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Liquid Air Energy Storage

How cryogenics can support a greener grid

Richard Riley, Business Development Manager, NA

CEC – Madison, WI – July 11th, 2017

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Liquid Air Energy Storage (LAES)

is based on **proven components** from century-old industries

and offers a **low-cost** solution

for **high-power, long-duration** energy storage

that can be built **anywhere**.

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Company Timeline

2005

UNIVERSITY OF LEEDS

2008

The power recovery cycle demonstrated in lab-scale tests

2010

Installation of power recovery cycle in pilot plant

2011

Installation of complete pilot CryoEnergy Storage plant

2012

Highview signs co-operation agreement with the Messer group

MESSER Gases for Life

2013

Highview enters into a licence agreement with General Electric

2014

Highview and project partners, Viridor, awarded funding for a 5MW LAES demonstration project by the UK Government

Viridor Transforming waste™

2015

NAVFAC Naval Facilities Engineering Command

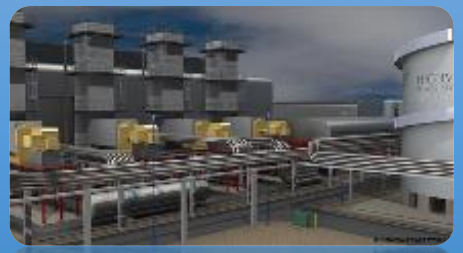
Multiple feasibility studies awarded, including an award from the U.S. Navy

Frost & Sullivan awards Highview with *Global Large-Scale Energy Storage Technology Innovation Award*

FROST & SULLIVAN

2016

Highview's grid scale High Grade Cold Store (HGCS) commissioned at the 5MW Pilsworth demonstration plant



Future

The new conceptual GigaPlant 200MW/1.2GWh

Highview expanding into the US with new office in New York, a key market for LAES

2017

acre

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Transition toward a greener grid

Past

- Centralized stable power generation
- Power generation balanced to demand

Future

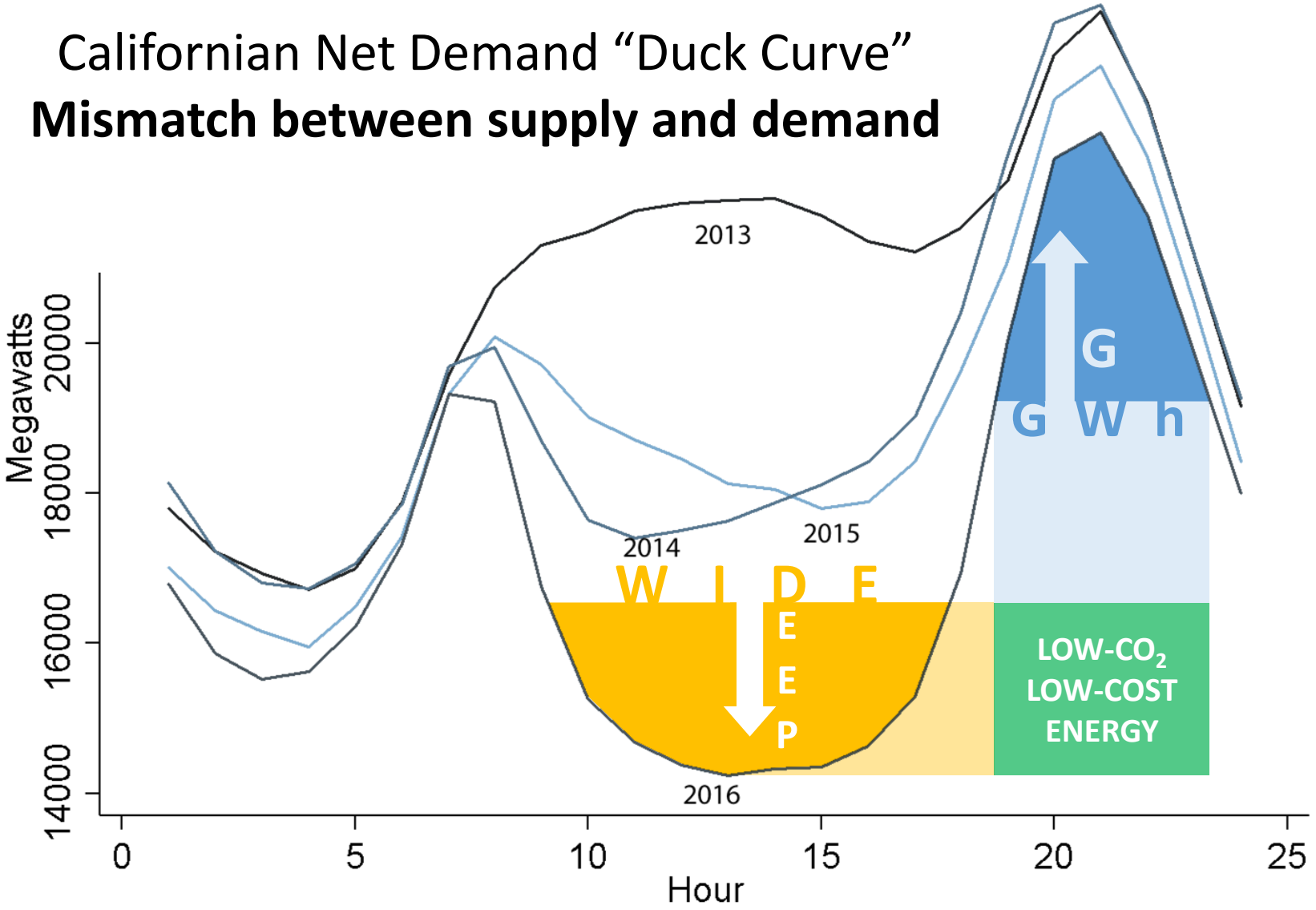
- More intermittent generation
- Power generation de-centralized
- Demand balanced to supply

Maintaining reliable supply while cutting carbon emissions

Why energy storage?

Californian Net Demand "Duck Curve"

Mismatch between supply and demand



Source: Adapted from http://reneweconomy.com.au/californias-duck-curve-has-arrived-earlier-than-expected-36106/

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Beyond energy arbitrage

Power Generation

- Managing intermittent renewable generation
- Energy Arbitrage
- More efficient baseload operation of gas and nuclear plant

Transmission

- Ancillary services
- Managing transmission constraints

Distribution

- Reactive power
- Voltage support
- Local reliability

End Users

- Reliability
- Demand charge reduction

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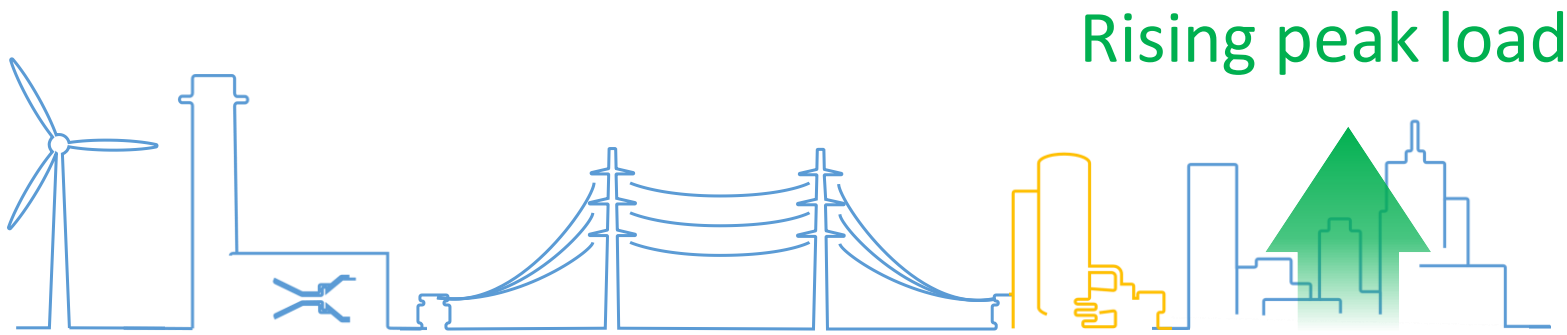
Transmission & Distribution deferral

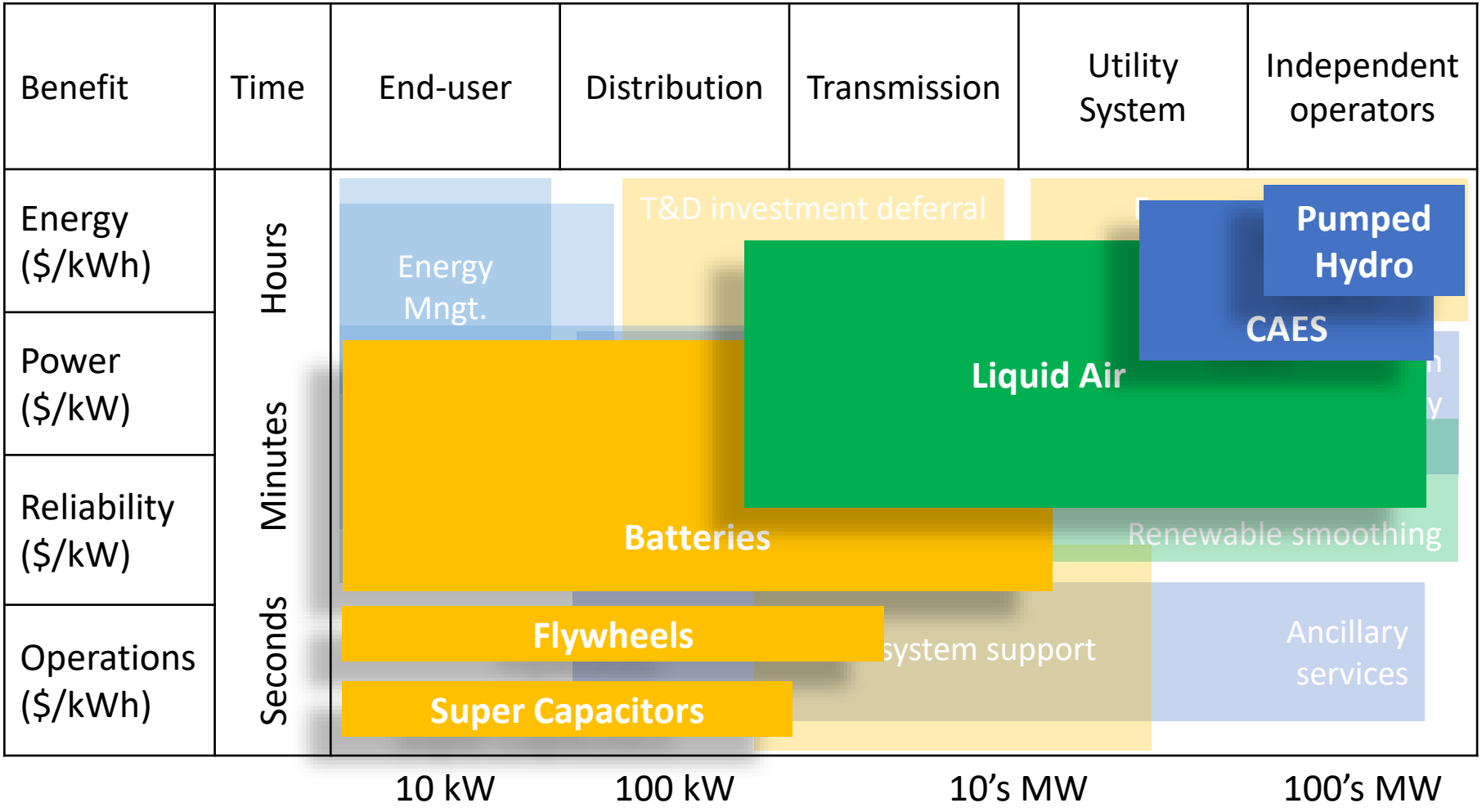
Traditional solution: Upgrade wires and transformers for the transmission peak



"Non-wire" solution: Serve extreme peak with energy storage

Energy Storage – different needs

Wide range of services performed by **different types of energy storage**



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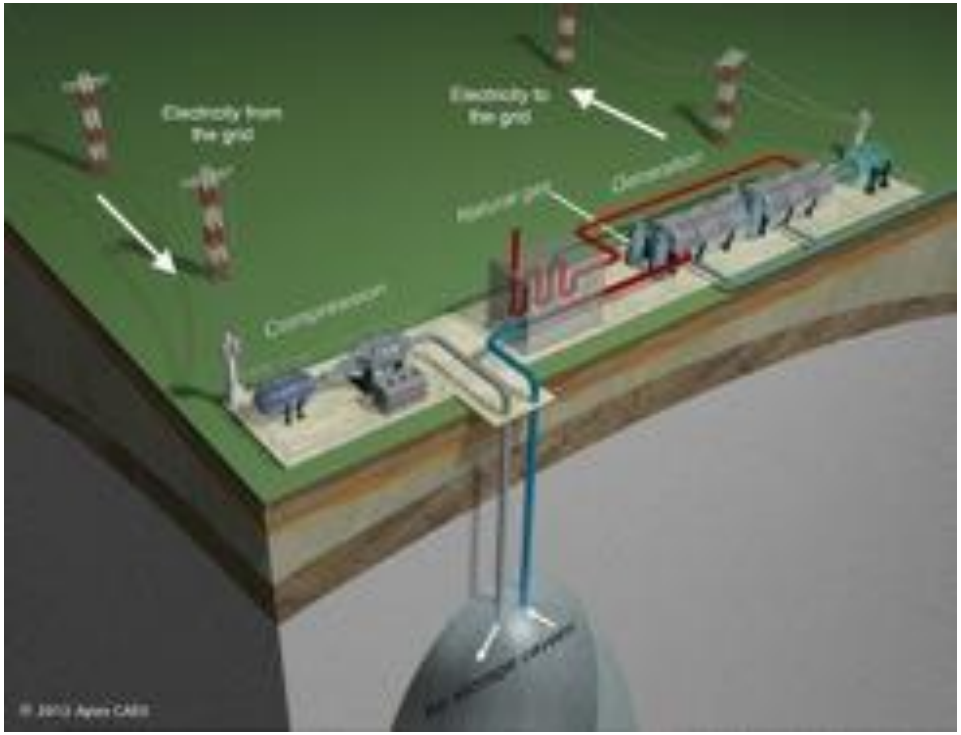
Current Solutions for bulk energy storage



Compressed Air Energy Storage (CAES) – requires caverns

Storing high pressure above ground is expensive

Pumped Hydro – requires mountains

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Video

https://www.youtube.com/watch?v=nl0WzD4EuwU

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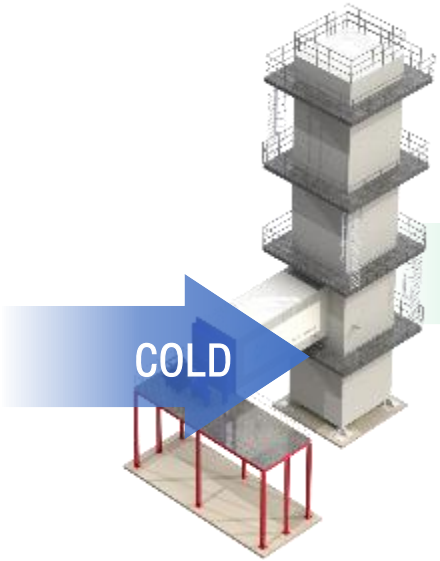
How does LAES work?

1. Charge

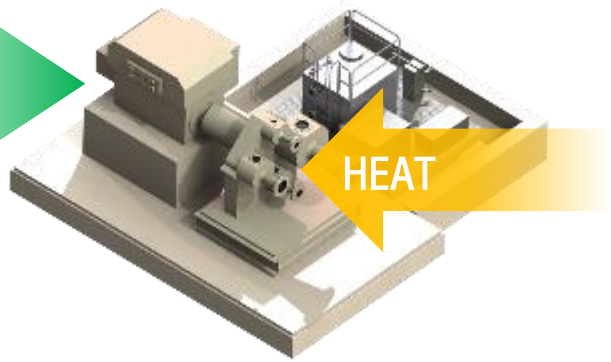


Off-peak or excess electricity is used to power an air liquefier to produce liquid air.

2. Store

The liquid air is stored in a tank(s) at low pressure.

3. Discharge

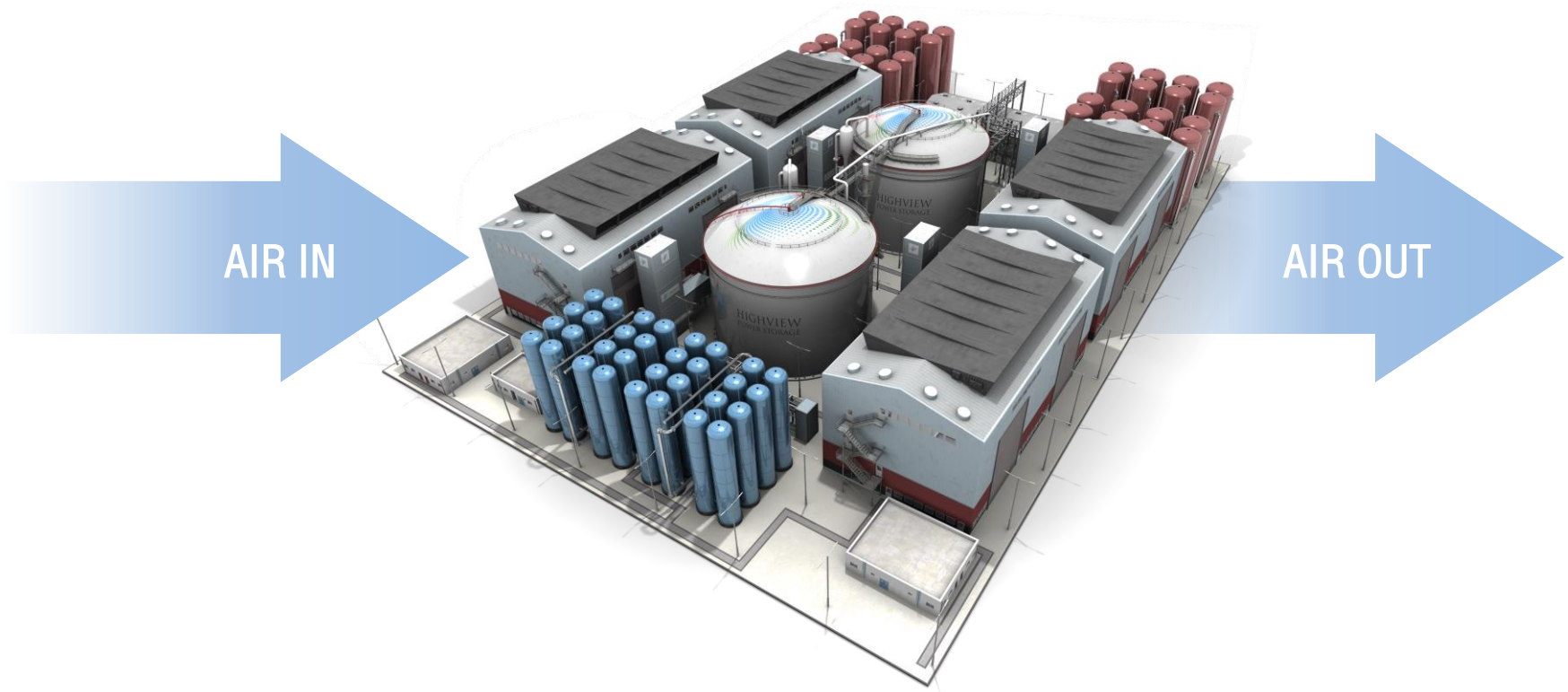


To recover power the liquid air is pumped to high pressure, evaporated and heated. The high pressure gas drives a turbine to generate electricity.

The three components are **independently sizeable**

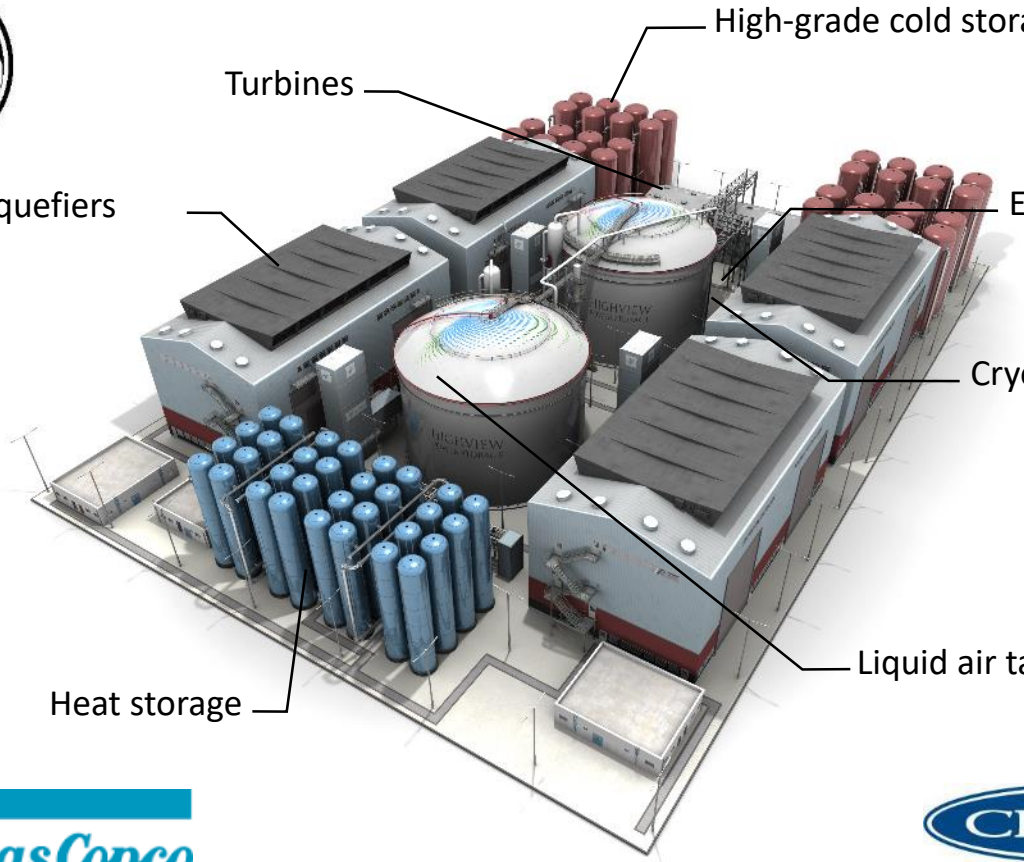
Environment

LAES cycle produces **zero emissions** and works with **benign materials**



Major Equipment Suppliers for LAES

Leveraging an **established supply chain** through relationships developed through our projects



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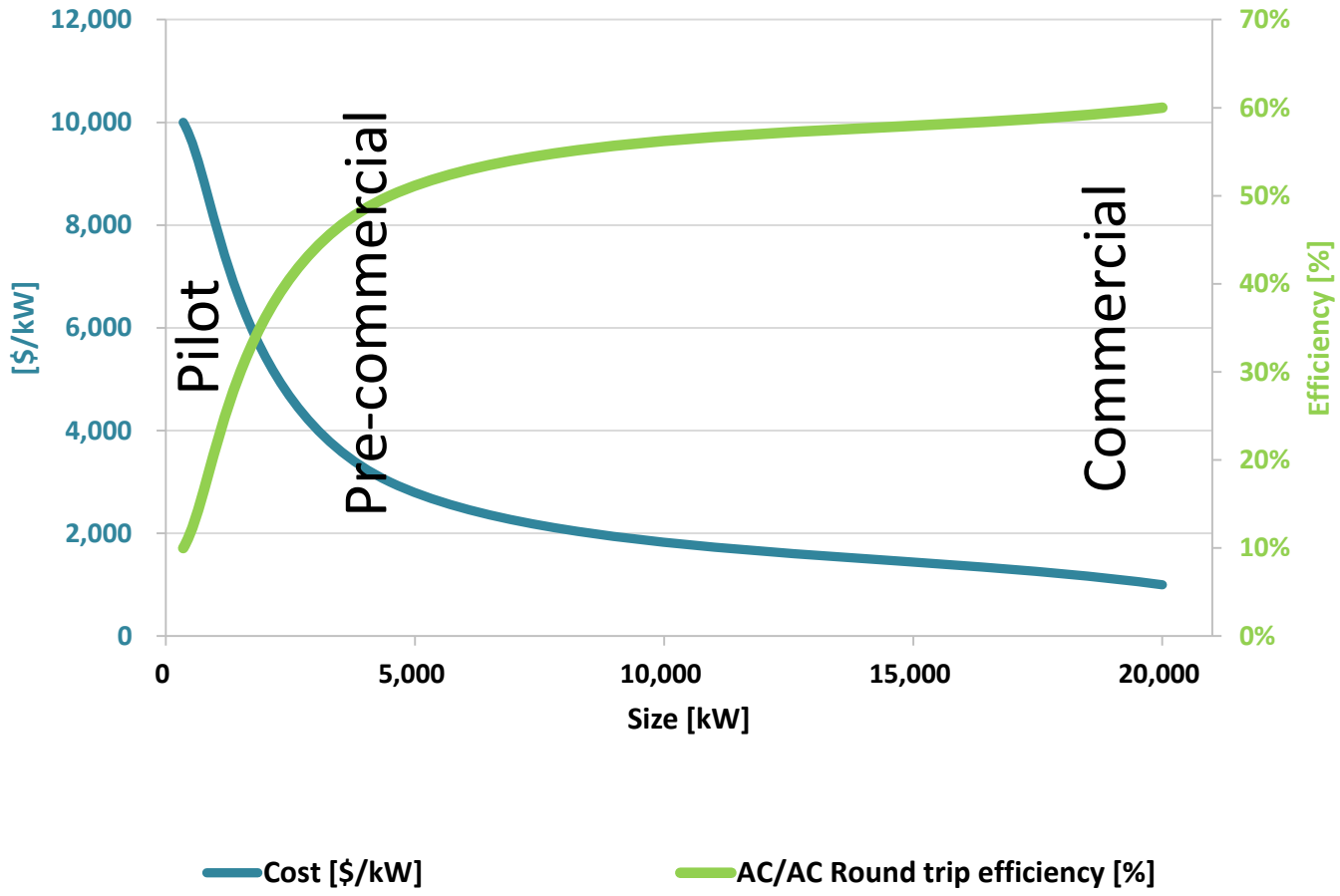
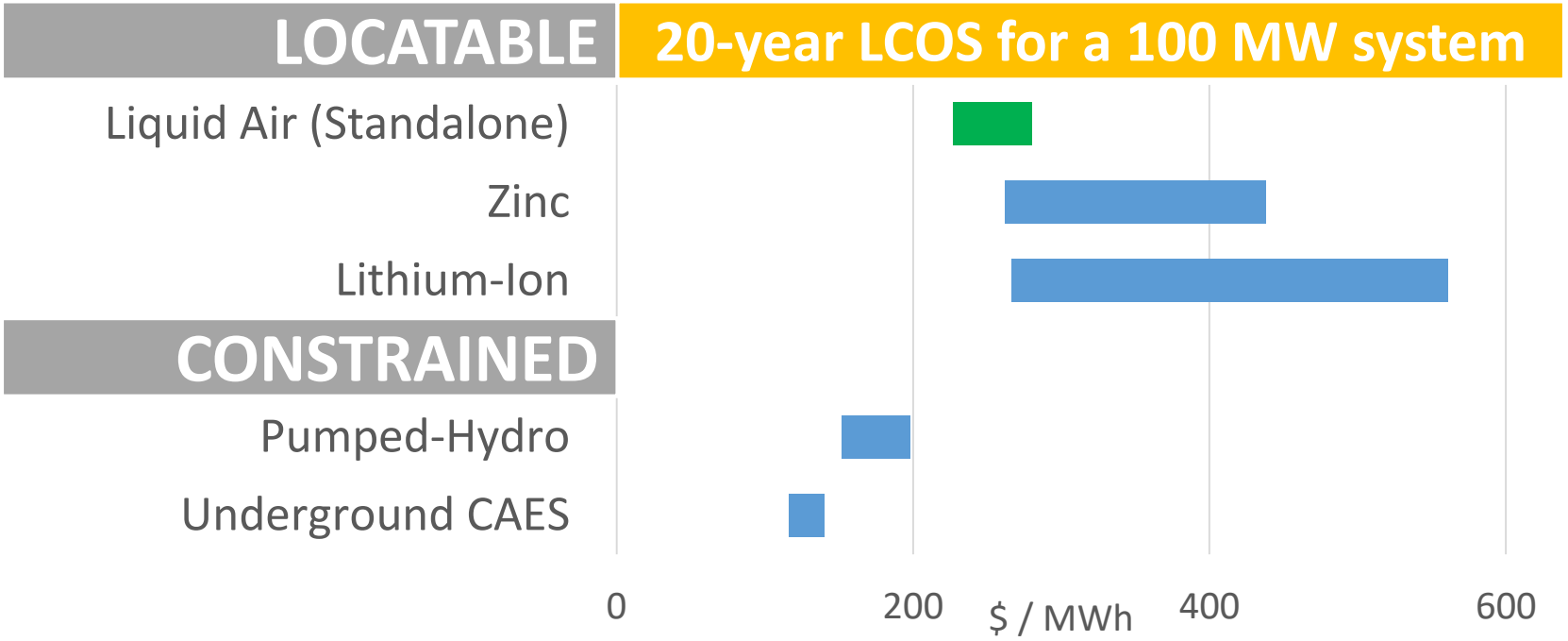
Cost & Performance



Lifetime cost

Lowest cost large-scale energy storage technology that can be **built anywhere**

$$\text{Levelized Cost of Storage} = \frac{\sum_t \left(\left(CAPEX_t + O\&M_t + Replacement_t + Fuel_t \right) * (1+r)^{-t} \right)}{\sum_t \left(Electricity\ Generated_t * (1-r)^{-t} \right)}$$

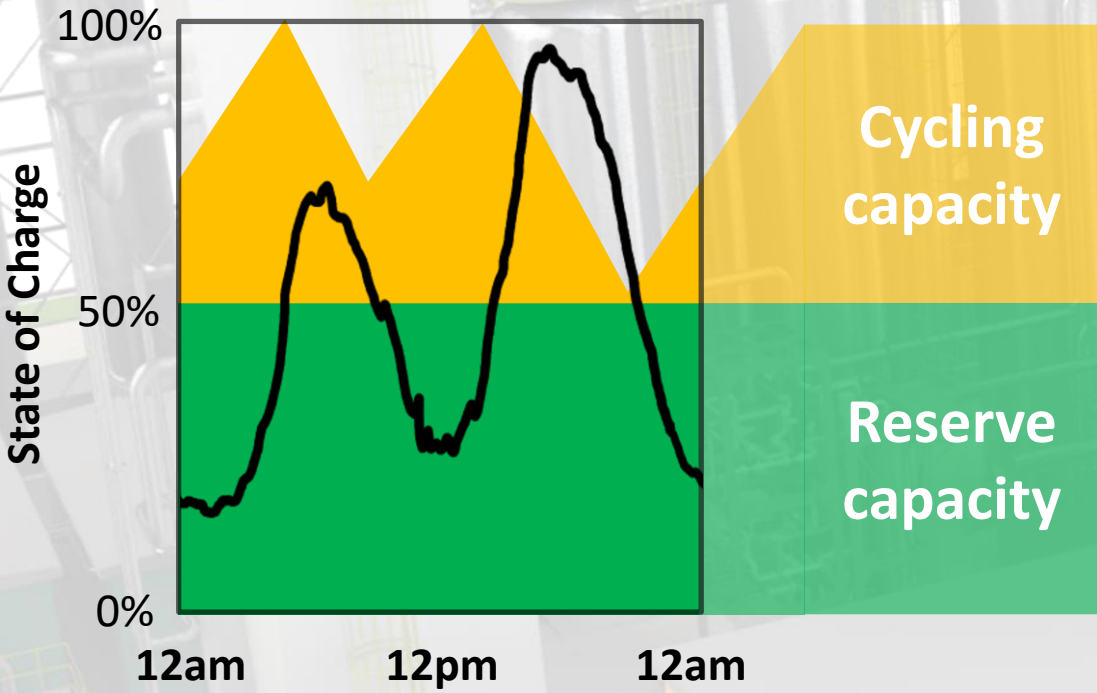


SOURCE: Data from *Lazard LCOS 2.0* (*https://www.lazard.com/media/438042/lazard-levelized-cost-of-storage-v20.pdf*)

Low marginal cost of additional energy capacity

(as little as 20 $/kWh$_{CAPEX}$*)

Low-cost Reserve Capacity can be held for events such as black start or infrequent peak events to avoid T&D upgrades.



*as low as $20/kWh with heat available, as low as $40/kWh without.

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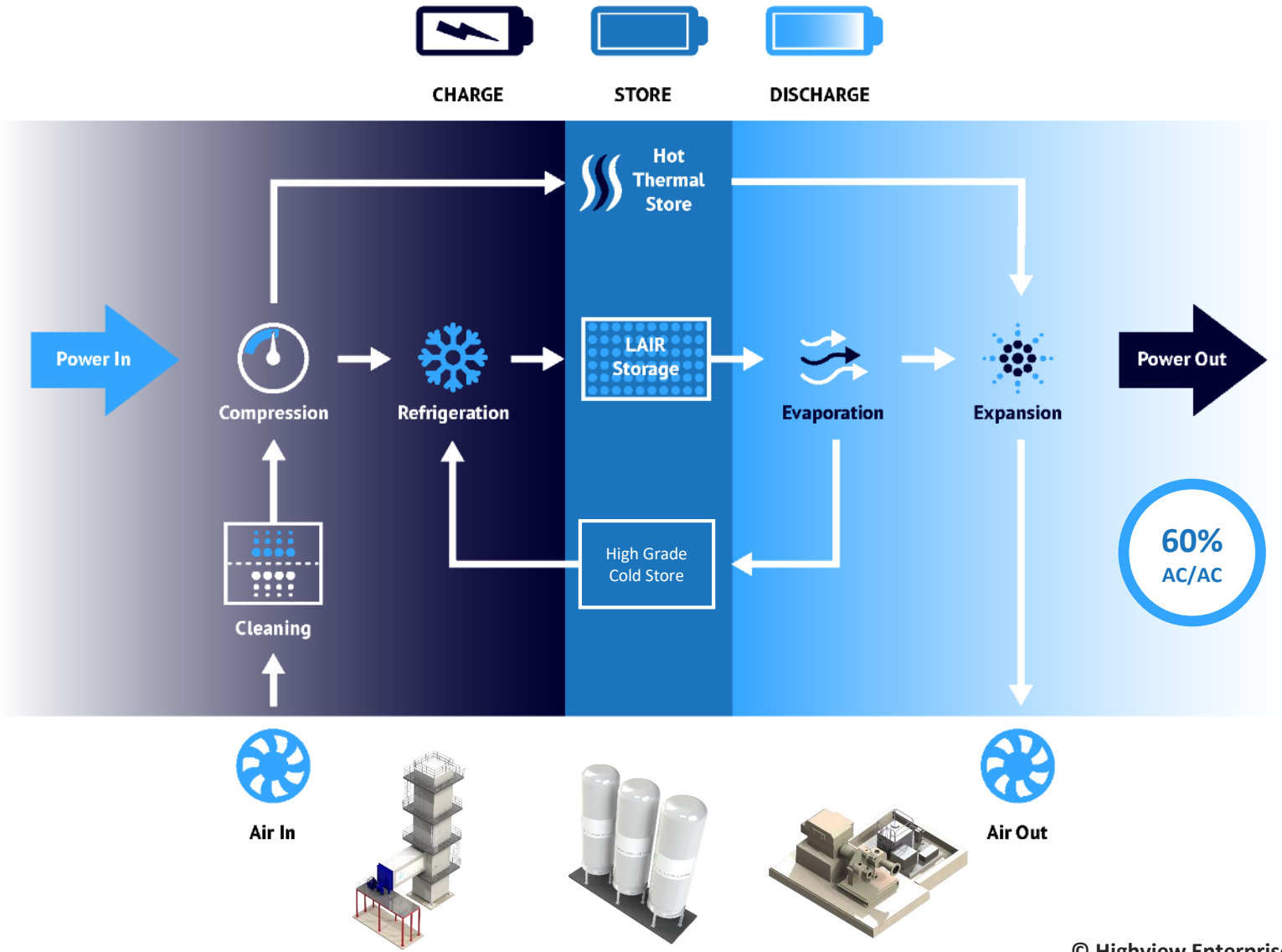
LAES – Standalone Configuration



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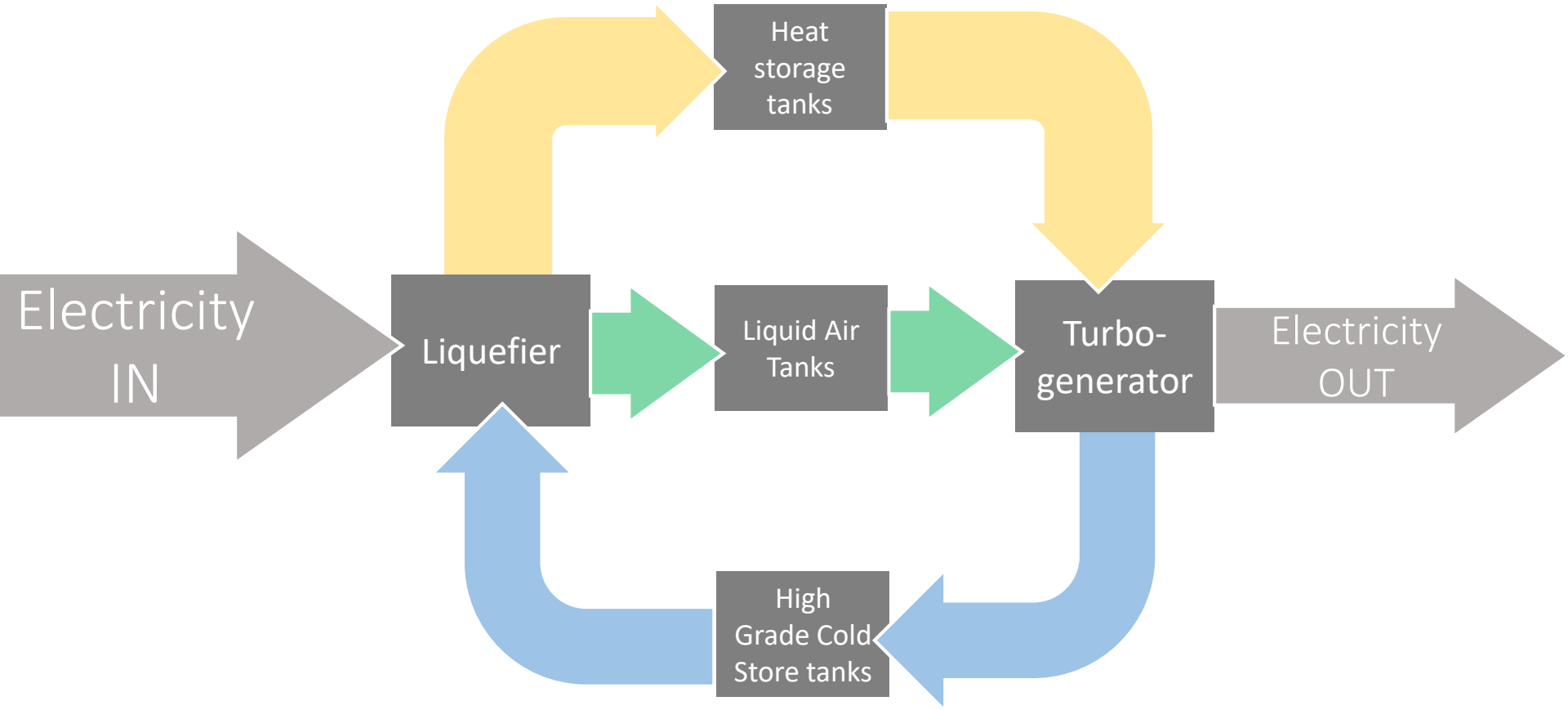
LAES – Standalone Configuration



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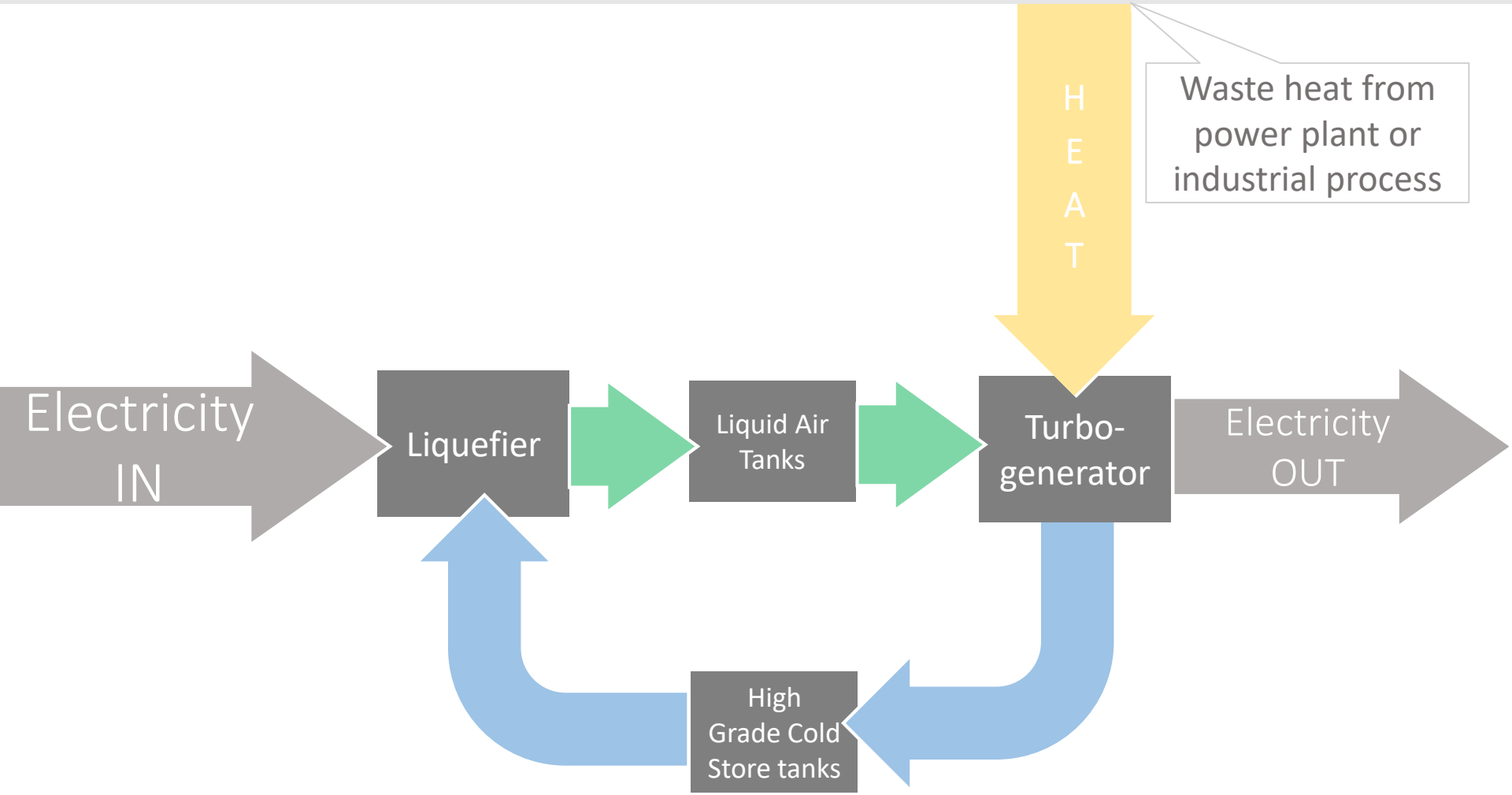
LAES – Waste heat configuration



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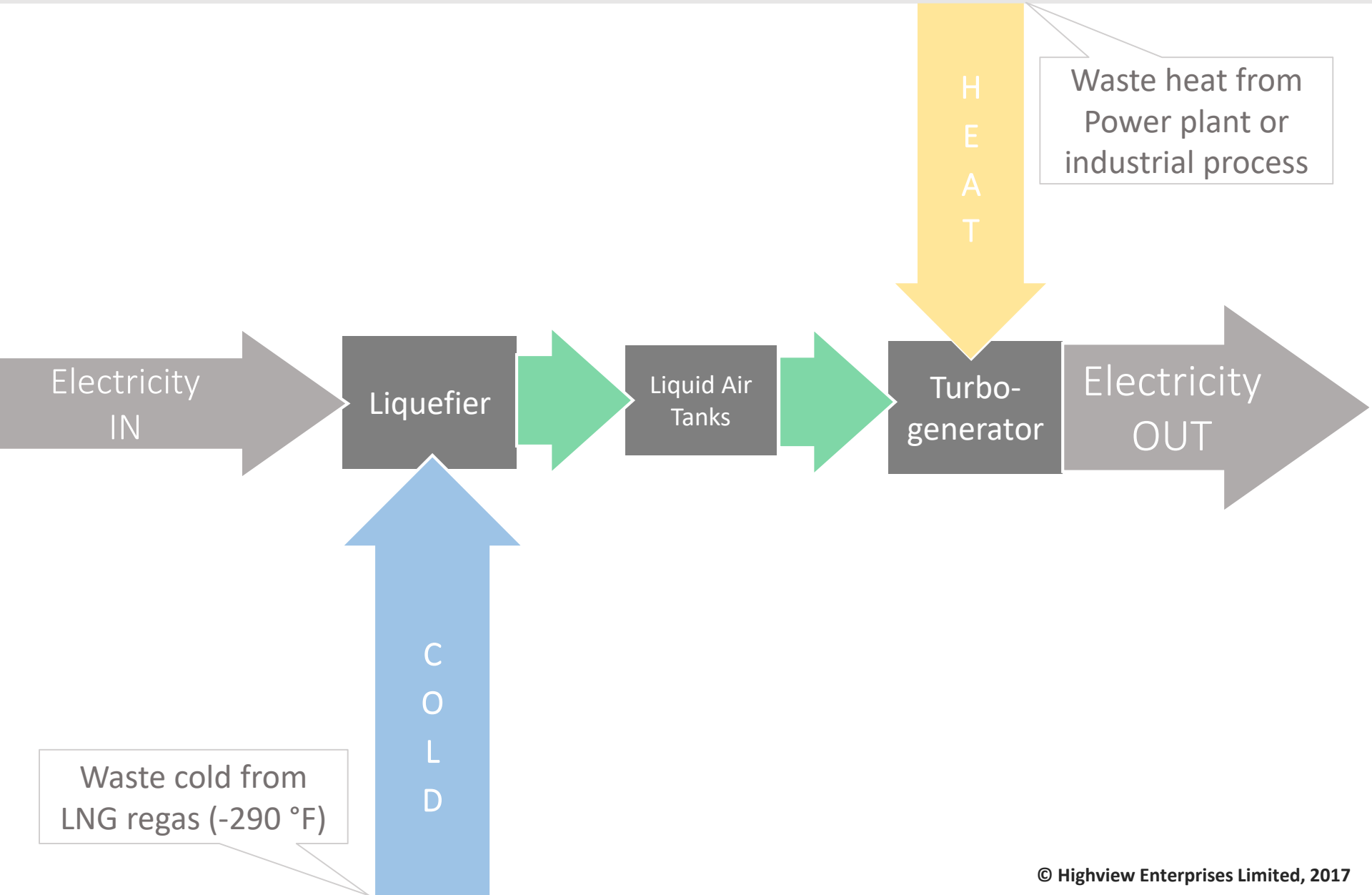
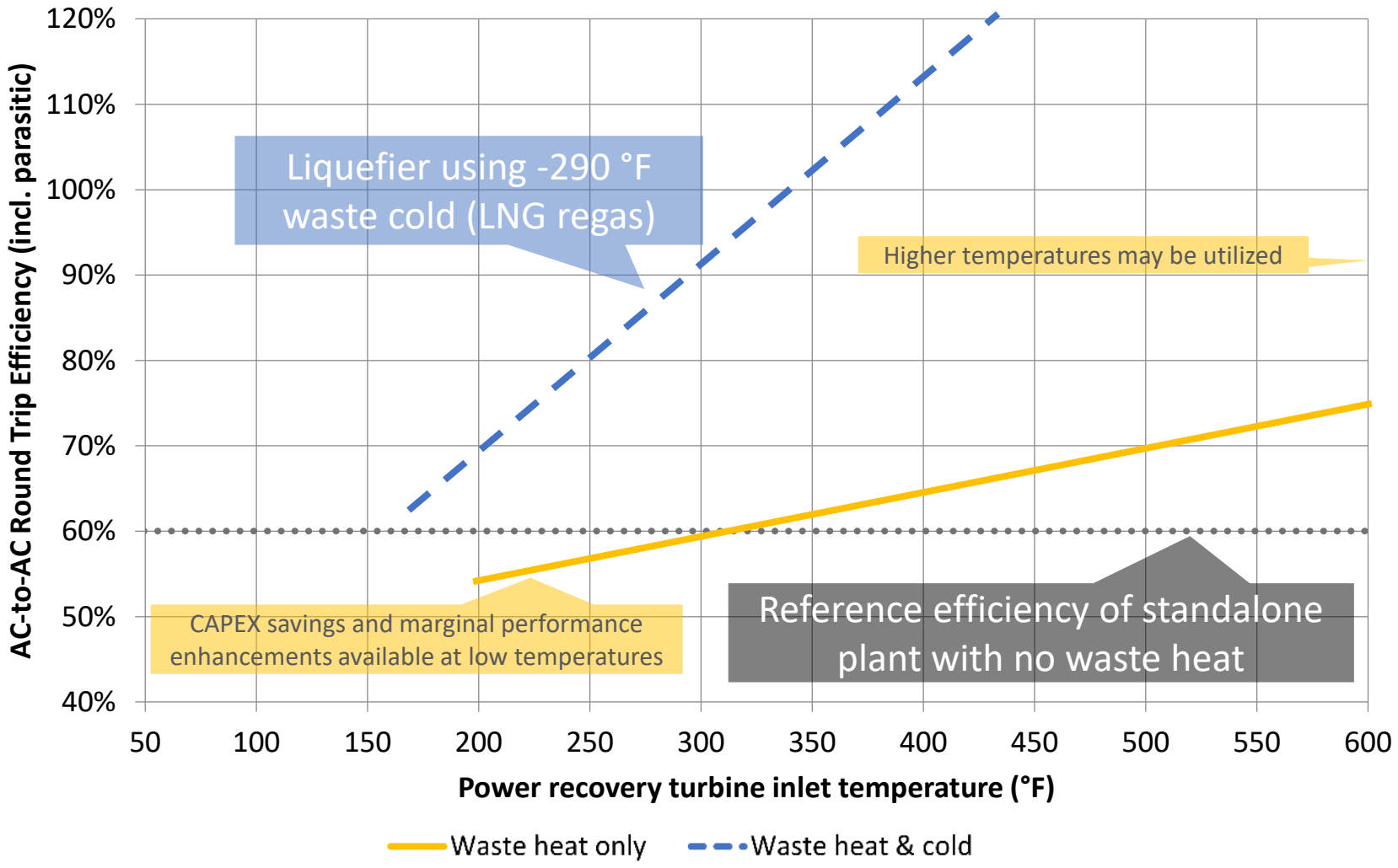
LAES – Waste heat & cold Configuration



Performance – Round Trip Efficiency

Efficiency depends on temperature of waste heat and availability of cold and on scale



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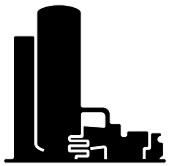
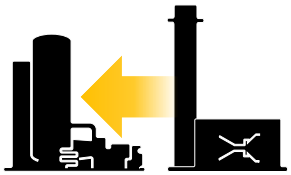
Applications



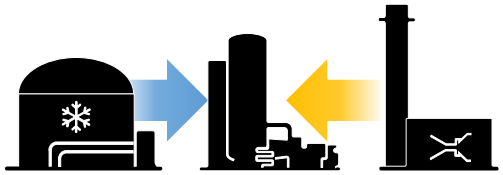
Standalone

- Deploy at maximum value location
- Perform grid services
- Optimise grid utilization



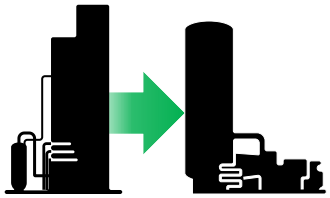
Waste heat integration

- Located next to thermal process
- Improved performance & reduced cost
- Synergetic operation with thermal process



Waste cold integration

- Located next to thermal process
- Very high performance and reduced cost
- Synergetic operation



Excess cryogen integration

- Located with ASU
- Significant cost offset (no dedicated liquefier)
- Synergetic operation with ASU or associated industry

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350 kW / 2.5 MWh Pilot

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5MW / 15 MWh Demonstrator

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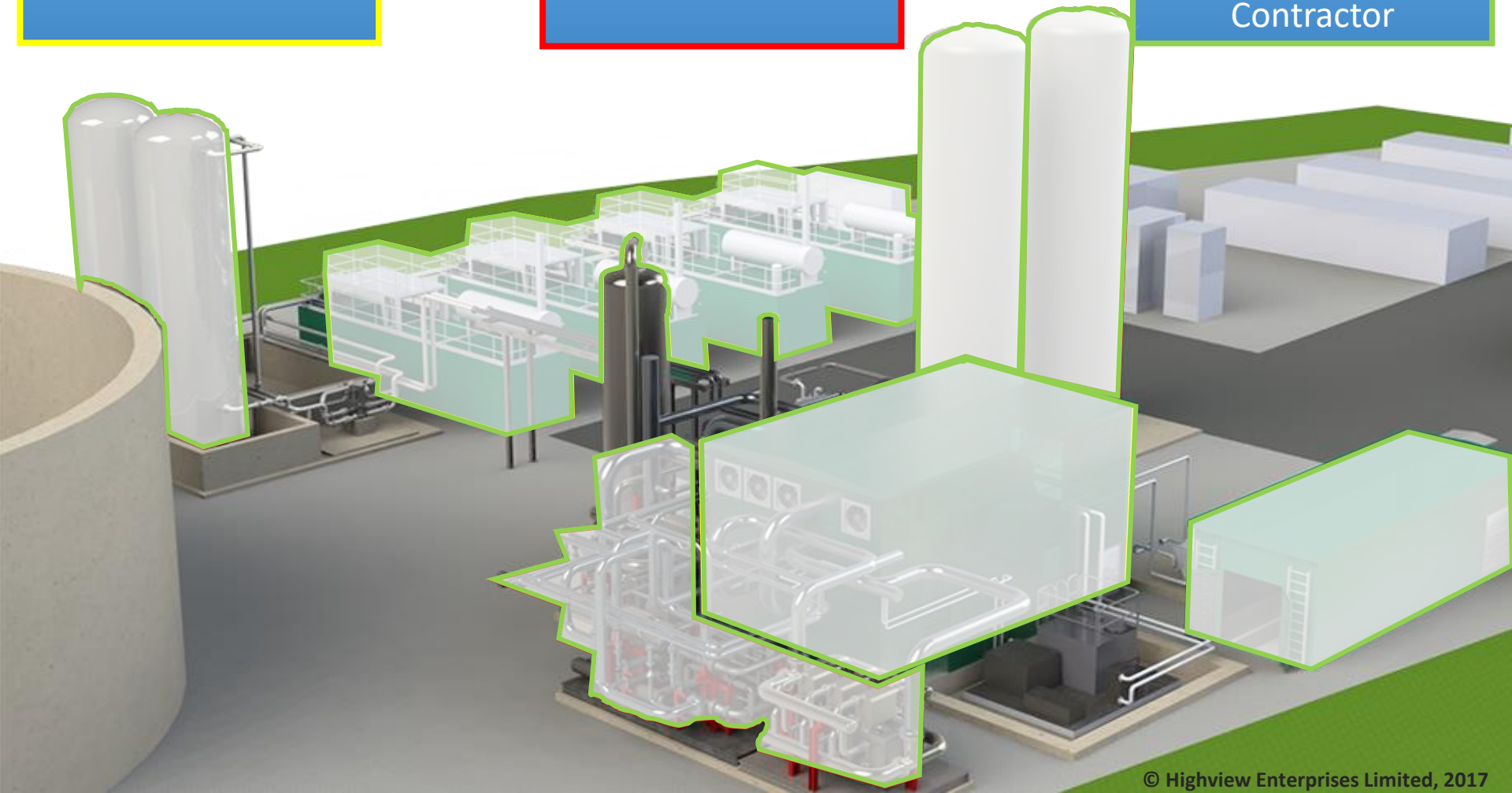
The Importance of the Supply Chain - Deliverability

Original Equipment Manufacturer - OEM

Balance of Plant (BoP) Providers

Engineering Procurement Construction (EPC) Contractor



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Peaker plant

Improved Peaker offering: enhanced capacity and storage services

- Developed in collaboration with General Electric
- Charge off peak / dispatch with the gas turbine
- 900 °F exhaust heat utilized
- Increased output
- Designs completed for 20 MW / 4-hour systems

CPV Sentinel Energy Project, image courtesy of GE Energy Financial Services

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GigaPlant

Site area 160m x 100m (4 acres) maximum height 22m

Project Economics

Total Capex	$230m
Output Power	200MW
Storage Capacity	1.2GWh
AC/AC RTE	60%
Cost per kWh	$191
LCOE per MWh	$155

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LAES technology benefits

A **highly customizable** storage solution offering **unique advantages**

Mature components with lifetime of **30+ years**

Cost and revenue **improve with scale**

Large-scale GW and GWh

Can be **built anywhere**

Zero emissions and benign materials

Ready to deploy with an established supply chain

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