The Carbon Dioxide for energy storage applications

2021 Low Emission Advanced Power (LEAP) Workshop

Mr. Simone Maccarini
PhD student at the University of Genoa

THERMOCHEMICAL POWER GROUP
UNIVERSITY OF GENOA (ITALY)
tpg.unige.it

Table of Contents

Need for
Energy Storage

unpredictability
and
non-dispatchability
of RES

Can *CO2*, as working fluid, help?

CO2 Battery
(aCAES-like system)

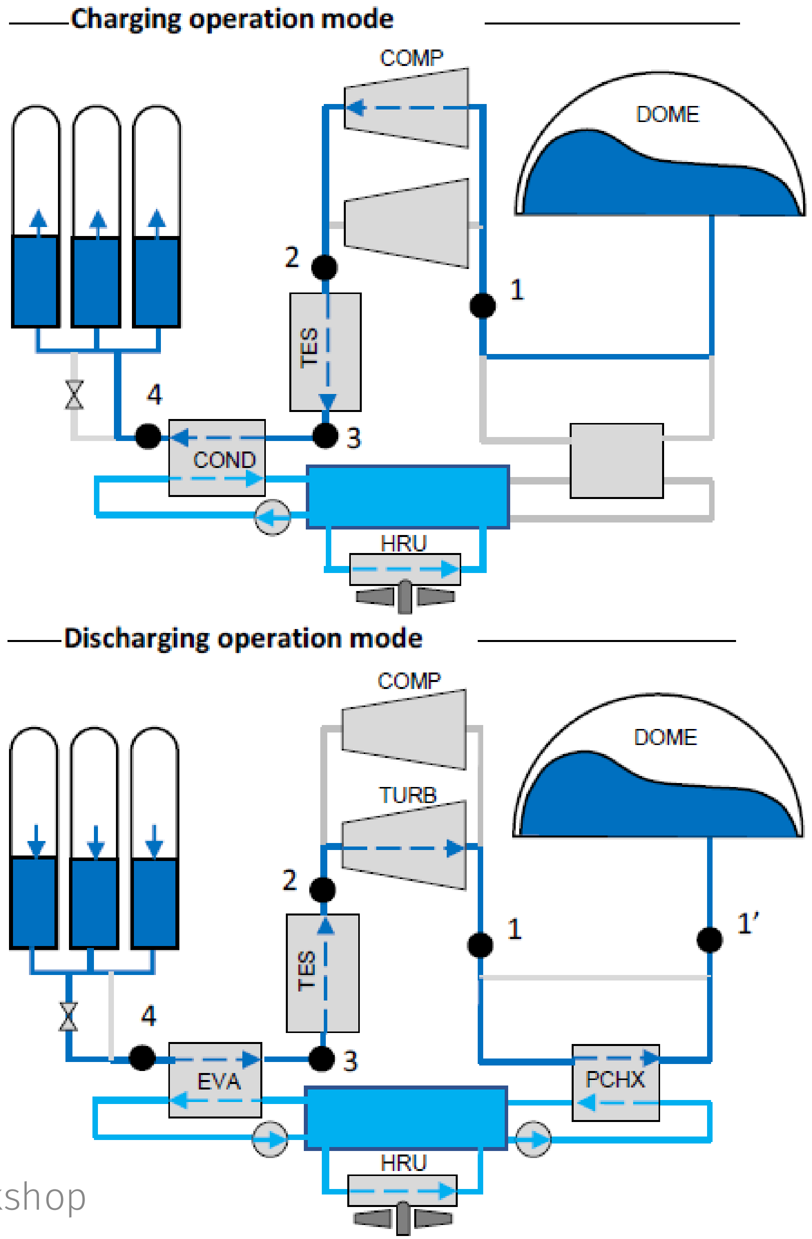
sCO2-PTES systems
(Carnot battery)

CO2 Battery

Pressure Storage + TES

- CO2 Battery from the Italian Energy Dome
- Liquid high-pressure storage, but gaseous low-pressure storage needed
- High RTE compared to CAES and Pumped Hydro
- No need of specific geographical location
- Low LCOS compared to Li-ion Batteries

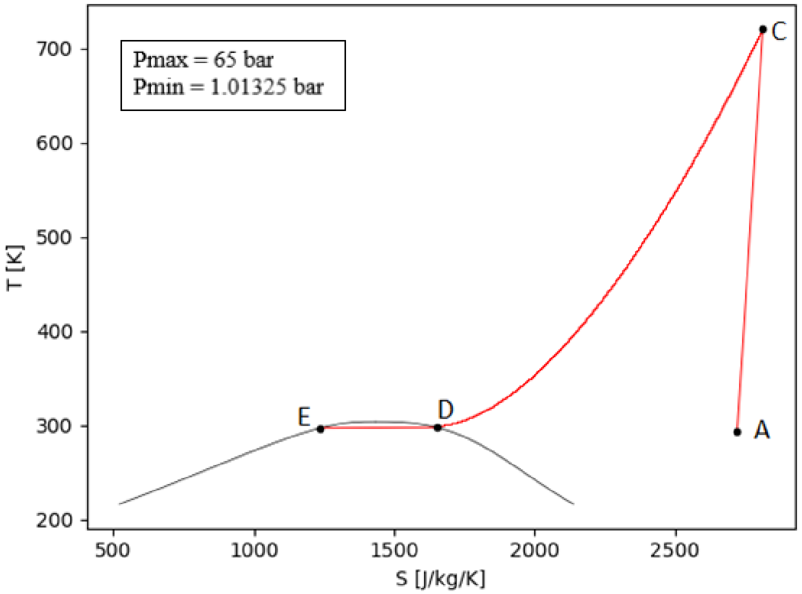
RTE = 77%
LCOS = 120 $/kWh

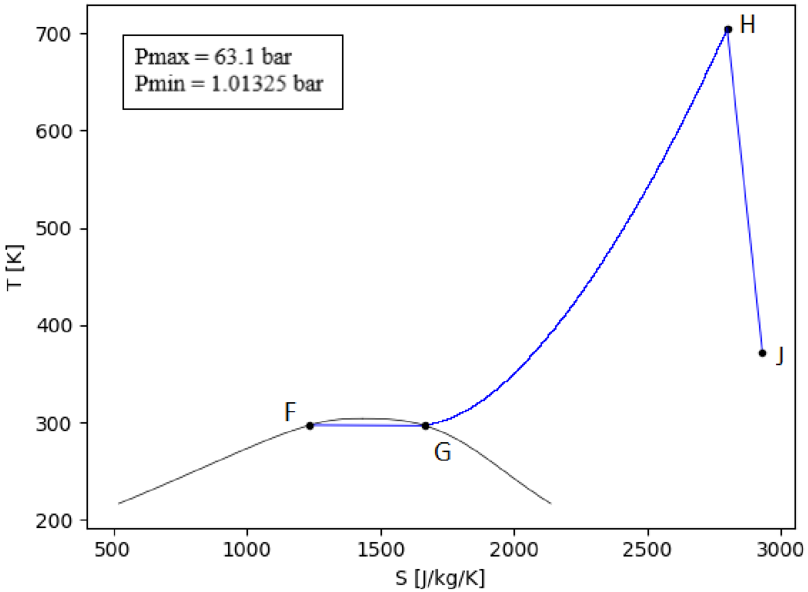


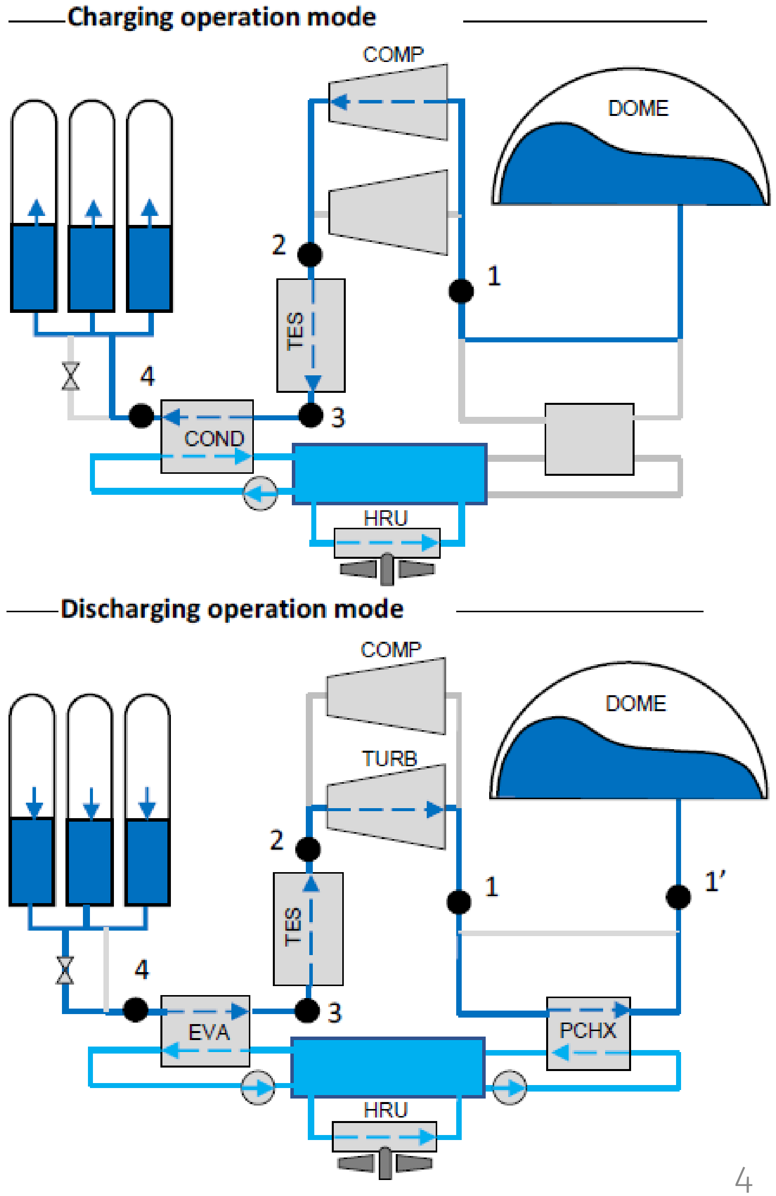
Astolfi et al. "A Novel Energy Storage System Based on Carbon Dioxide Unique Thermodynamic Properties." *Proceedings of the ASME Turbo Expo 2021*. Virtual, Online. June 7–11, 2021

CO2 Battery

Pressure Storage + TES







Manzoni et al. "Adiabatic compressed CO2 energy storage." *4th European sCO2 Conference for Energy Systems.* Virtual, Online. June 7–11, 2021

Astolfi et al. "A Novel Energy Storage System Based on Carbon Dioxide Unique Thermodynamic Properties." *Proceedings of the ASME Turbo Expo 2021*. Virtual, Online. June 7–11, 2021

sCO2 – PTES

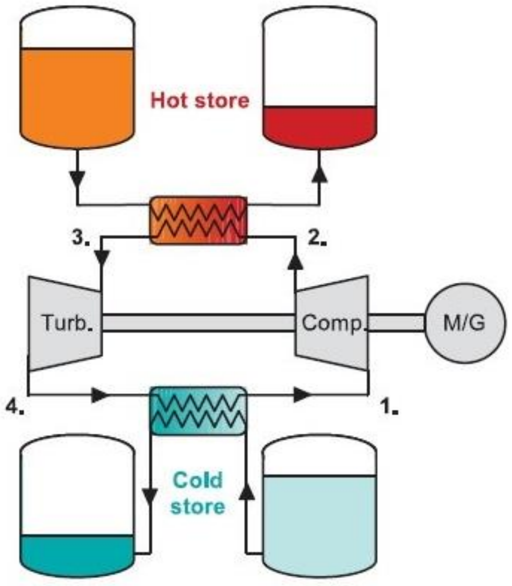
Carnot batteries

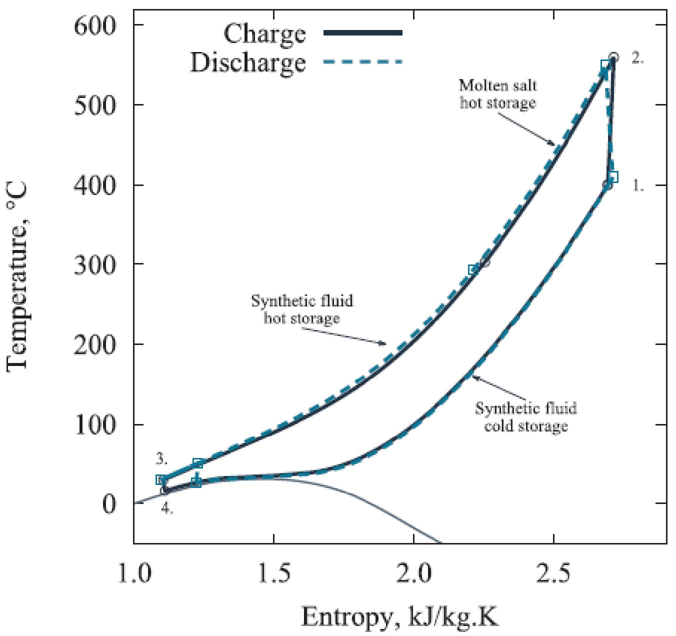
Pumped Thermal Energy Storages are based on charge and discharge phase (heat pump cycle + power cycle), storing thermal energy, both hot and cold.

- Possibly GWh-scale storage
- No geographic constraints (typical of PHS and CAES)
- Lower cost than battery technology
- Possible integration with CSP or WHR systems

		PTES	PHS	CAES	Li-ion
Round-trip efficiency	%	40 – 70	60 – 80	50 – 70	80 – 90
Energy density	kWh / m^3	50	1.4	10	250 – 750
Cost	$ / kWh	25 – 250	5 – 100	2 – 50	200 – 800
Cost	$ / kW	300 – 2800	600 – 2000	400 – 800	1000 – 1700

McTigue et al. “Pumped thermal electricity storage with supercritical CO2 cycles and solar heat input.”, *AIP Conference Proceedings 2303, 190024* (2020)

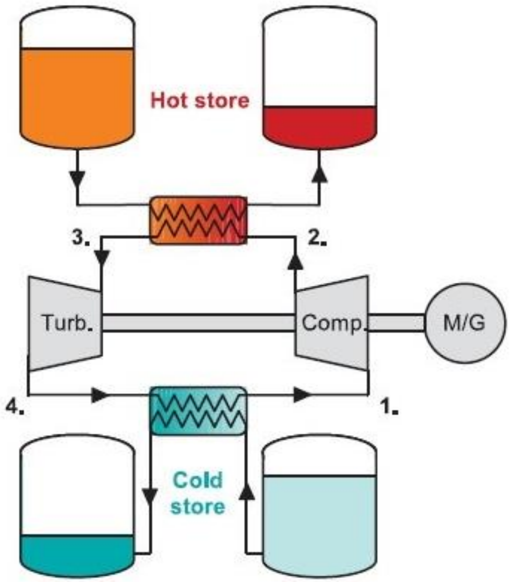


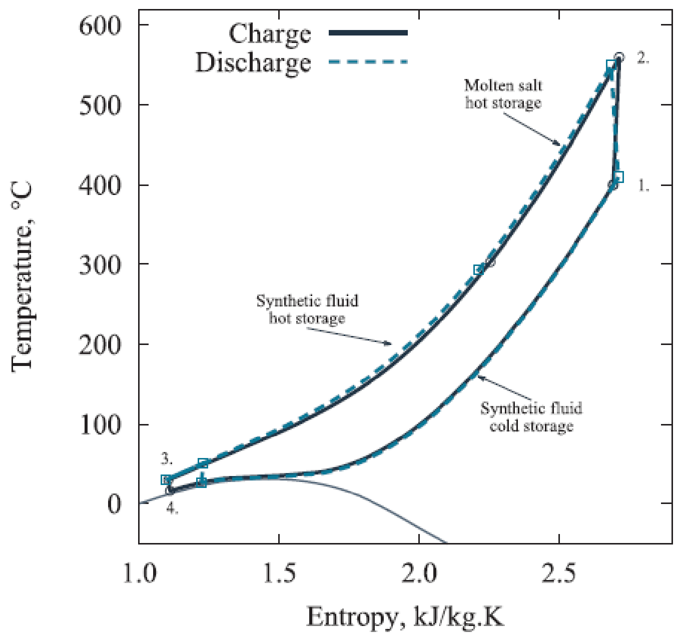


sCO2 – PTES

Carnot batteries + sCO2

		Ideal-gas cycle	Low temp. sCO_2	High temp. sCO_2
Working fluid		argon	CO_2	CO_2
T_1	°C	350.0	100.0	400.0
T_2	°C	560.0	200.0	560.0
T_3	°C	30.0	30.0	30.0
T_4	°C	-30.2	17.7	16.3
P_1	bar	80.0	80.0	80.0
β_{chg}		1.94	2.73	3.06
β_{dis}		2.20	2.44	3.26
Work ratio		3.91	5.22	10.9
Power density	kW / (m^3/s)	3.12	4.73	7.83
Round-trip efficiency	%	61.5	60.4	78.4
Isentropic efficiency	%	90.0		
Pressure loss factor	%	1.0		
ΔT	°C	5.0		





McTigue et al. "Pumped thermal electricity storage with supercritical CO2 cycles and solar heat input.", *AIP Conference Proceedings 2303, 190024* (2020)

UniGe

TPG

The Carbon Dioxide for energy storage applications

Simone Maccarini