Haddington Ventures, L.L.C.

Renewable Integration and Compressed Air Energy Storage (CAES)



February 6, 2019

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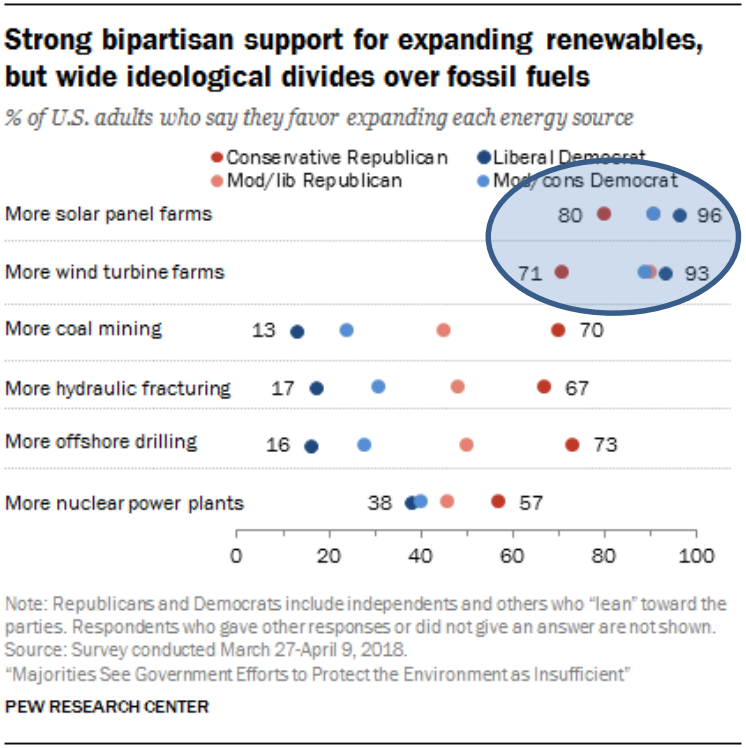
Haddington's Underground Storage Experience

- Successful history over 30 years in underground storage across storage media and regulatory jurisdictions
- Haddington has successfully developed, built and operated storage facilities in:
  - NGLs (Natural Gas Liquids), natural gas and crude oil
  - New build salt cavern, salt cavern product conversions and depleted reservoir

Project Name	Product Stored	Storage Medium	Status	Storage Capacity[1]	Sale Date	Buyer	Sale Price / TEV ($MM)
TPC Corporation							
Moss Bluff Gas Storage	Natural Gas	Salt Caverns	Sold	7.8 Bcf	1997	PacificCorp	NA[2]
Egan Gas Storage	Natural Gas	Salt Caverns	Sold	4.7 Bcf	1997	PacificCorp	NA[2]
Haddington Ventures							
Lodi Gas Storage	Natural Gas	Depleted Reservoir	Sold	12.0 Bcf	2002/2005	ArcLight	$230
Norton Energy Storage (CAES)*	Electricity	Limestone Mine	Sold	80.0 MMbbls	2009	FirstEnergy Corp.	Undisclosed
Bobcat Gas Storage	Natural Gas	Salt Caverns	Sold	19.0 Bcf	2010	Spectra Energy Corp.	$540
Magnum NGL Storage	Natural Gas Liquids	Salt Caverns	Sold	1.9 MMbbls	2015	NGL Energy Partners	$280
Fairway Energy Partners	Crude Oil	Salt Caverns	In Construction	19.3 MMbbls	NA	NA	NA
Apex (CAES)*	Electricity	Salt Caverns	Dev. Phase	8-10 MMbbls	NA	NA	NA
Magnum Gas Storage	Natural Gas	Salt Caverns	Dev. Phase	40.0 Bcf	NA	NA	NA
Magnum Refined Products Storage	Refined Products	Salt Caverns	Dev. Phase	4.0 MMbbls	NA	NA	NA
Magnum CAES	Electricity	Salt Caverns	Dev. Phase	TBD	NA	NA	NA
Magnum Crude Oil Storage	Crude Oil	Salt Caverns	Dev. Phase	TBD	NA	NA	NA

Renewable Electricity Penetration Continues to Grow

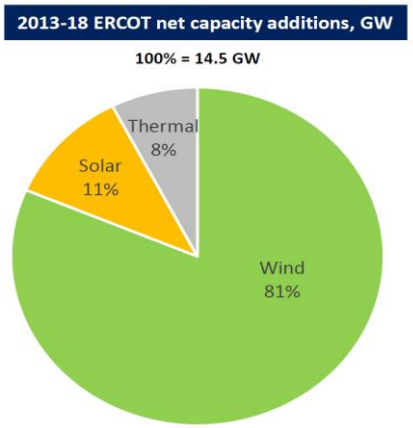
- Public opinion strongly supports aggressive development of renewable energy*
  - For the foreseeable future renewables likely to dominate new additions the grid, despite integration challenges



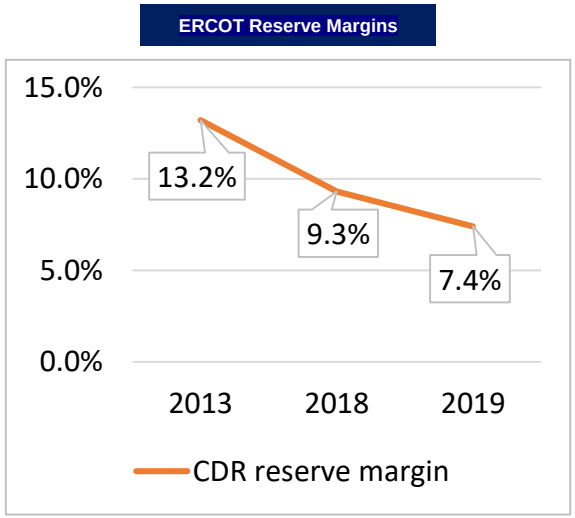
*http://www.pewinternet.org/2018/05/14/majorities-see-government-efforts-to-protect-the-environment-as-insufficient/ps-05-10-18_report-08/

Intermittency Puts Pressure on the Grid … But Creates Opportunities

- Associated intermittency putting continued pressure on the grid
  - In Texas, low power prices driven by wind and solar additions make it uneconomic to build new natural gas generation capacity while reserve margins continue to fall (see below)



Wind and solar penetration rising in ERCOT while peak hour capacity reserves declining



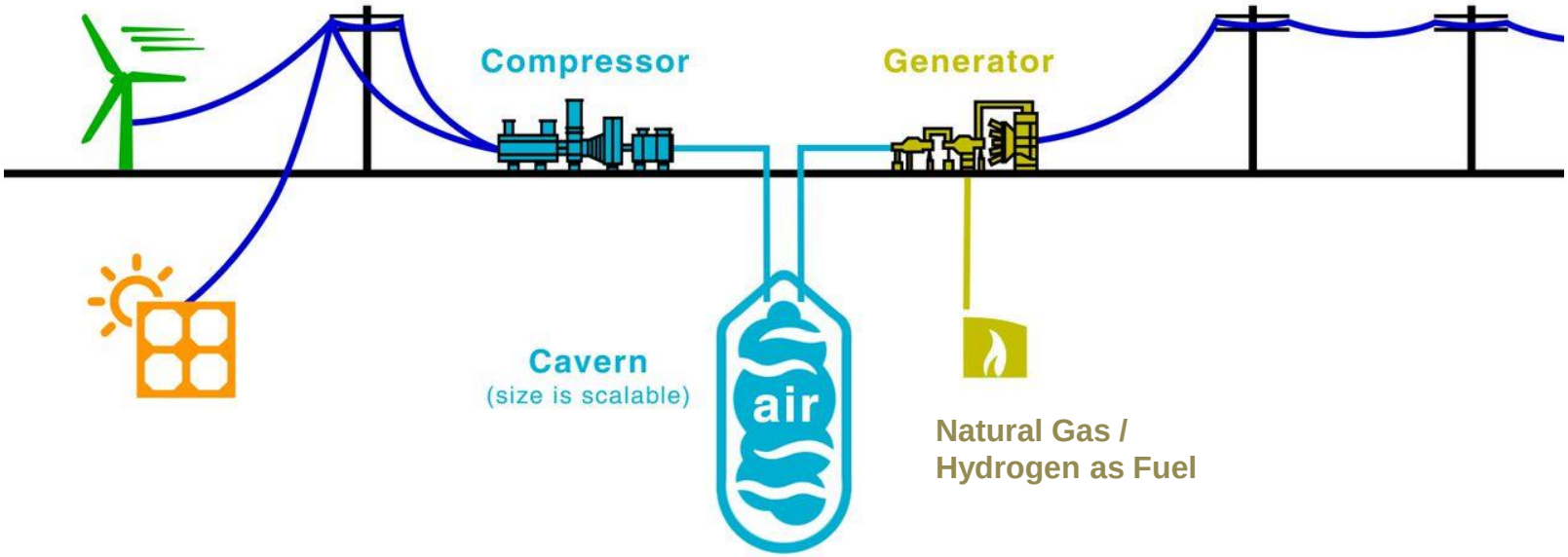
- Haddington is focused on CAES projects serving Texas and California
  - Texas has the highest wind installed capacity, with solar additions growing
  - California has the highest solar installed capacity, going to 100% renewable energy by 2045 with passage of SB100

How to Deal with the Intermittency of Renewables

- **Conventional Approach (the practical approach)**
  - →Natural Gas Storage + Gas Generation
  - →Natural gas is an ideal bridge fuel
  - →High deliverability gas storage needed to balance intraday swings

- **Storage Approach (the purist approach)**
  - →Lithium Ion Batteries
  - →Flow Batteries, Flywheels and other technologies
  - →Pumped Hydro

Compressed Air Energy Storage (a Halfway Point)



- Stores excess electricity as compressed air energy
- Compressed air is the primary generation fuel
- Low amounts of fuel added to reheat compressed air during expansion
- Multiple carbon-neutral expander fuel options: hydrogen, biomethane
- Can store and deliver renewable energy – **simultaneously**
- Uses existing equipment installed in 60+ locations around the world*

* Magnum/Apex proposed equipment is from Siemens: Compression installed today in 64 air separation plants, Generator today installed in 120+ locations around the world

CAES Shines for Long Duration Storage

Comparison of CAES to Lithium Ion Battery*

Cost	Lithium-ion 4 hour, 100 MW (low end estimate)	Bethel CAES 48 hour, 331 MW (actual cost)
Facility capital cost	$1,540/kW	$1,318/kW
Operating life	20 years[1]	+30 years
Monthly capacity cost[2] @ 10% IRR	$12.75/kW-month	$9.35/kW-month
Augmentation/Warranty Charges[1]	$8.92/kW-month	N/A
Fixed O&M/G&A/property taxes	$1.93/kW-month[3]	$3.03/kW-month
Total fixed costs (year one)	$23.60/kW-month	$12.38/kW-month

*** Source: APEX CAES**

Levelized Cost of Energy**

Table 3-3. SUMMARY OF SUPPLY-SIDE RESOURCE ASSUMPTIONS

	Levelized Cost ($/MWh)[1]	Capacity Factor	Peak Load Dependable Capacity (3 to 5 PM)	Net Load Dependable Capacity[2] (7 to 9 PM)
Solar Photovoltaic - PPA	$56	28% - 35%	27%- 38%	0% - 2%
Solar Photovoltaic - LA Solar	$175	19% - 23%	27%	3% - 5%
Solar - Owens	$30	25%	27%	3% - 5%
Solar Feed-in-Tariff	$173	20%	27%	3% - 5%
Wind	$105	24% - 33%	10%	0%
Wind Firmed and Shaped	$106 to 132	24% - 33%	45% - 100%	45% - 100%
Geothermal	$78	91% - 95%	90%	90%
Castaic Improvement	$29	46%	100%	100%
Beacon Battery (1/2 hour)	$480	4%	43-61%	12%
Distribution Battery (2 hour)	$178	12%	100%	48%
Transmission Battery (4 hour)	$93	17%	99%	96%
New Combined Cycle Gas	$75 to 85	42%	96%	96%
New Simple Cycle Gas	$500 to 600	3% - 5%	96%	96%
CAES	$55	44%	92%	96%

[1]Net Present Value (annual costs, 2017-2037) / NPV of Energy Produced
[2]Net Load represents the hour when the net energy for load minus variable energy resources is maximum

**** Source: Los Angeles Department of Water and Power 2017 IRP**

CAES is roughly half the cost of a 4 hour battery with 10x the storage duration

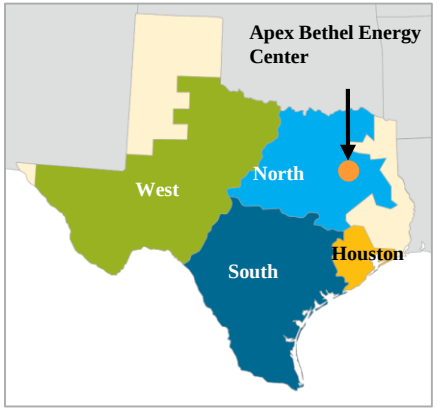
CAES is 20x's cheaper per unit of long duration storage

Apex CAES – Bethel Energy Center

BETHEL ENERGY CENTER – PROJECT OVERVIEW

Project rendering

Location



Key facts

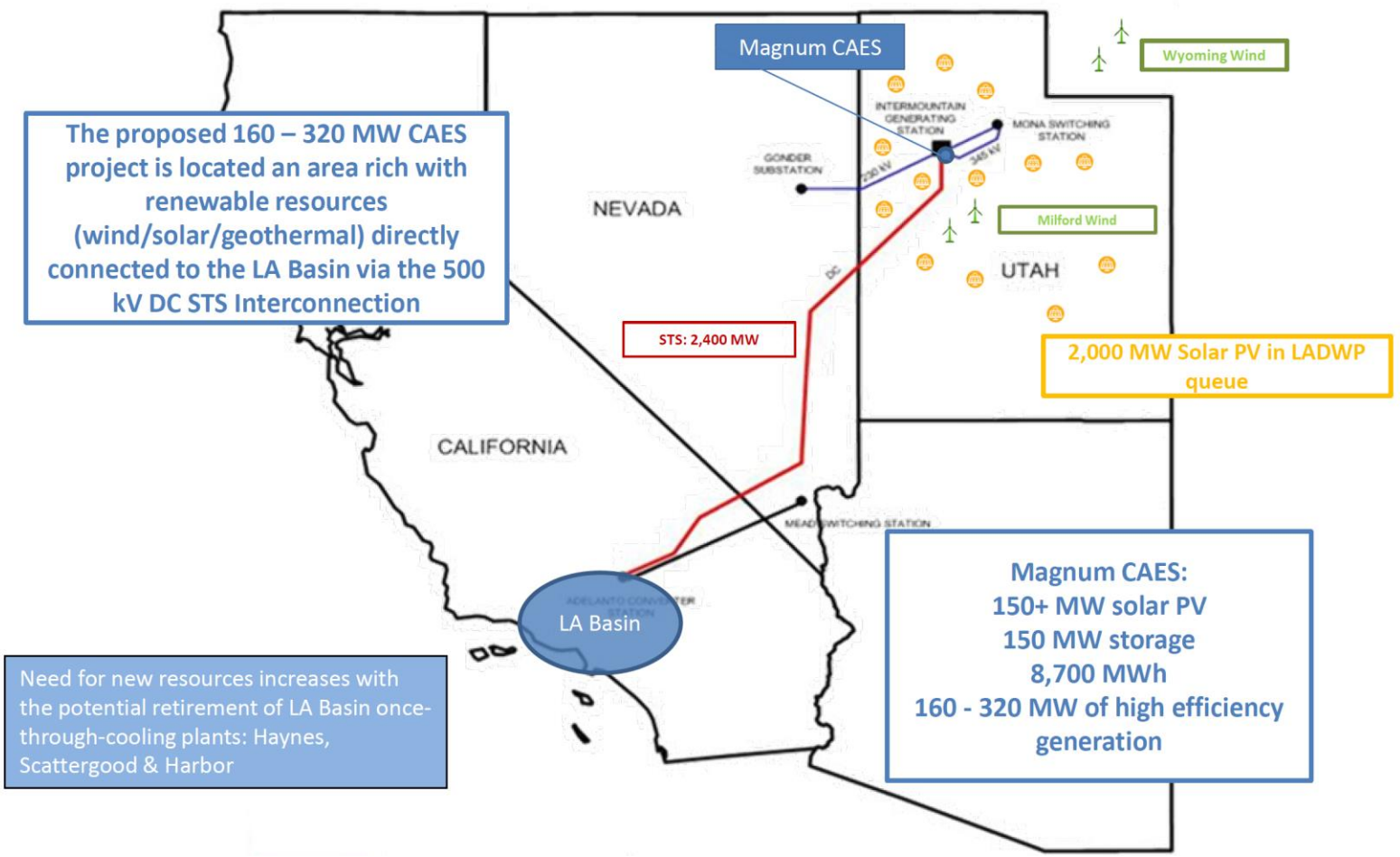
Rated capacity:	324 MW generation ~145 MW compression
Storage capacity:	324 MW for 48 hours – 15,552 MWh
Storage media:	4 MMbbl cavern at Bethel Salt Dome; 5 existing natural gas storage caverns demonstrate suitability of salt
Notice to proceed:	May 2019
On-line:	2Q 2022
Delivery point:	345 kV, ERCOT North Zone
Fuel supply:	Energy Transfer
Surface footprint:	22 acres

Project team & sponsors

- **Apex CAES LLC** - Project development/ construction/commercialization team
- **Haddington Ventures** – Principal project sponsor; over 25 years of underground storage investing
- **Siemens AG** – Equipment supplier, EPC provider, O&M/major maintenance provider, equity investor

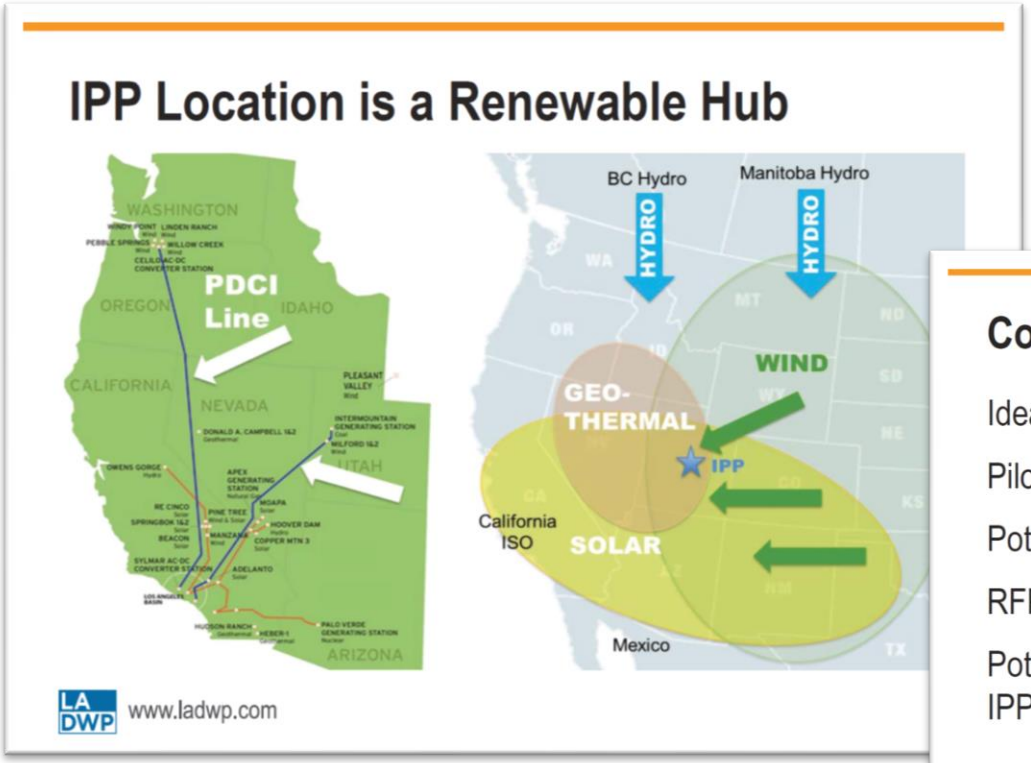
Magnum CAES Overview

Magnum CAES' Strategic Location on Southern Transmission System (STS) is Valuable



Source: Magnum CAES

LADWP Plans For CAES & Rewable Hub



Compressed Air Energy Storage Project

Ideal site

Pilot Project: 160 MW

Potential for multiple CAES Units at site

RFP issued through SCPPA

Potential joint CAES project with several other IPP Participants

" [CAES] technology has been used since 1991 in a 226 MW facility in McIntosh, Alabama and since 1978 in a 290 MW facility in Huntdorf, Germany. Potentially utilizing newer technology at the larger capacity will allow testing to determine if CAES can be utilized. Initial research indicates that there is the potential of between 1,500 and 2,000 MW at the Delta site. Staff will report back within 90 days as to the status of the potential project."

Source: LADWP Board Presentation (June, 2018)

In Summary

- The grid will need flexible natural gas storage and other forms of energy storage to balance the intermittency of renewables
- Ultimately a variety of approaches and technologies will be deployed as solutions – there are likely no single winners
- Haddington has two near term CAES projects which we expect to go to construction in 2019
- We believe CAES is an ideal solution for longer duration (greater than 4 hour) storage opportunities, to the extent there is appropriate underground geology