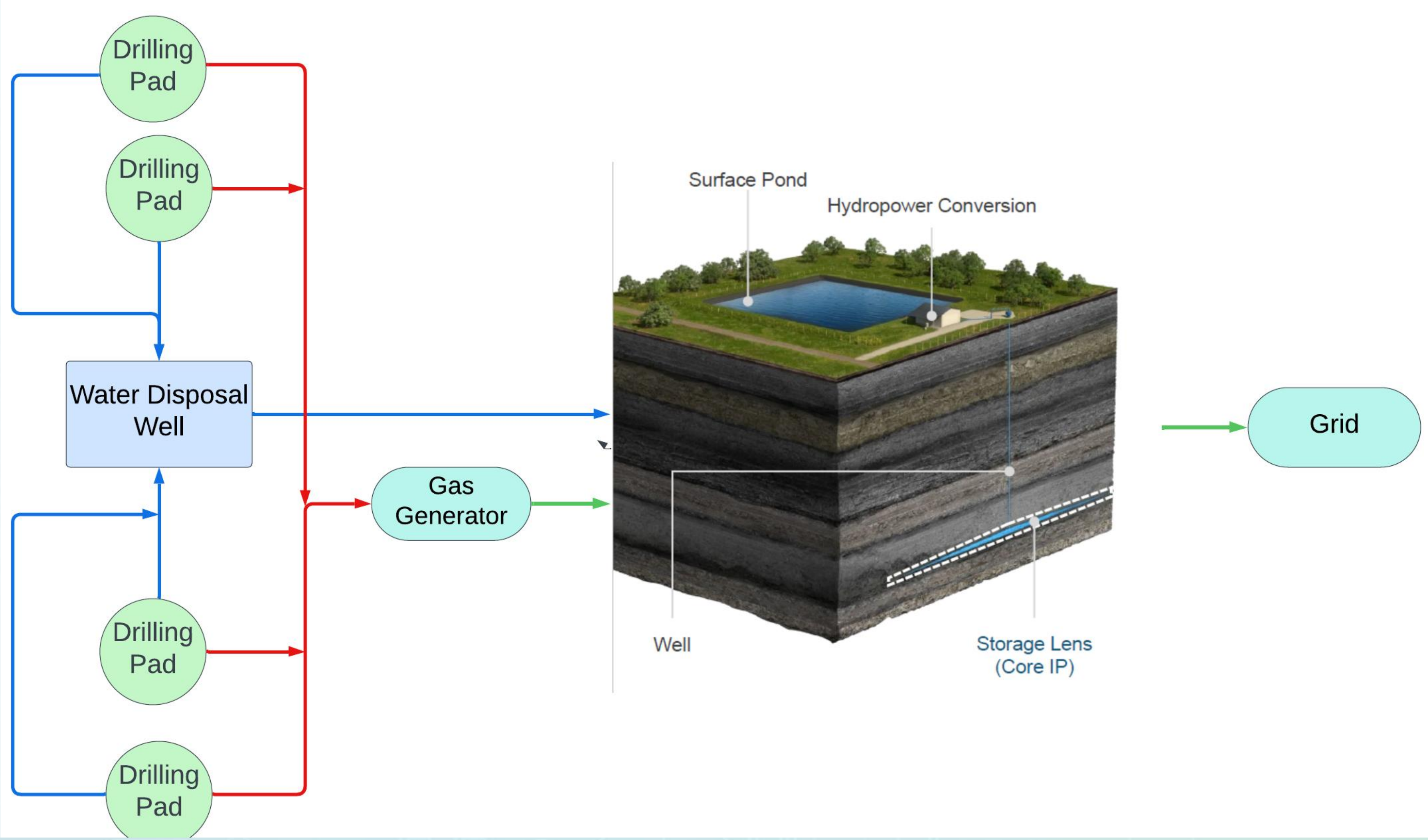
Gas Flaring:

- Increased production in areas with limited takeaway capacity.
- Limited existing pipeline infrastructure, high capital cost to build new pipeline.

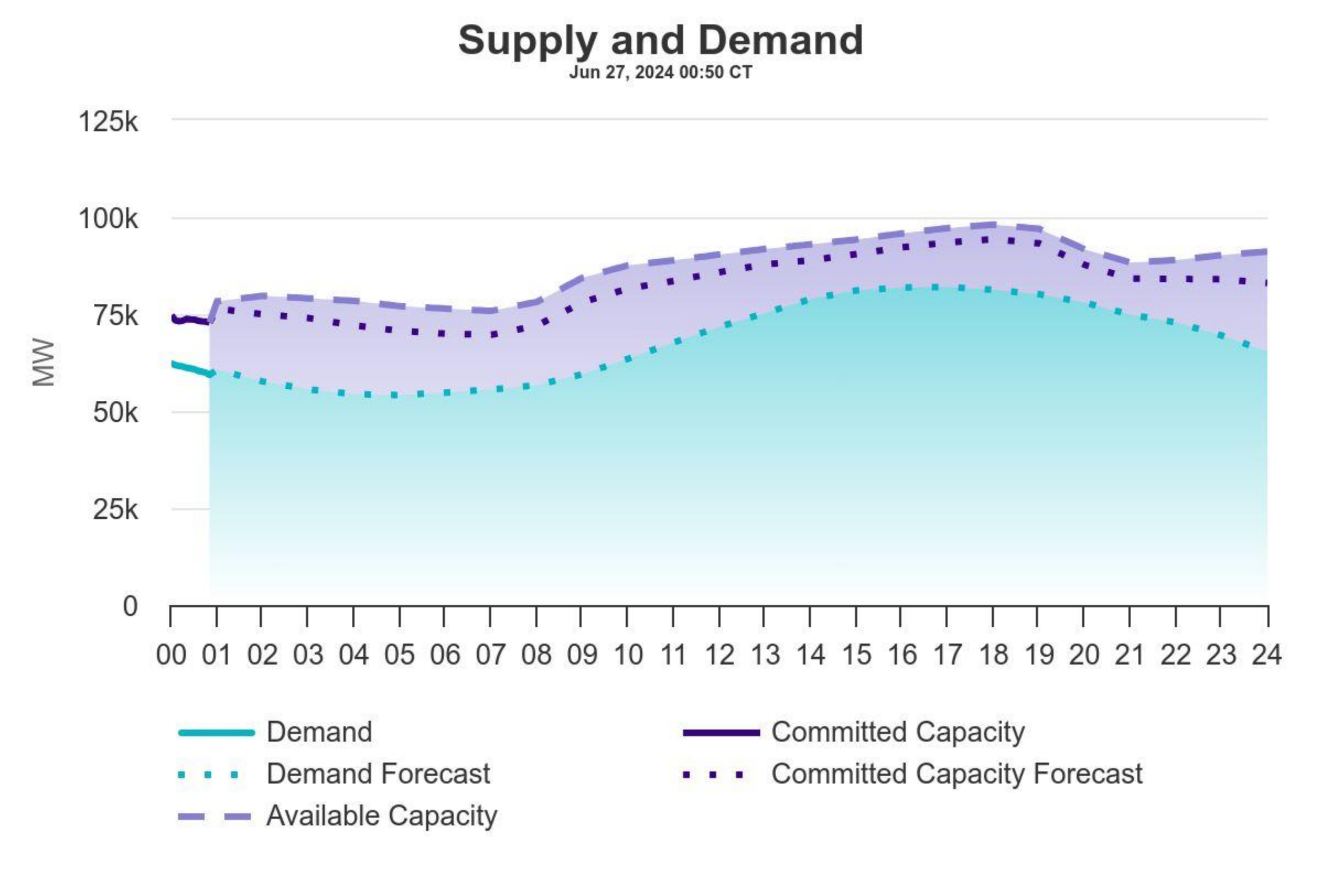


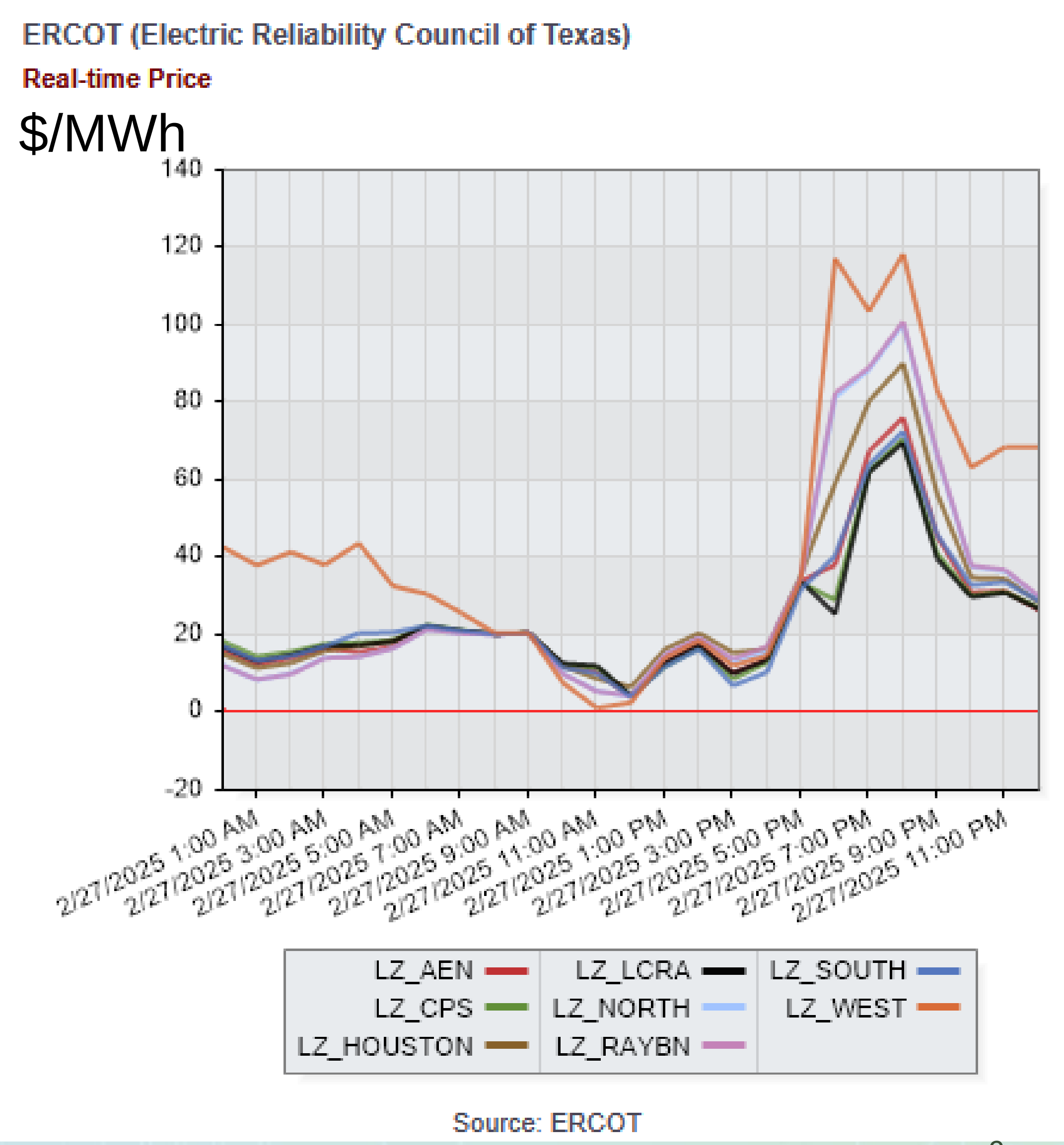
https://dot-ready.com/water-hauling-market-in-the-permian-basin

FLOWCHART


Drilling Pad
Drilling Pad
Water Disposal Well
Gas Generator
Drilling Pad
Drilling Pad
Surface Pond
Hydropower Conversion
Well
Storage Lens (Core IP)
Grid

ELECTRICITY SUPPLY IN TEXAS



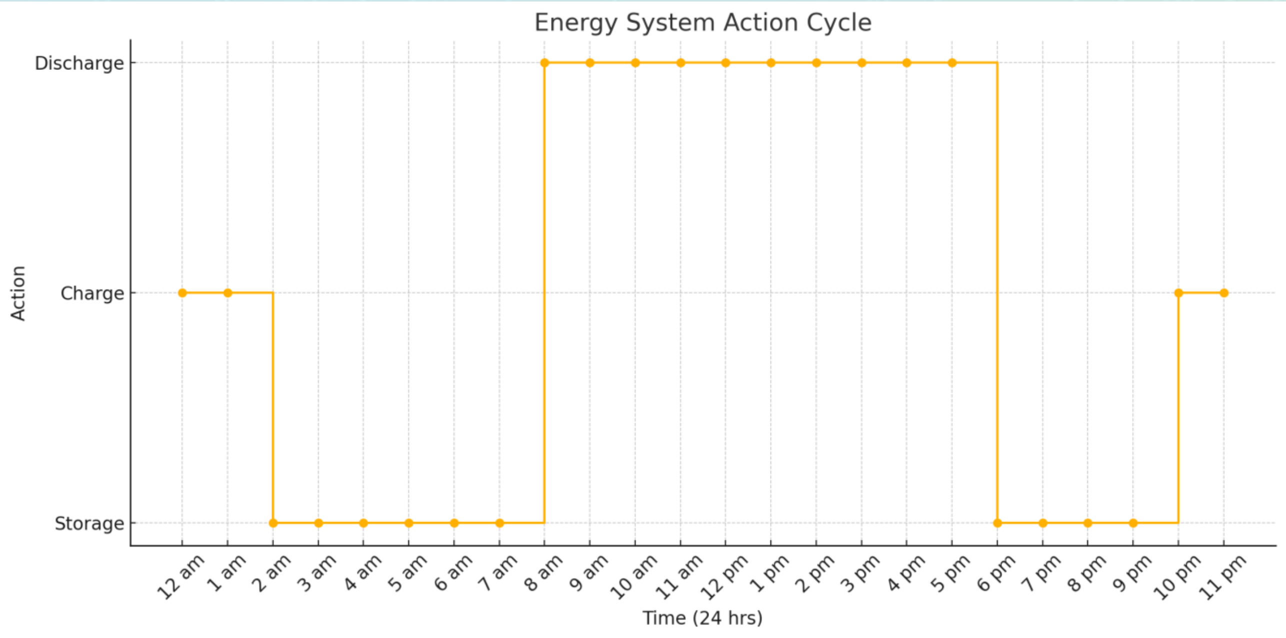


http://www.energyonline.com/Data/GenericData.aspx?DataId=4

CASE DETAILS

We assume the LDES system:

- Discharge electricity 10 hrs per day during daytime during peak period for electricity
- Charge to full capacity at night and store energy overnight
- One cycle per day
- Charging electricity is generated by flare gas
- Water is supplied by produced water from fracked wells



TECHNOLOGICAL PARAMETERS

The chart summarizes technical parameters.
We assume the LDES system can discharge electricity for:

- 10 hrs per day for discharge
- 14 hrs per day for charge and storage time.

Technology Parameter	Units	Value
Storage Type	N/A	Geomechanical
Rated Storage Power Capacity	MW	100
Rated Storage Duration	hr	10
Round Trip Efficiency (RTE)	%	65.0%
Depth of Discharge (DOD)	%	90.0%
Max Cycles at Depth of Discharge	#	10,000
Calendar life	years	20
Project life	years	20

ANNUAL ENERGY OUTPUT (AEO)

The chart summarizes annual energy output of energy system.

Energy per cycle at DOD (kWh)	900,000
Round Trip Efficiency (%) - AC	65.00%
Discharge Time (hrs)	9
Total hours per cycle	24.00
Max cycles per day at DOD - Unlimited	1.00
Max cycles per day at DOD - With Cycle Limitations	1.00
Max cycles per year at DOD	347
AEO - Annual energy discharge per year corresponding to max annual cycles at DOD (MWh)	312,125

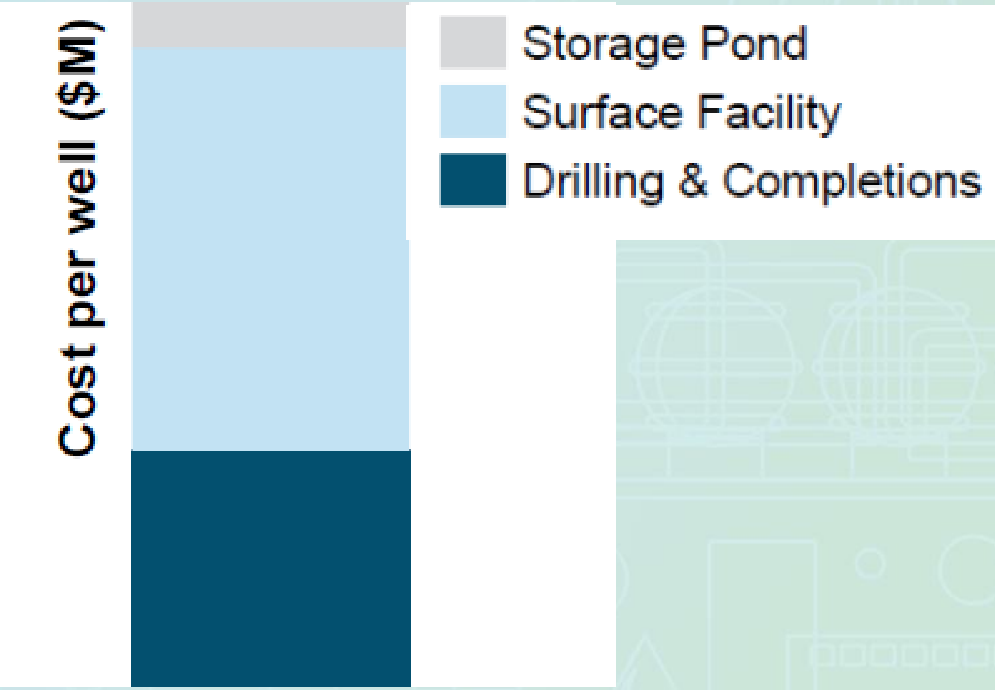
Year	0	1	2	3	4	5	6
Annual Energy Output (MWh)	-	312,125	312,125	312,125	312,125	312,125	312,125

COST PARAMETERS

The chart summarizes cost parameters used for economics calculation. Capital cost is total initial capital cost incurred as if the storage system could be operational overnight.

CAPEX: $1,300 per kW

- Surface facility (water-turbine, pump) : ~60%
- Drilling & Completion: ~30%
- Storage pond: <10%



https://www.pnnl.gov/pumped-storage-hydropower-psh

CAPEX

- CAPEX is assumed to be spent at beginning of project and the energy system is operational at beginning.
  - CAPEX is calculated as $1300/kW * 100MW = $130 MM
- ITC is 30%, we treat tax credit as reduction to CAPEX at project starting time.
  - Tax rebate is 30% * $130 MM = $39 MM

Year	0	1	2	3	4	5	6
CAPEX ($)	-$130,000,000	$ -	$ -	$ -	$ -	$ -	$ -
Tax credit ($)	$39,000,000	$ -	$ -	$ -	$ -	$ -	$ -

COST PARAMETERS

Fixed operations & maintenance cost (O&M): all costs necessary to keep the storage system operational throughout its life that do not fluctuate based on energy throughput, such as planned maintenance, parts, and labor and benefits for staff.

Fixed O&M per year refer to data from Gravitational/Pumped Storage Hydropower system.

Cost Parameter	Units	Value
Overnight Capital Cost (OCC)	$/kW	$ 1,300
Fixed O&M	$/kW-yr	$ 25
Variable O&M	$/kWh-discharged	$ -

https://www.pnnl.gov/pumped-storage-hydropower-psh

COST

- Fixed O&M cost with 3% annual inflation
  - $25/kW-yr * 100MW = $2,500,000 per year
- Assume there is no variable O&M cost

O&M Cost by Year	0	1	2	3	4	5	6
Fixed O&M ($)	$ -	$ 2,500,000	$2,575,000	$ 2,652,250	$ 2,731,818	$ 2,813,772	$ 2,898,185

- Cost due to electricity charge:
  - Total charge cost: $ 46/MWh
  - RTE: 65%, there is energy loss during electricity charge and discharge
  - $ 30/MWh, original charge cost
  - $ 16/MWh, charge cost due to RTE loss, back calculated
- Abandonment cost: assume $50K abandonment cost per well and no residual value at end of project life (20 years).

BEFORE TAX DISCOUNTED CASHFLOW

We calculate future net income before tax:

- Calculate LCOS that reach discounted NPV = 0.
- LCOS is calculated to be **$ 90/MWh**.
- Discount factor is 10%, project life is 20 years.

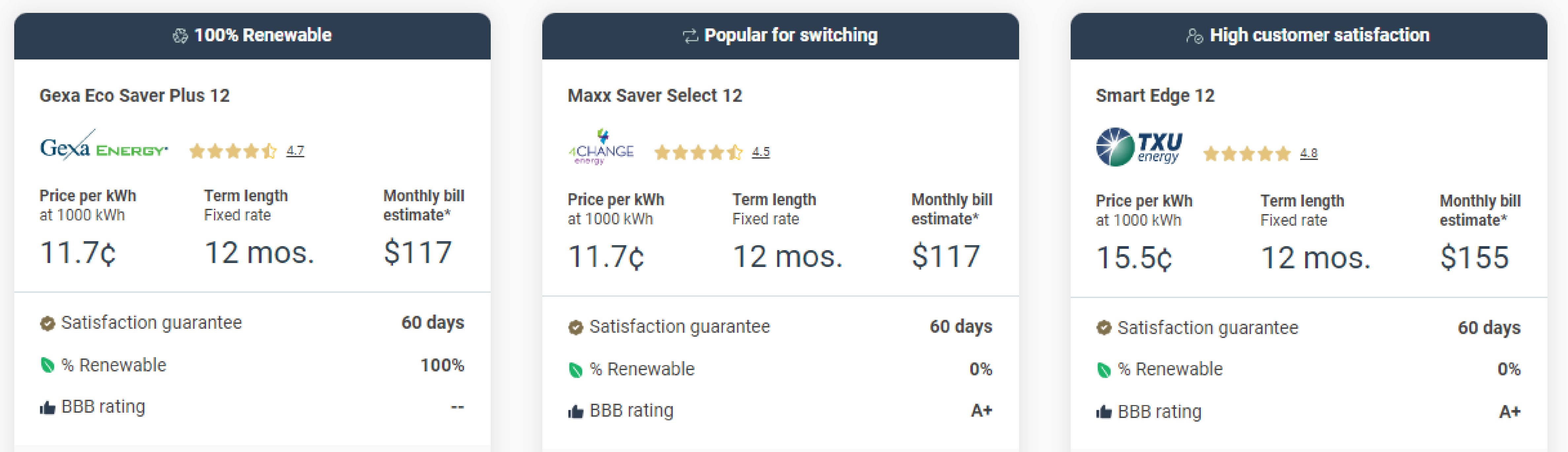
Year	0	1	2	3	4	5	6
Total Annual Costs ($)	$ -	$ 16,930,770	$ 17,006,520	$ 17,084,543	$ 17,164,906	$ 17,247,680	$ 17,332,937
CAPEX ($)	-$130,000,000	$ -	$ -	$ -	$ -	$ -	$ -
Tax credit ($)	$39,000,000	$ -	$ -	$ -	$ -	$ -	$ -
Annual Energy Output (kWh)	-	312,125,020	312,125,020	312,125,020	312,125,020	312,125,020	312,125,020
Revenue ($)	-	28,212,303	28,212,303	28,212,303	28,212,303	28,212,303	28,212,303
FNI before tax ($)	(91,000,000)	11,281,532	11,205,782	11,127,760	11,047,397	10,964,623	10,879,365
Discounted FNI at 10%($)	(91,000,000)	10,255,939	9,260,977	8,360,451	7,545,521	6,808,168	6,141,118
NPV at 10% ($)	0						
Before Tax IRR	10.00%						

break-even point

COST COMPARE WITH RESIDENTIAL PRICE

LCOS is $ 90/MWh.

Recent lowest residential electricity price in Houston is $117/MWh including ~$43/MWh delivery charge.



https://www.choosetexaspower.org/compare-offers/?zipCode=77007&m=moven

Thank you!

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