alacaes

Creating a Sustainable, Large-Scale Electricity Storage Solution

Company Presentation

- **ALACAES** is a private Swiss company that is developing an advanced adiabatic compressed air energy storage (**AA-CAES**) technology for large-scale electricity storage

- From its inception, ALACAES had strong ties to academia and is the main industrial partner in 3 cross-institutional R&D projects
- ALACAES' industrial partners are key players in their respective sectors

Scientific and Industrial Partners:

MAN Diesel & Turbo

GEOSTOCK ENTREPOSE

ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

aet

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Scuola universitaria professionale della Svizzera italiana SUPSI

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

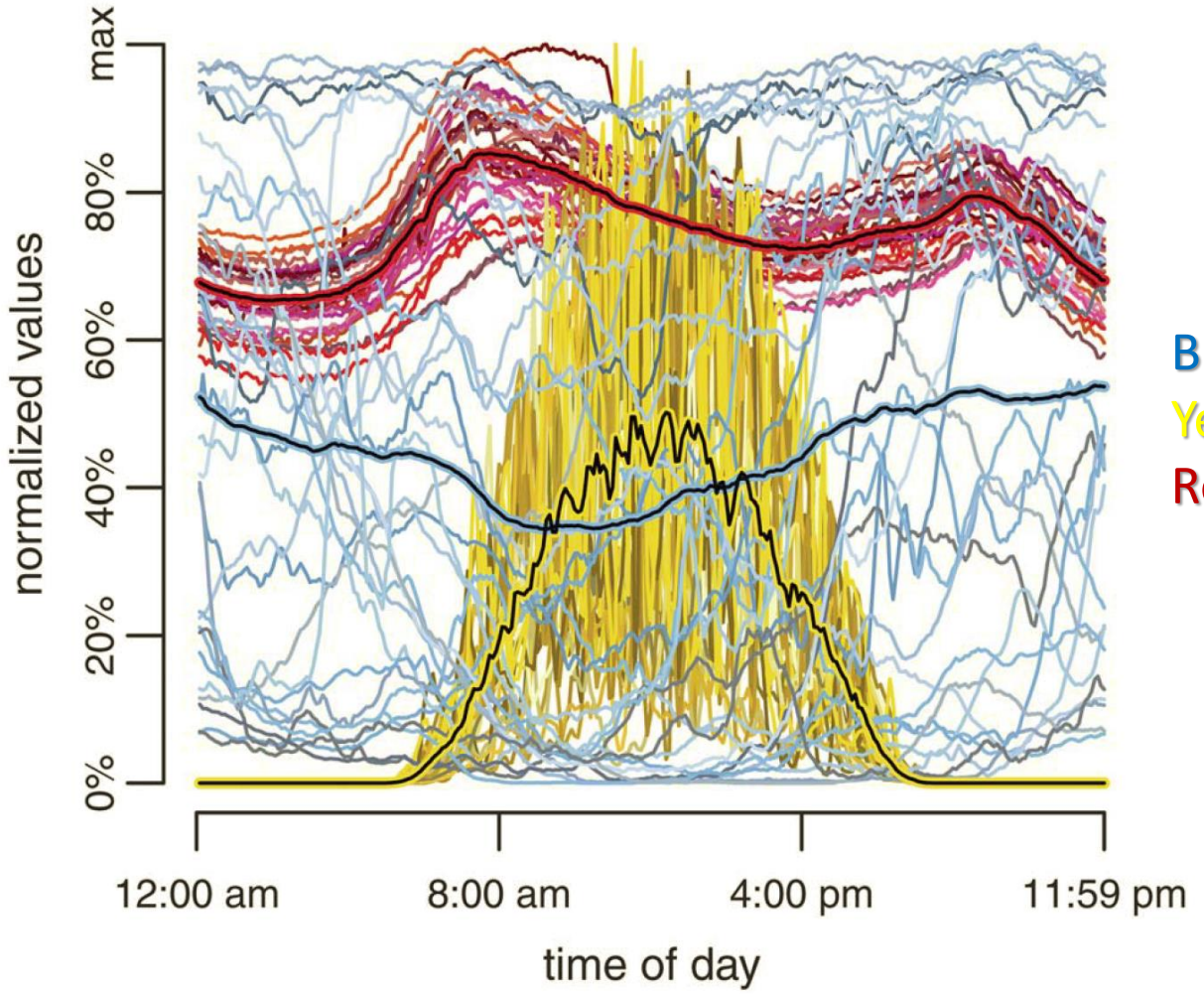
Bundesamt für Energie BFE
Office fédéral de l'énergie OFEN

PAUL SCHERRER INSTITUT PSI

alacaes

Motivation

Typical wind and solar electricity production vs. grid consumption patterns



Blue: Wind Production

Yellow: Solar Production

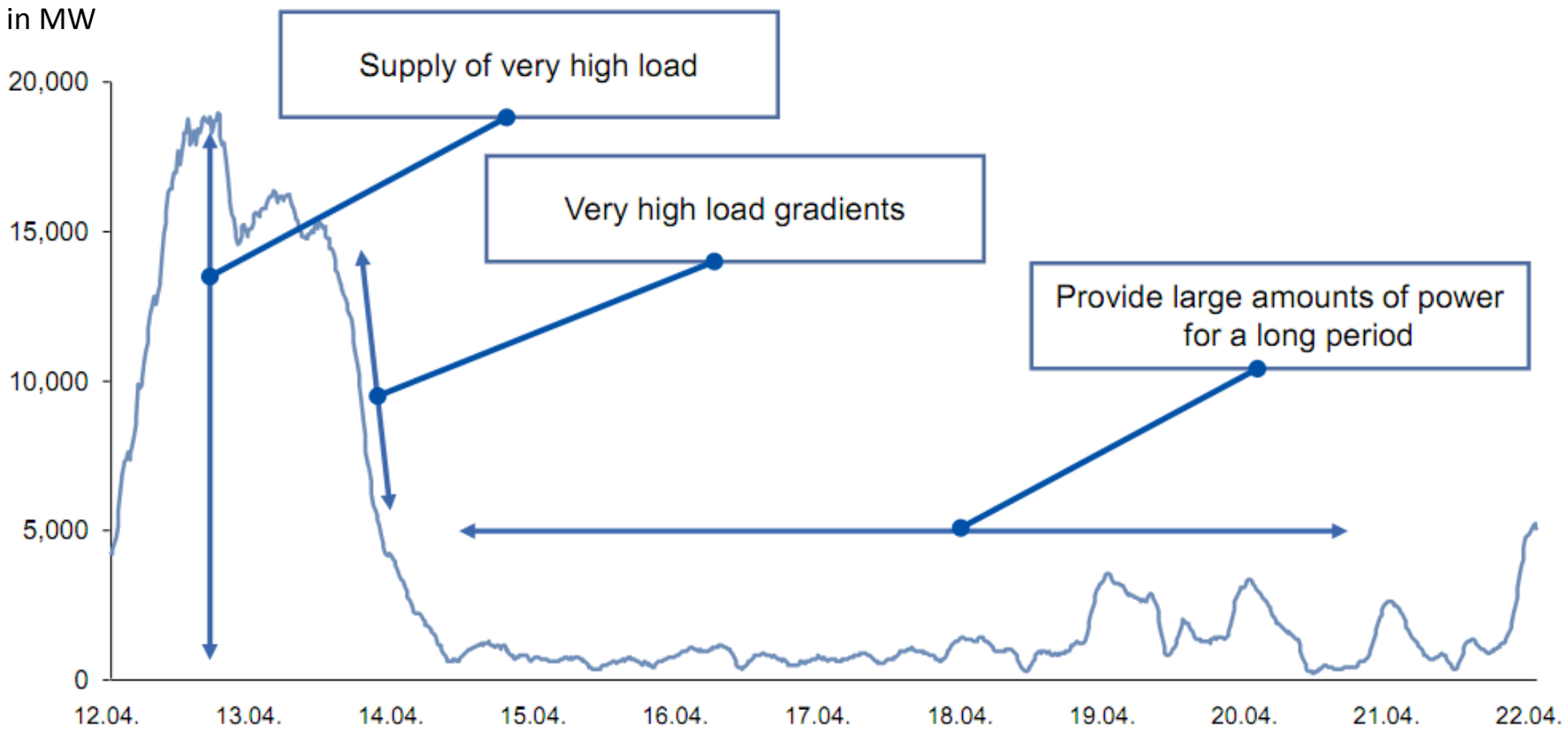
Red: Grid Consumption

Barnhart, Benson, The energetic implications of curtailing versus storing solar- and wind-generated electricity, Energy Environ. Sci., 6, 2804, 2013.

alacaes

Motivation

Typical wind park electricity production fluctuations



Source: RWE

Motivation

Why Large-Scale Energy Storage?

- Compensate intermittent nature of renewable energy sources; i.e. wind and solar
- Shave production peaks and reduce/eliminate curtailment of wind and PV farms
- Deferral of Transmission and Distribution grid expansion by optimizing output of large-scale renewable energy plants
- Stabilize grid during peak consumption periods
- Offer vital role in case of black-outs (black-start ready)

Motivation

Why Large-Scale Energy Storage?

- Co i.e. wi
- Sh ind ar
- De op
- St
- Of

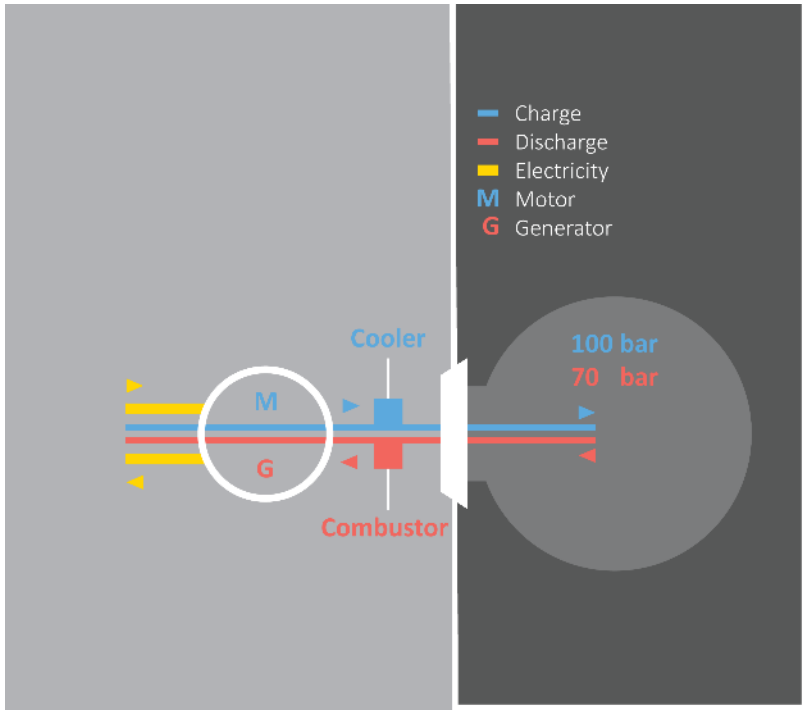
Daily Mail MORE STORIES

Gone with the wind! National Grid pays operators £350million to switch off turbines producing too much power

By Rachel Millard For The Daily Mail
01:19 11 Nov 2017, updated 01:26 11 Nov 2017

alacaes

Conventional CAES Technology



In conventional CAES plants:

- Air is compressed using excess electricity from the grid and stored in underground caverns
- Compressed air is later expanded in turbines to generate electricity
- Compression generates heat that is dissipated to the environment
- In release mode air is heated by means of a fossil fuel burner

Existing Plants:

Huntorf (DE) in **1978**

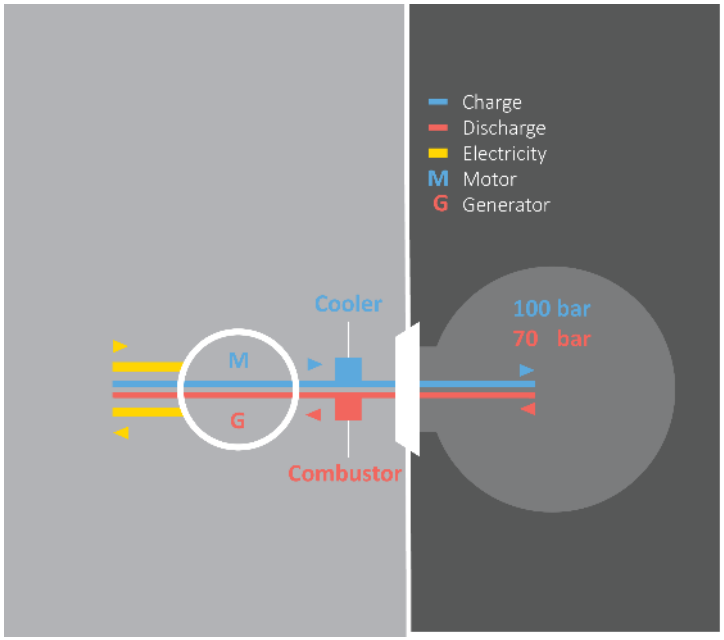
- **Gas burner** to heat the compressed air
- **Salt cavern** for air storage
- 3h of production with a storage capacity of 640 MWh
- Efficiency: **40%**

McIntosh (US) in **1991**

- **Gas burner** and **heat recuperation**
- **Salt cavern** for air storage,
- 26h of production with a storage capacity 2860 MWh
- Efficiency: **54%**

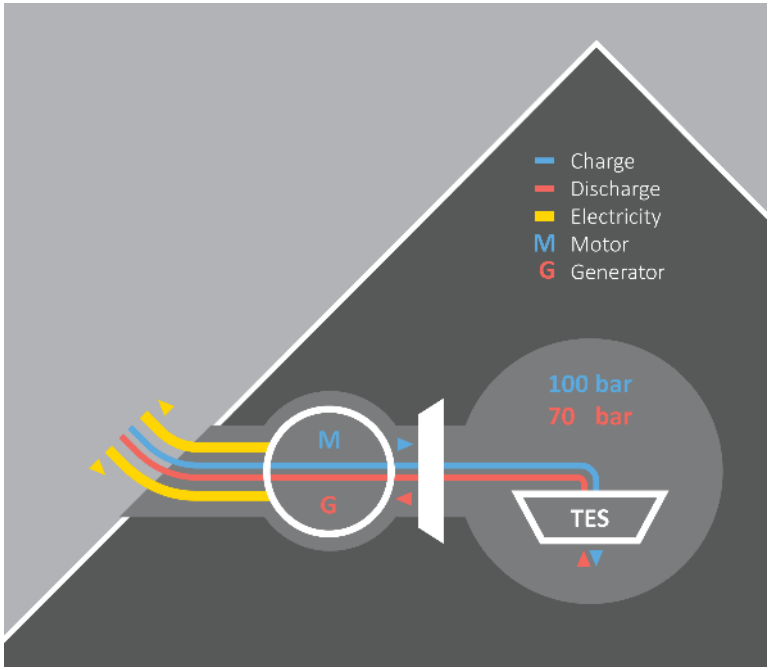
alacaes

ALACAES Technology



Existing CAES plants

With **TES*** systems the **heat** generated at the compression stage **is first stored** and **then used** at the expansion stage



ALACAES' Solution

Up to **several GWh** of storage capacity

Heat recovery allows a global efficiency of above 70%

Zero CO_2

<5 min of ramping times

No electricity needed for start-up (Black-start)

TES: Thermal Energy Storage

alacaes

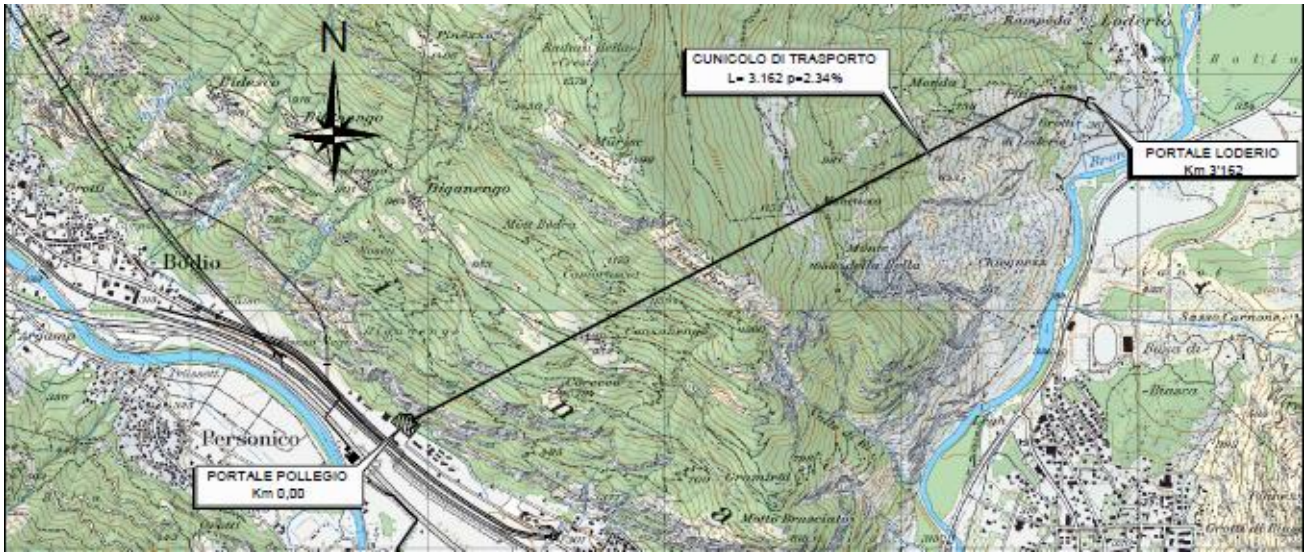
The ALACAES Technology
Summarized

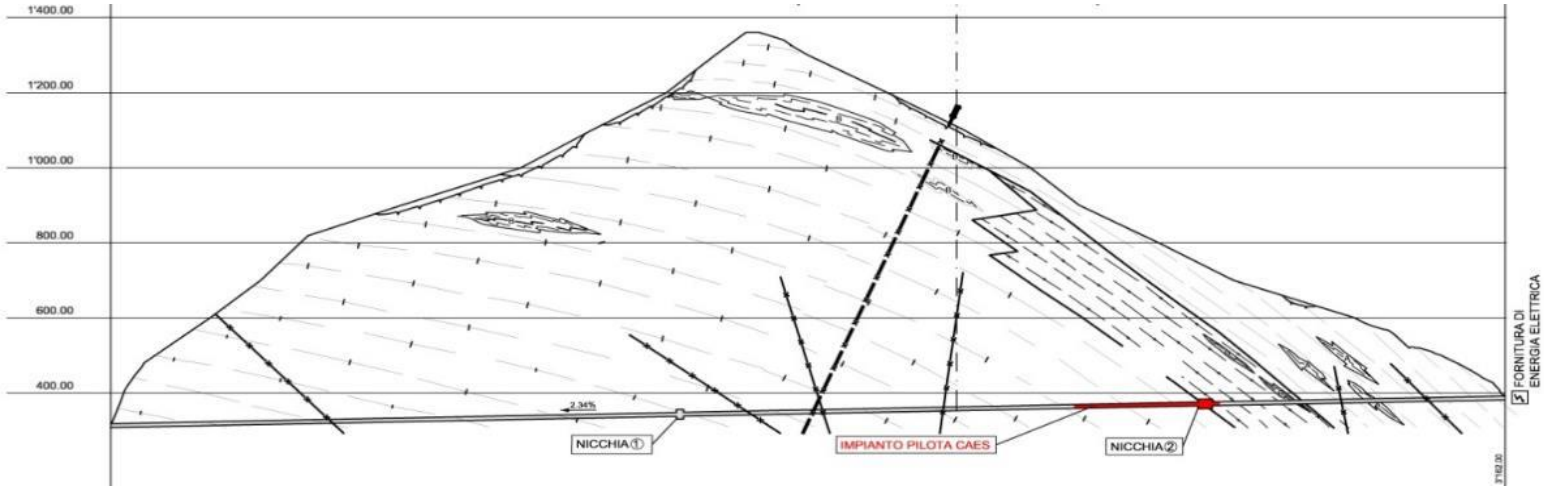
- Use of **underground caverns as the pressure reservoir** – easily accessible and vast experience from gas storage caverns
- **Packed bed of rocks Thermal Energy Storage (TES)** developed for CSP technology – high round-trip efficiency, high reliability
- Placement of the **TES inside the pressure cavern** – TES tank not pressurized, costs and complications of the TES solution significantly reduced
- Placement of the **turbomachinery inside the cavern** (optional) – reducing the visibility of the plant and therefore its public acceptance, vast experience from pumped hydro plants
- See also the video on our homepage: www.alacaes.com

alacaes

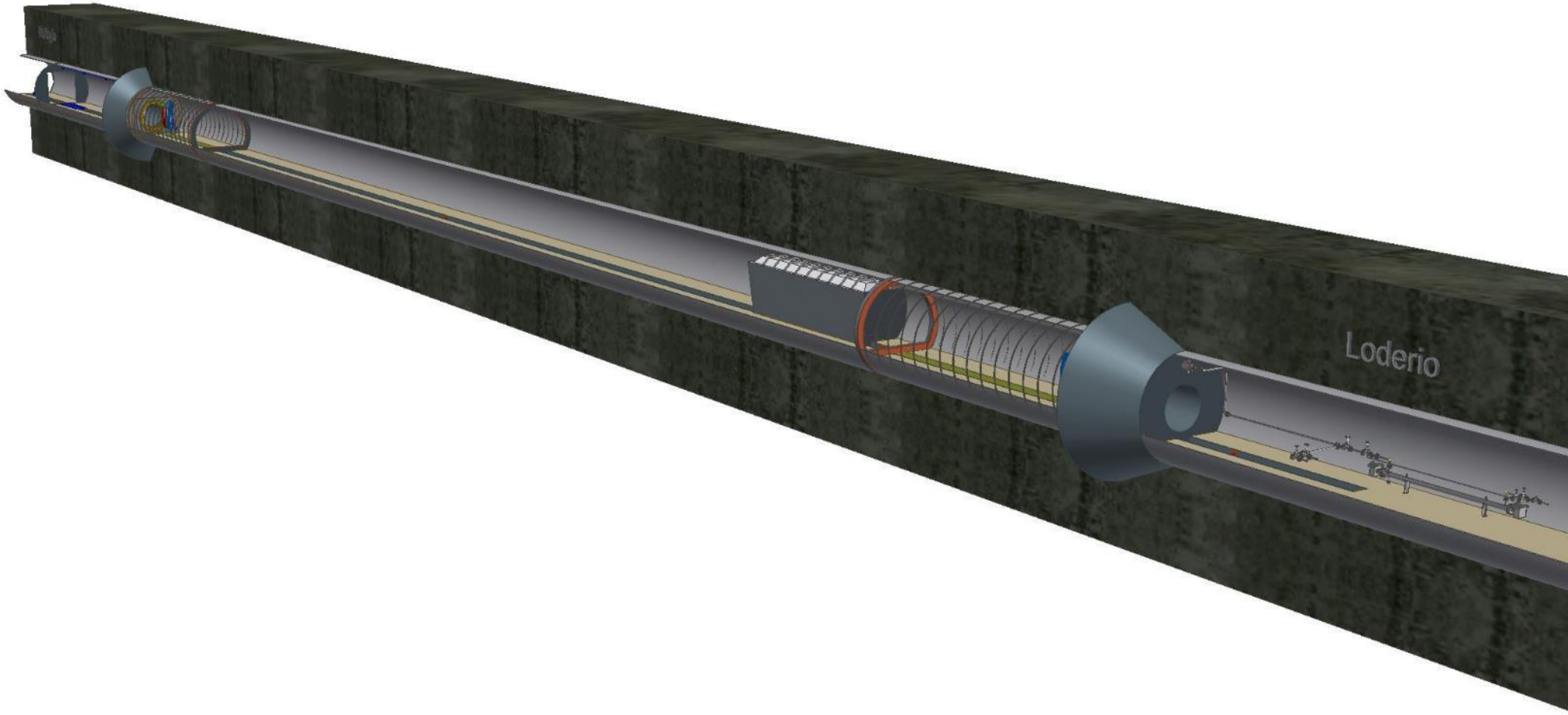
Pilot Plant

Placed in an unused tunnel in the Swiss Alps





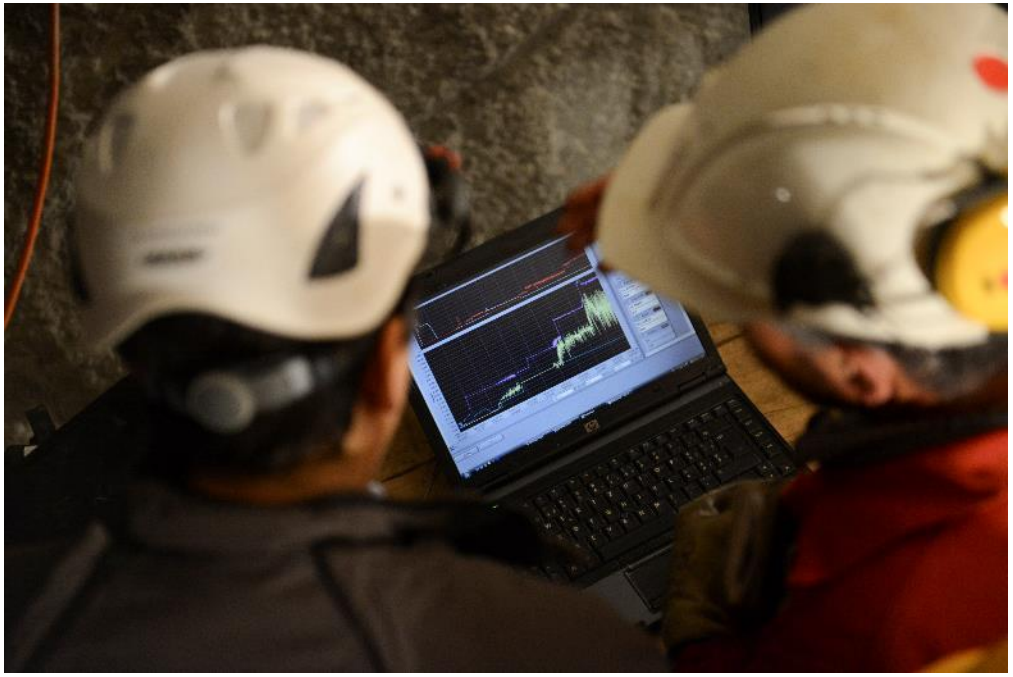
Pilot Plant



alacaes

Pilot Plant

Pilot Plant



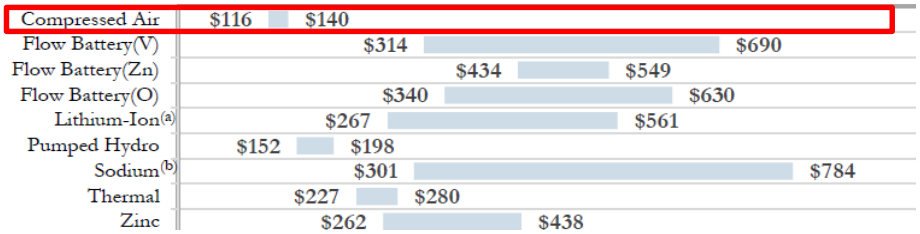
Pilot Plant

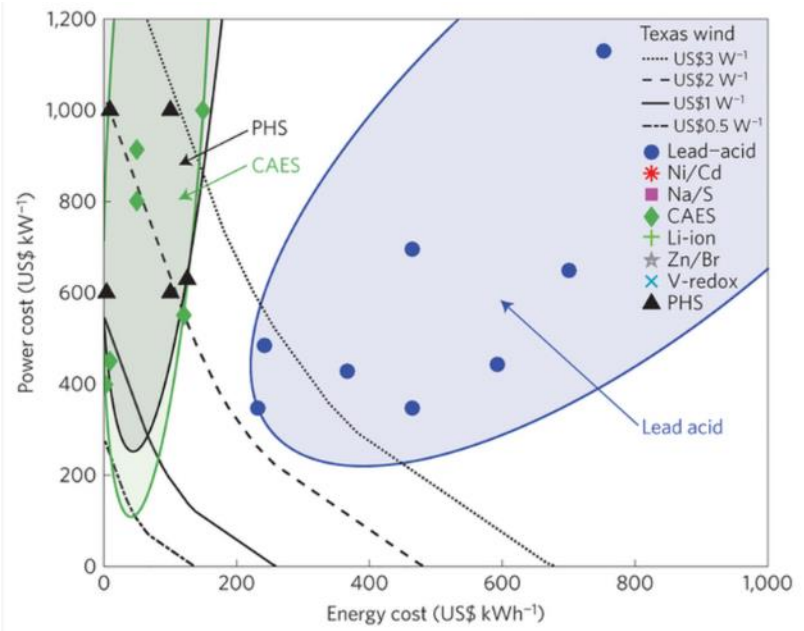
Pilot Plant
Thermal Energy Storage

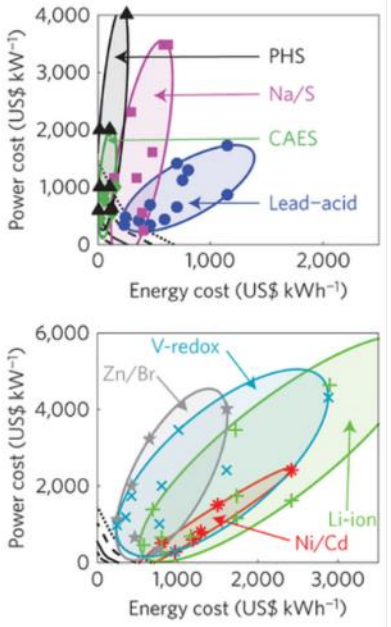
alacaes

CAES vs Other Storage Technologies
Cost Comparison

- Compressed Air Energy Storage has the lowest cost per installed capacity among all storage technologies*
- CAES is a **factor of 4-8 cheaper** than Li-ion batteries
- CAES is **30-50% cheaper** than pumped hydro plants







*Lazard's levelized cost of storage – 2.0, Dec. 2016
*Sandia Report 2015-1002, Electricity Storage Handbook, Feb. 2015
Power to Energy Cost graphs: Braff et al., Value of energy storage for wind and solar energy, Nature Climate Change, 6, 2016

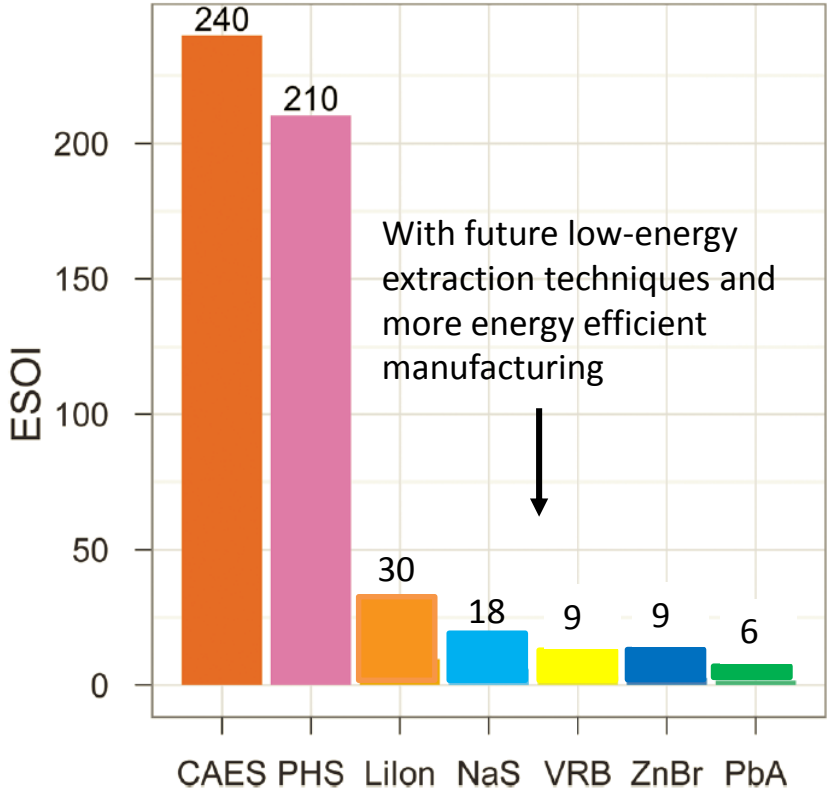
alacaes

CAES vs Other Storage Technologies
Sustainability

ESOI = Energy Stored on Invested = $\frac{\text{Energy stored over lifetime of storage device}}{\text{Energy required to build it}}$

- CAES has the best **sustainability performance** among all storage technologies
- CAES **lifetime** is 40-60 years vs. 10-15 years for batteries

	η^a	λ^b at depth-of-discharge (DOD)			
	%	100%	80%	33%	$\varepsilon_{gate}{}^c$
Li-ion	90	*4000*	*6000*	8500	454
NaS	75	*2400*	*4750*	7150	488
PbA	90	*550*	*700*	1550	321
VRB	75	*2900*	*3500*	7500	694
ZnBr	60	*2000*	*2750*	4500	504
CAES	70	>25 000 DOD indep.			73
PHS	85	>25 000 DOD indep.			101



Barnhart, Benson, On the importance of reducing the energetic and material demands of electrical energy storage, Energy Environ. Sci., 6, 1083, 2013.

CAES vs. Pumped Hydro

- CAES has 20-30% cheaper CAPEX
- Smaller environmental footprint
- No dams necessary: Drastically smaller concrete usage
- No artificial lakes created: No damage to local flora and fauna
- Not competing with drinking or agricultural water supply

Summary

- ALACAES is developing a low-cost, zero emission storage technology based on compressed air energy storage (CAES)
- AC-to-AC efficiency = 70-75%
- ALACAES successfully built and tested the world's first advanced adiabatic CAES (AA-CAES) pilot plant in 2016
- Partners are leaders in their respective industries
- Now optimizing plant cost and performance with partners and business development

alacaes

www.alacaes.com

Follow us on Twitter :@ALACAES