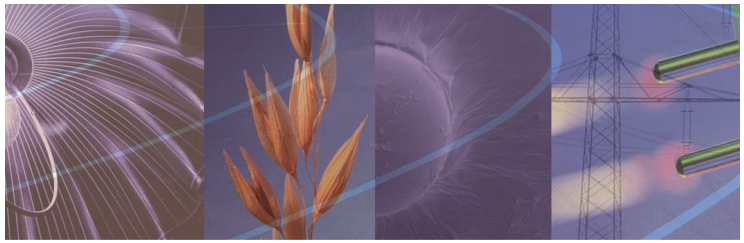
LTA-CAES
Low-temperature Adiabatic Compressed Air Energy Storage

IRES 2011
November 28, 2011



Daniel Wolf

Fraunhofer
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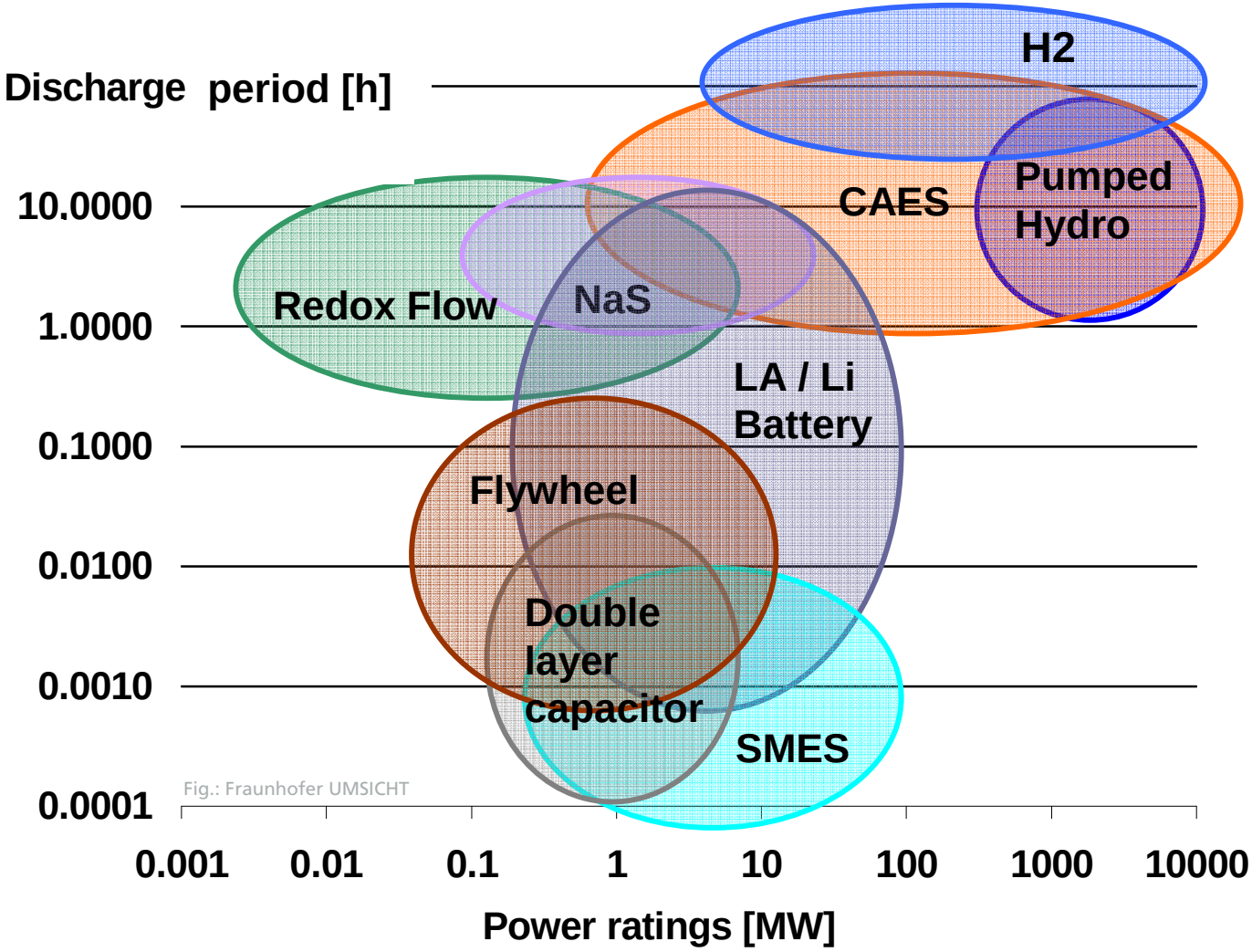
Why CAES ?

Comparison of storage technology and application

Storage Technologies



Application

- Long-term wind fluc. compensation
- Load levelling
- Island grid
- Peak shaving
- Tertiary reserve
- Secondary reserve

- Primary reserve
- Uninterruptible power supply
- Flicker compensation
- Voltage sag correction

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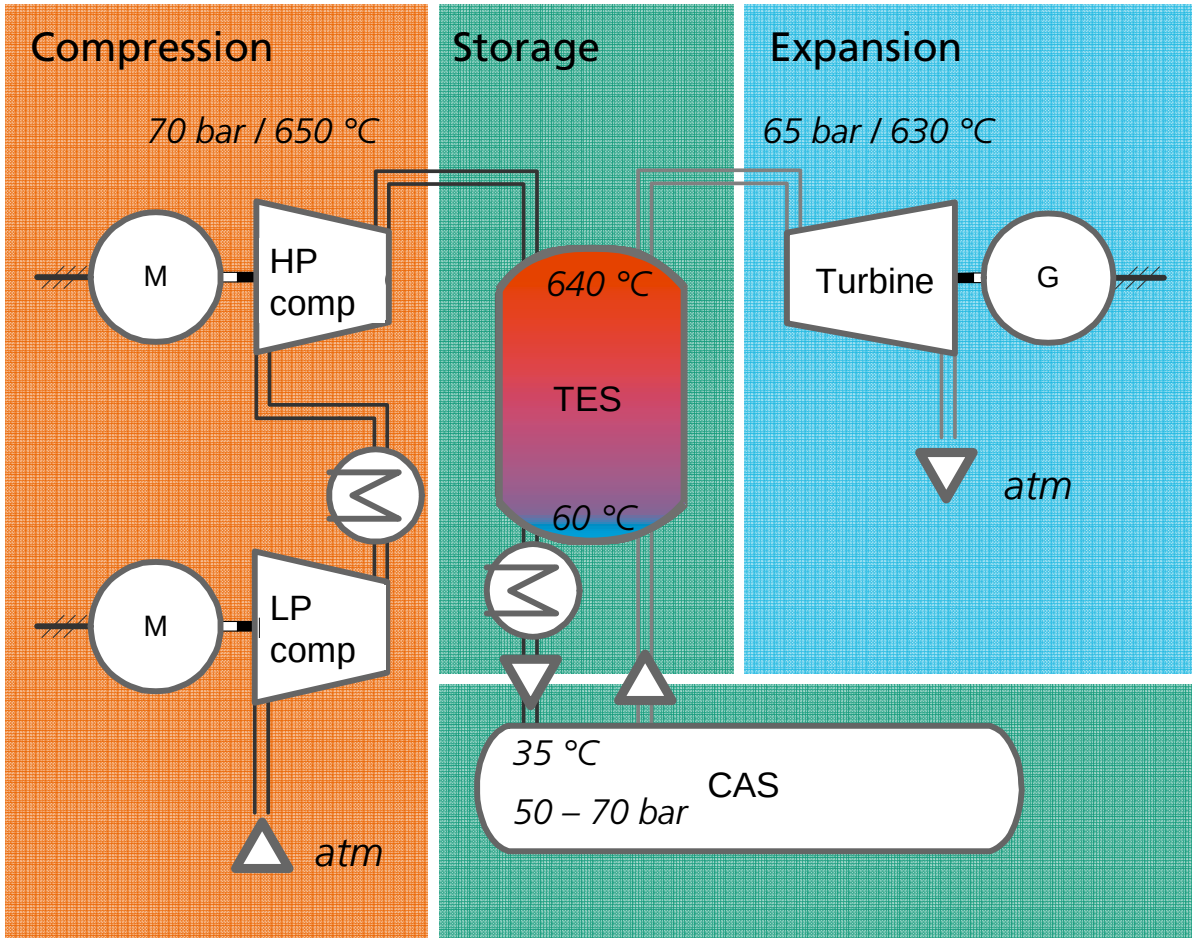
Current A-CAES visions

Adiabatic CAES

Current approach on high-temperature A-CAES



Advantages

- Cheap solid TES material
- High TES energy density
- High CAES cycle efficiency (~ 70%)

Challenges

- Demanding compressor outlet temperatures
  → compressor redesign required
- Pressurized TES at high temperatures
  → active jacket cooling required
  → risk of abrasion

→ Results in start up times of ~15min

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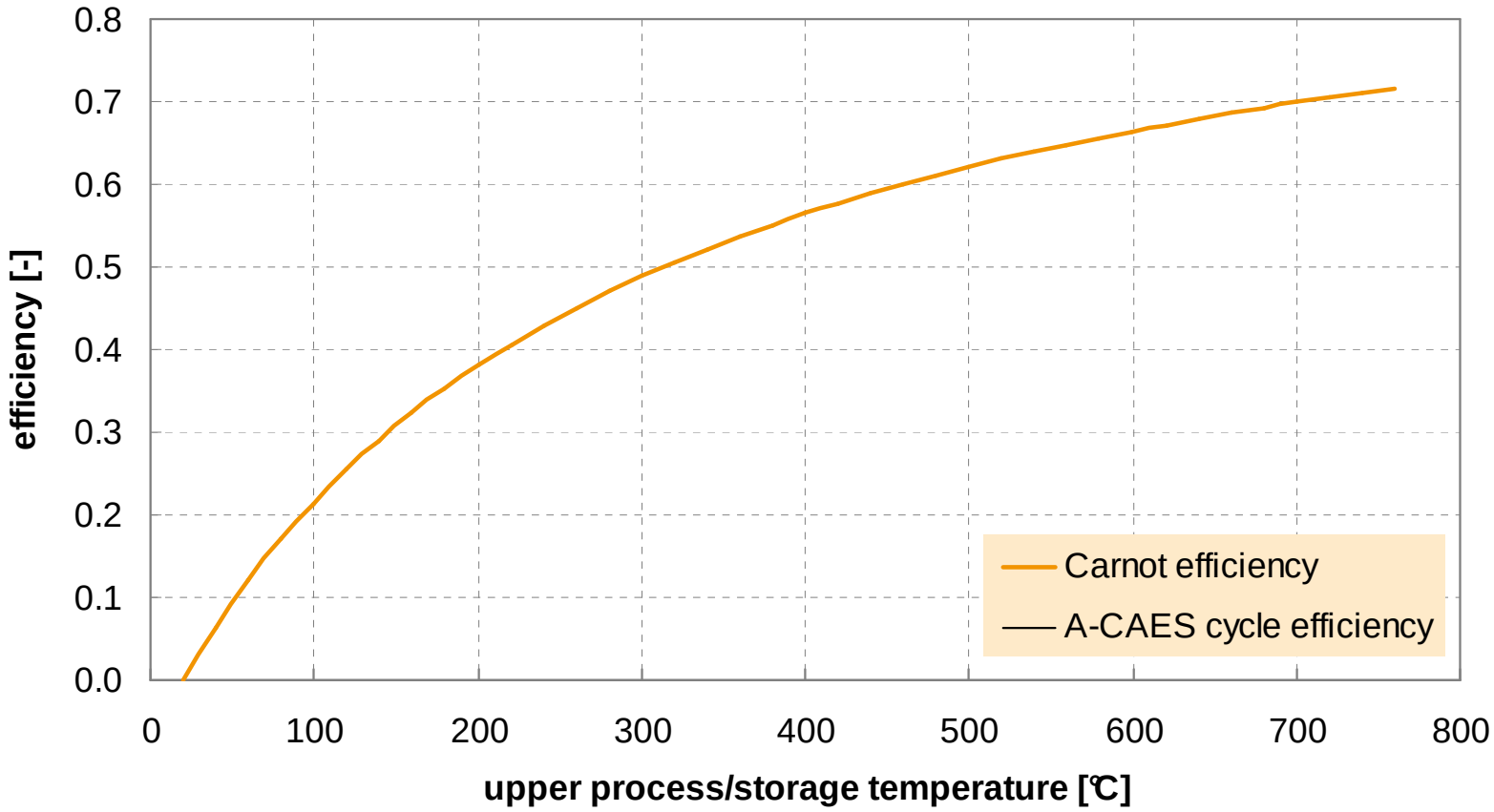
A-CAES cycle efficiency

How temperature dependent is A-CAES cycle efficiency?

$$\eta_{Carnot} = 1 - \frac{T_{min}}{T_{max}}$$



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A-CAES cycle efficiency

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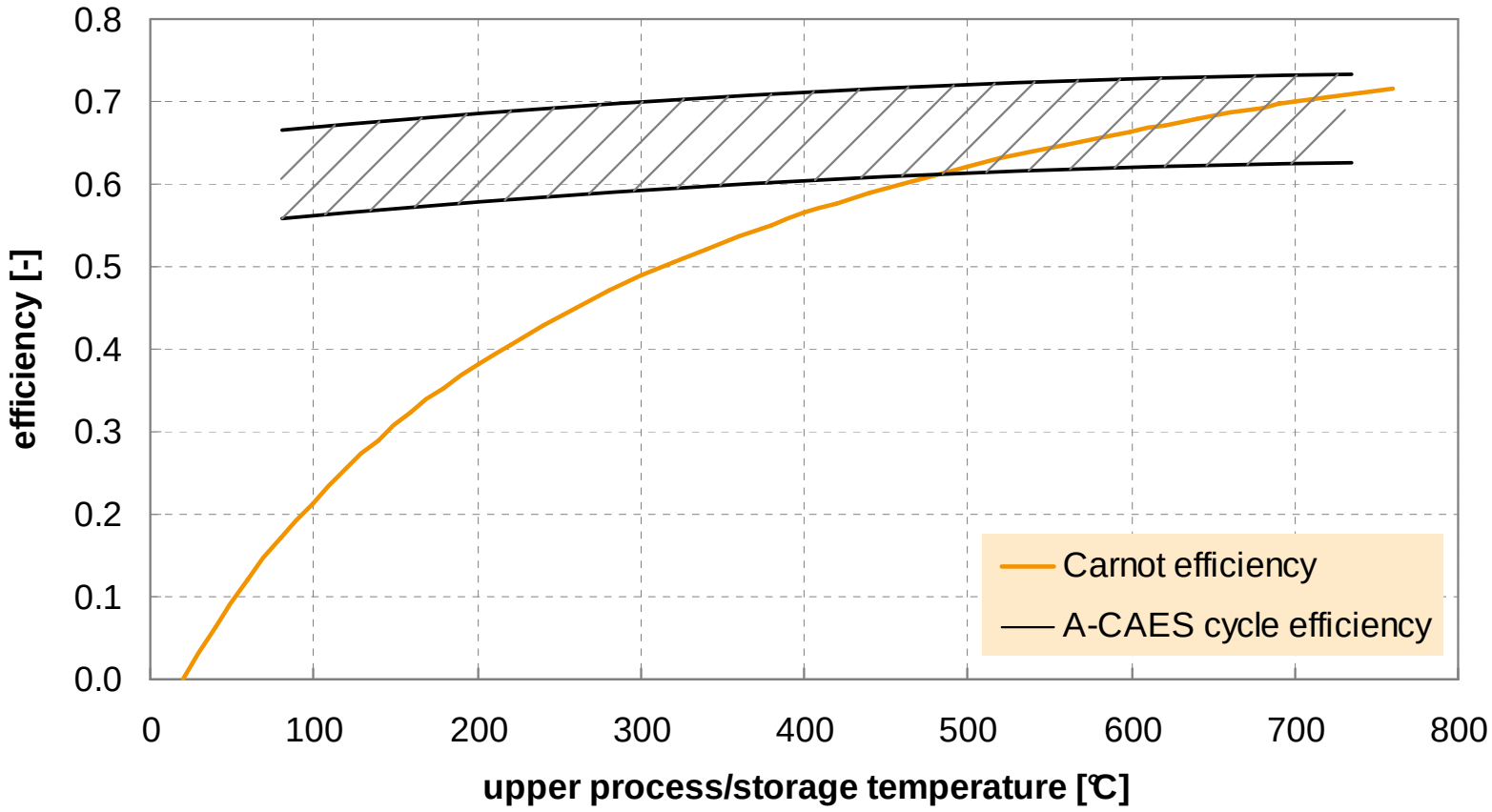

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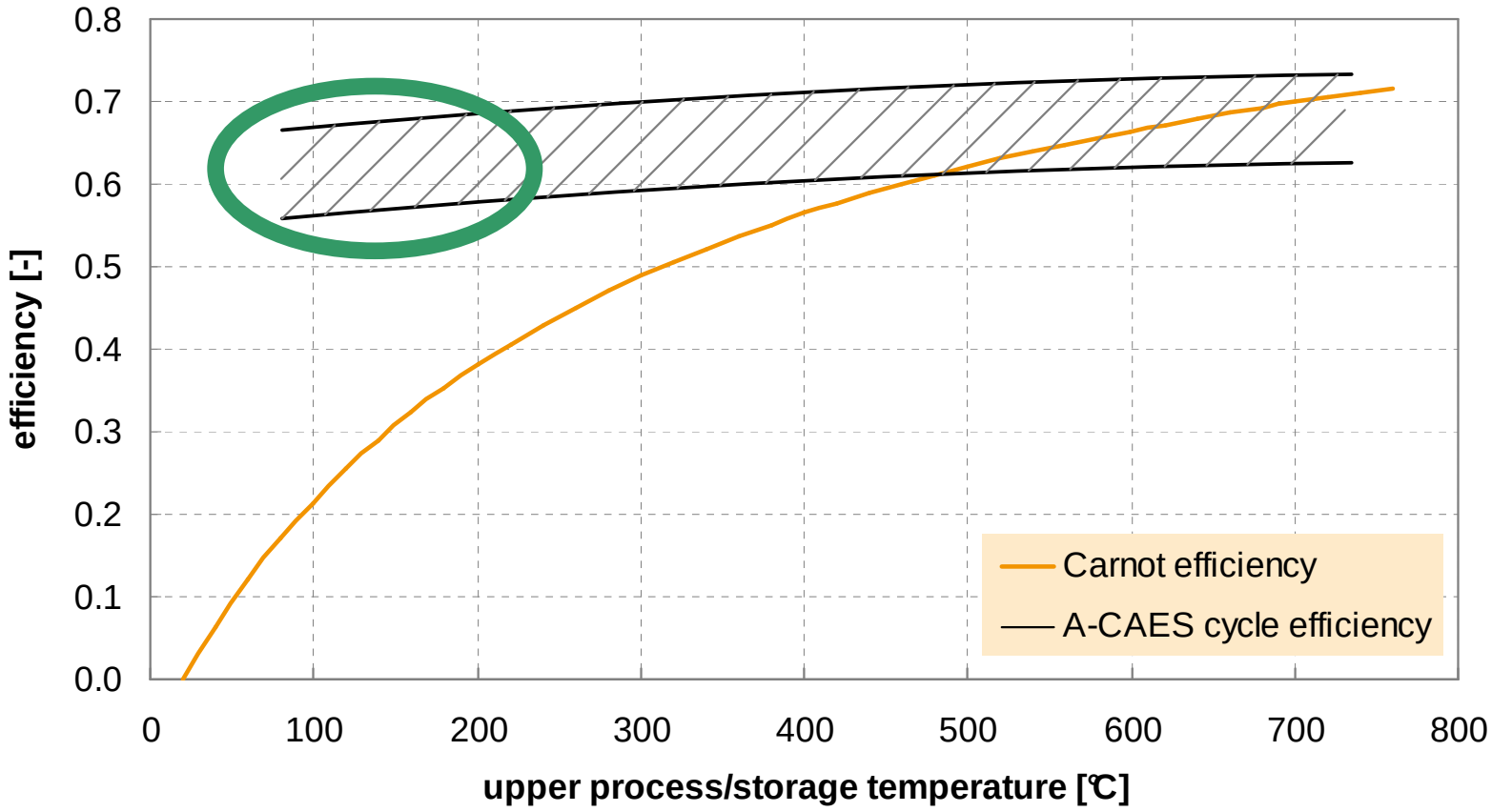

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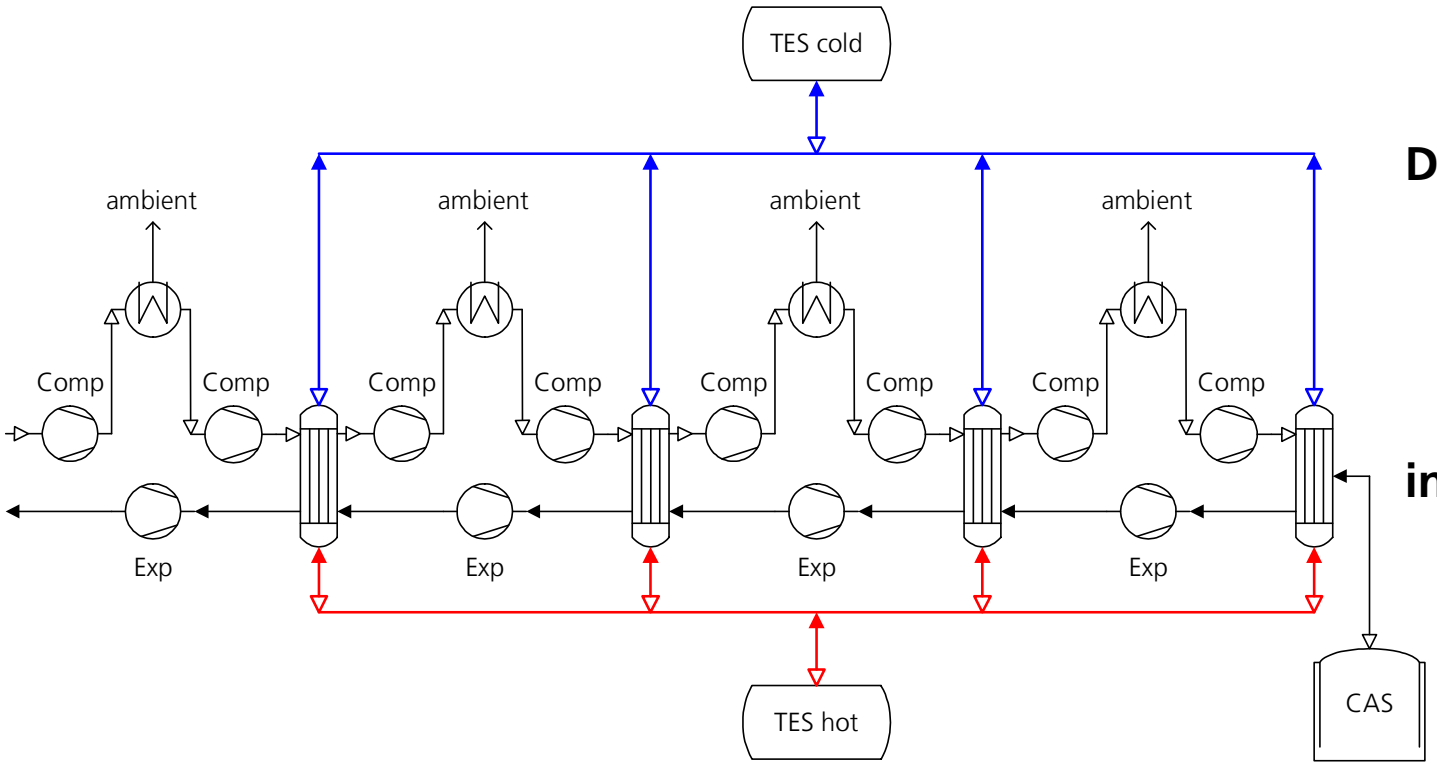
LTA-CAES

LTA-CAES

Basic technical characteristics

- **Turbomachinery: Radial compressor and expander stages**
- **Heat transfer: Shell/tube heat exchangers**
- **Thermal Energy Storage (TES): Two-tank with liquid TES medium**



Detailed plant design for:

- 5 MW_{comp} / 70 bar
- 50 MW_{comp} / 150 bar

in collaboration with:

TURBOMASCHINEN BERLIN

OELTECHNIK

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LTA-CAES

Integrally geared radial stages

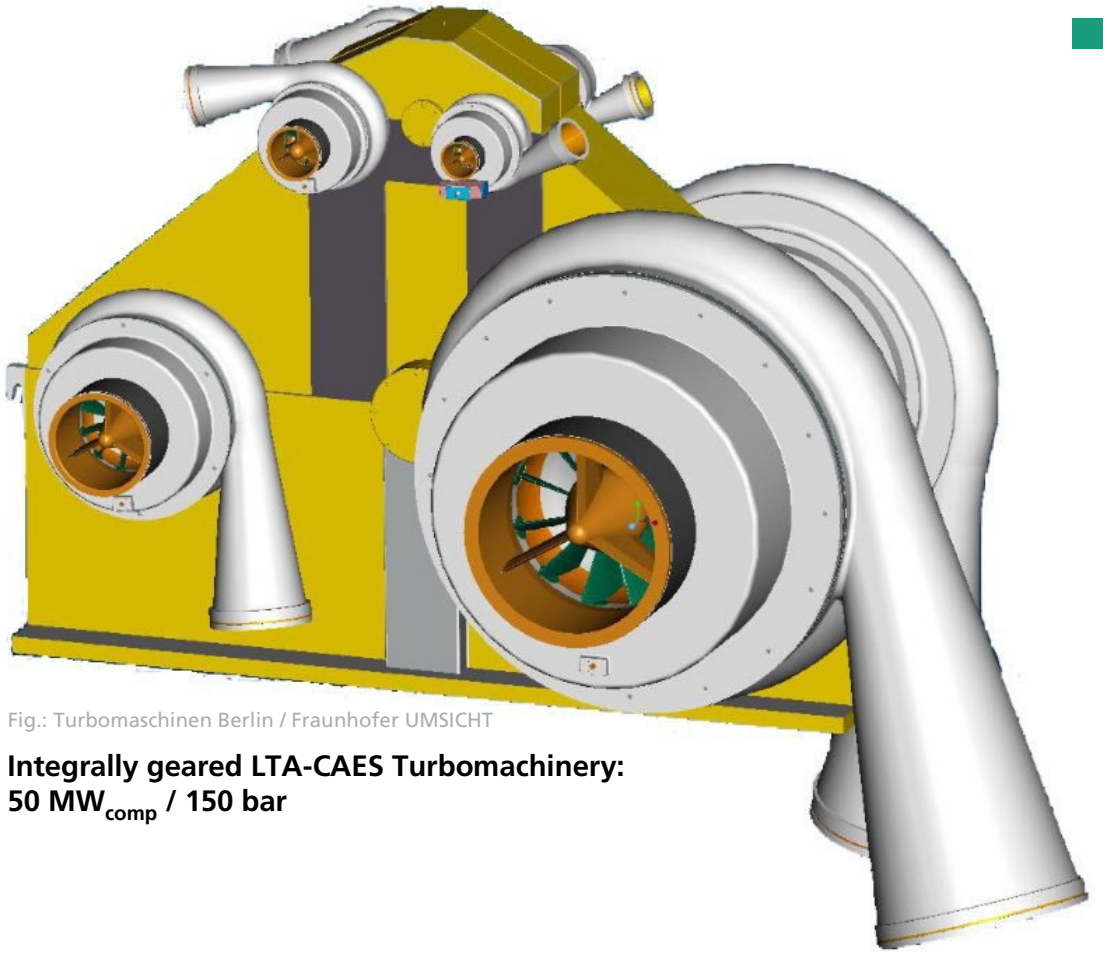

Fig.: Turbomaschinen Berlin / Fraunhofer UMSICHT

Integrally geared LTA-CAES Turbomachinery: 50 MW_{comp} / 150 bar

- Integrally geared drive
  - One shaft drives two radial stages
  - Individual rotational speeds for each shaft
  - Inlet guide vanes for each stage
    → broad control range

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Alternative drive concept: Directly driven radial stages

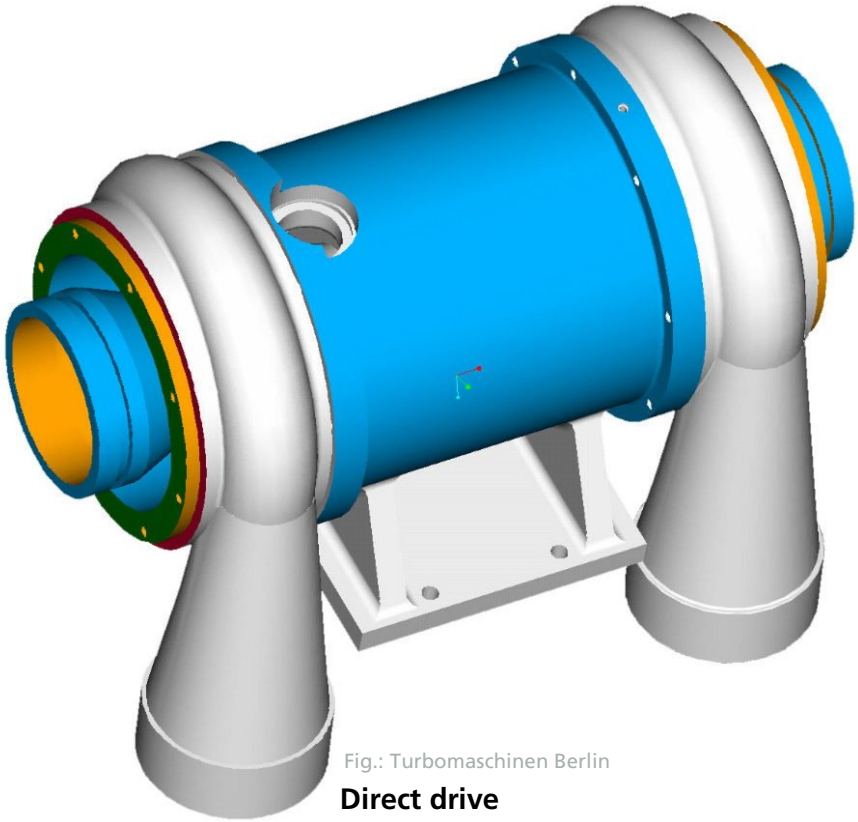

Fig.: Turbomaschinen Berlin

Direct drive

- Direct drive
  - Variable rotational speeds for each shaft
    → even broader control range
  - Single compressor/expander-unit
    "KompEx" possible !
    → significant decrease in initial investment

*for a integrally geared, two-digit MW plant with 8h of storage volume

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Summarizing plant characteristics

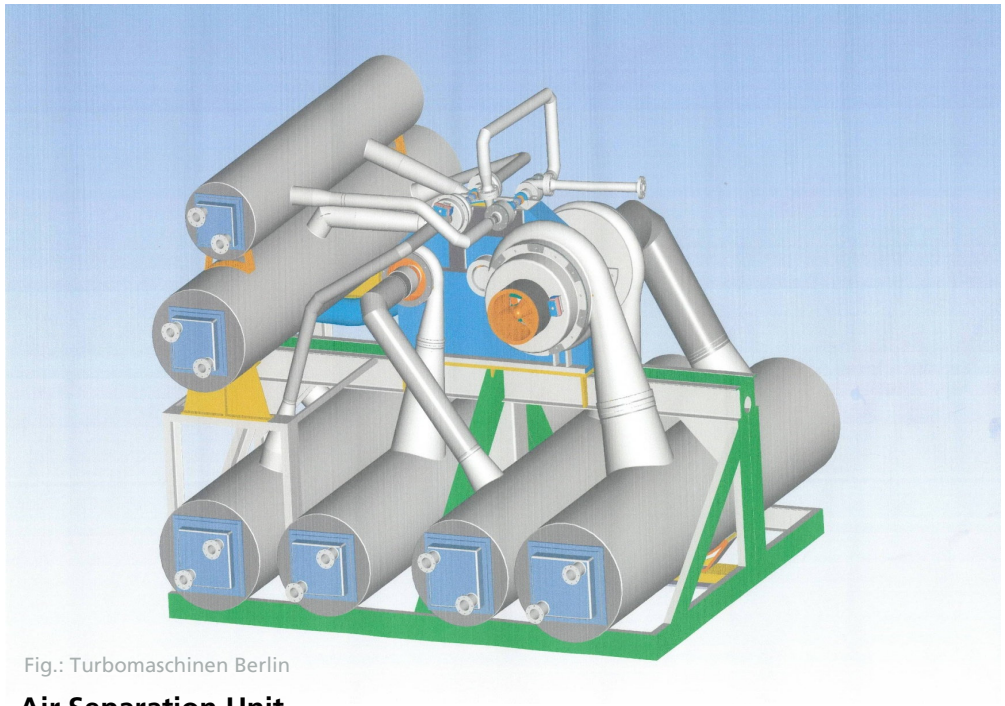

Fig.: Turbomaschinen Berlin

Air Separation Unit

- **Characteristics**
  - Based on proven components
  - Liquid, easy-to-handle TES medium
  - Broad control range
  - Fast start-up: < 5min
  - Cycle efficiency: 58 – 67%

- **Initial investment estimates:** **< 1,000 €/kW$_{turb}$***

*for a integrally geared, two-digit MW plant with 8h of storage volume

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LTA-CAES economics

Economics of LTA-CAES

Case study with GOMES®

- **Markets:**
  - Day-ahead spot market
  - Secondary reserve market
- **Plant configuration:**
  - 50 MW_{comp} / 35 MW_{turb}
  - Storage volume: 8h
- **Sensitivity:**
  - 0.60 and 0.65 cycle efficiency
  - 50 and 30% part load ability

Cycle efficiency	Part load ability	Spot market* only
[%]	[%]	Break even initial cost [€/kW_{Turb}]
60	50	272
	30	290
65	50	342
	30	387

*German spot and reserve market data from 2008 and 2009 were used

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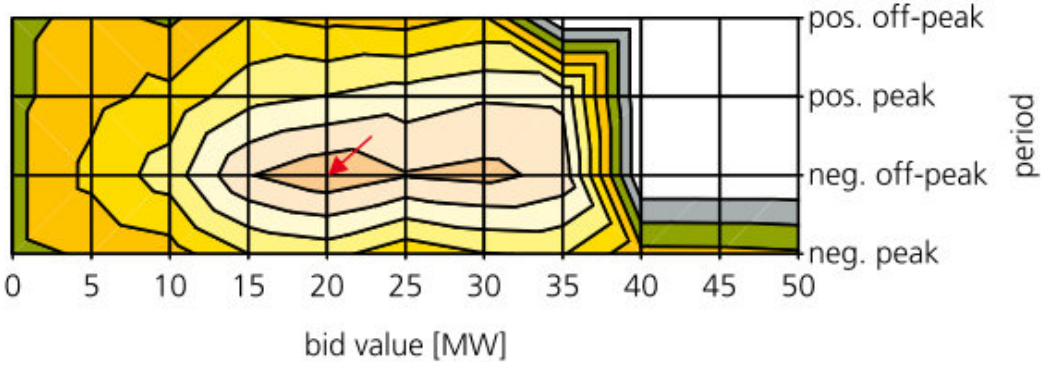
Economics of LTA-CAES

How does a more flexible operation translate into revenue?

Secondary reserve bid strategy:



Annual revenue:

< 5 Mio. €	5 Mio. €-10 Mio. €	10 Mio. €-15 Mio. €	15 Mio. €-20 Mio. €	20 Mio. €-25 Mio. €
25 Mio. €-30 Mio. €	30 Mio. €-35 Mio. €	35 Mio. €-40 Mio. €	40 Mio. €-45 Mio. €	45 Mio. €-50 Mio. €

Cycle efficiency	Part load ability	Spot market* only	Secondary Reserve (SRC) & spot market
[%]	[%]	Break even initial cost [€/kW$_{Turb}$]	Break even initial cost [€/kW$_{Turb}$]
60	50	272	1,115
	30	290	1,197
65	50	342	1,124
	30	387	1,249

*German spot and reserve market data from 2008 and 2009 were used

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Conclusion

Conclusion

- **LTA-CAES makes use of the fact that CAES is not constrained by Carnot efficiency!**
- **LTA-CAES aims at lower storage temperatures, which…**
  - …allow for the use of liquid TES in two-tank system
  - …still deliver relatively high cycle efficiencies
  - …enable a fast plant start-up and high part load flexibility
  - …allow for the use of today's compressor technology
- **LTA-CAES shows competitive initial cost (< 1000 €/kW) being profitable already under today's market conditions**

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http://forschungsjahrbuch.de/FKZ/0325211/

Fraunhofer UMSICHT

Kontakt:
Dr.-Ing. Daniel Wolf
+1 212 854-7441
daniel.wolf(_at_)umsicht.fraunhofer.de

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