

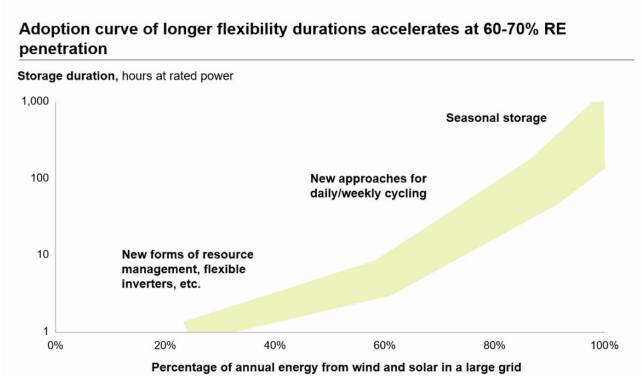
Heat Battery

Flexibility and decarbonization for industrial processes

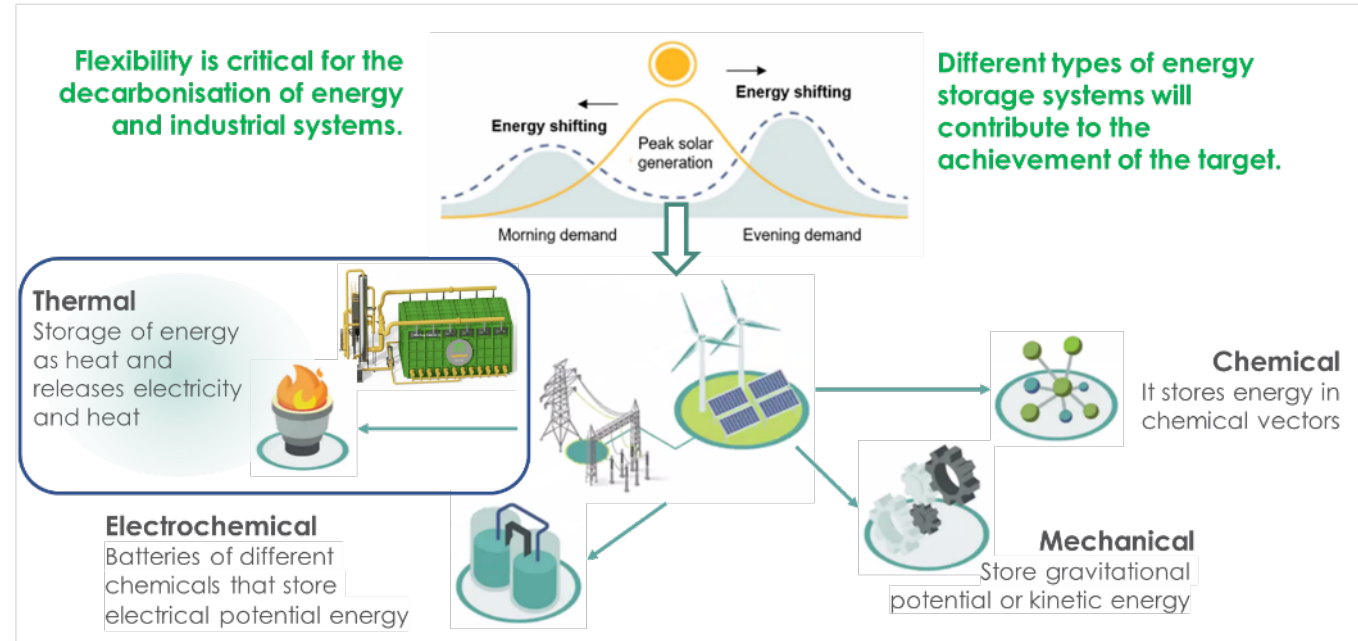
Heat electrification, through the integration of renewable energy sources and advanced thermal energy storage technologies, offers a transformative path to decarbonize industries and achieve net-zero targets

June 2025

MGTES competes to get low cost green electricity and transform it into green heat to decarbonizing industrial processes and give flexibility to the grid.



- RES integration leads to new system challenges
- Power supply and demand not always in balance
 - Transmission flow changes potentially require costly and lengthy transmission upgrades
 - Retirement of conventional, synchronous generators creates need for new sources of grid support services, e.g., reactive power, inertia



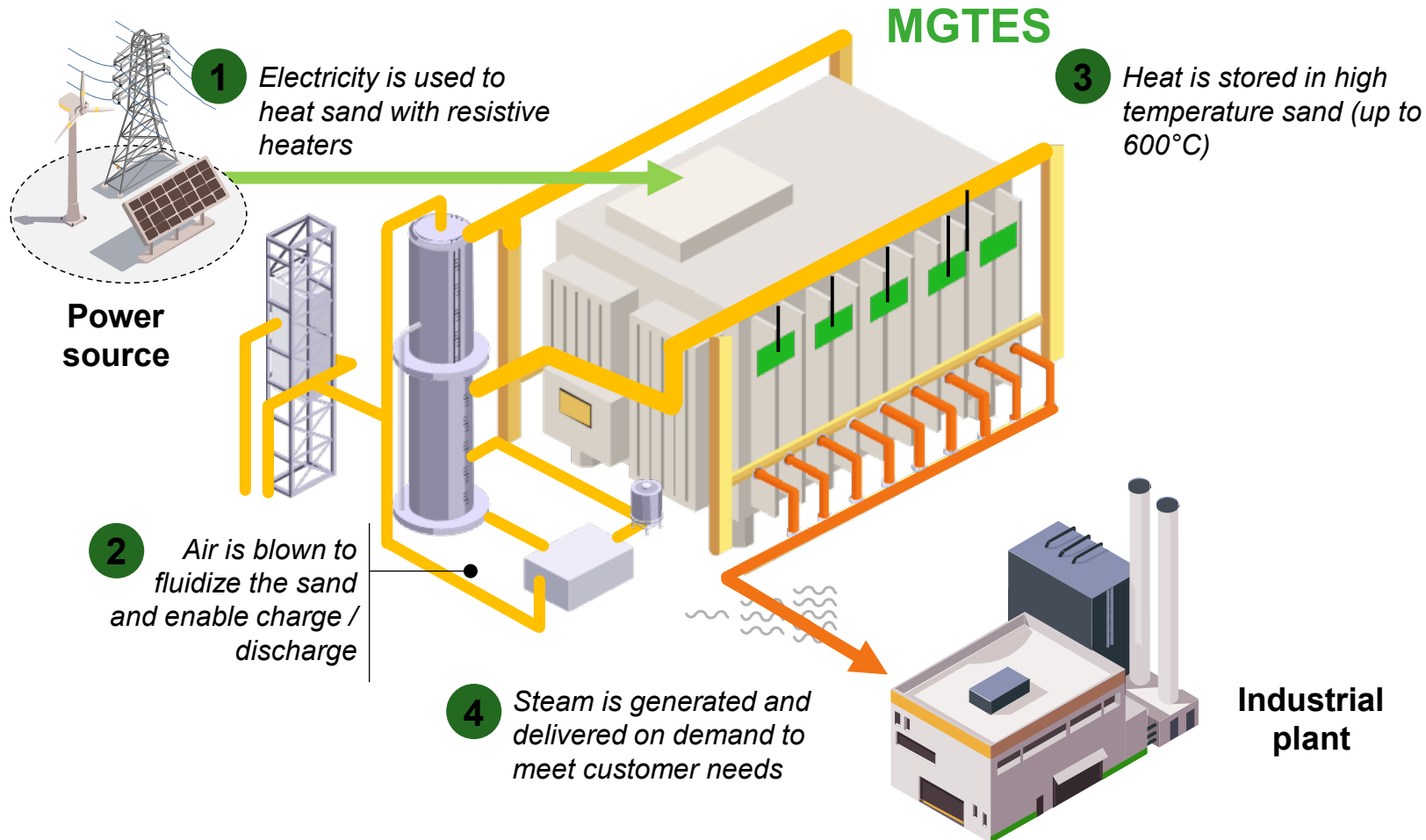
Energy shifting + Grid services



Magaldi Green Thermal Energy Storage (MGTES): overview and highlights

IMAGE NOT TO SCALE³

Overview of MGTES "Power to Heat" storage system



Technical highlights

Produced steam temperature up to **500°C**

No rare materials: Energy is stored in **Silica Sand**

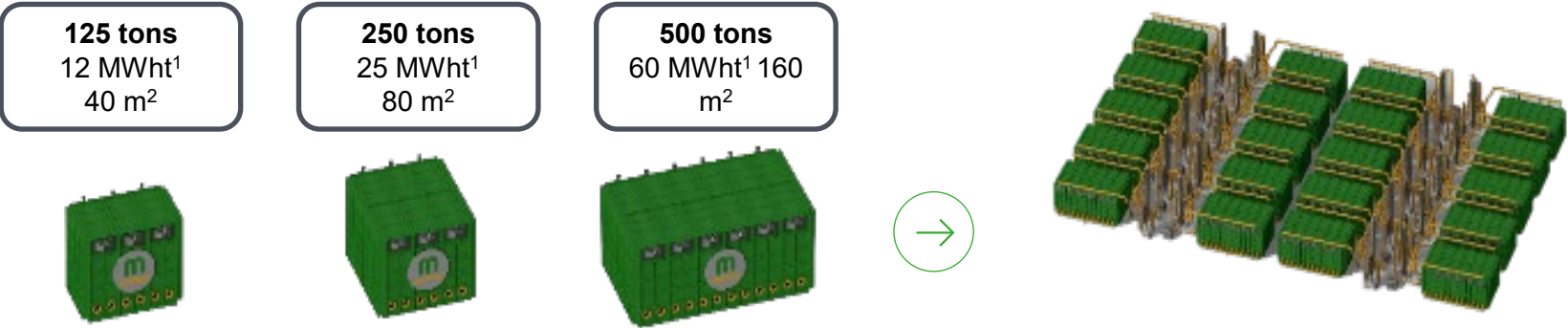
5-10x
cheaper vs. Li-Ion batteries²

90%
round trip efficiency

1. Round Trip Efficiency | 2. Projections of LDES Council for at-scale systems | 3. Exemplary 60 MWh MGTES would occupy ~160 m²

MGTES: combining charge, storage and discharge in a single module for easier constructability, operability and maintainability

Modularity



ESG	No rare materials, and supply chain constrains, 100%: the materials used are mainly sand and steel
Storage media temperatures	Silica Sand up to 1000 °C, compared to 250-560 °C of Molten Salts
Charging time	Power to Heat configuration,4-5 hours to reach full storage capacity, simultaneous charging and discharging 24/7
Response time & Losses	Fluid bed activation time < 2 minutes, negligible daily heat losses < 1.5%, +200h long duration energy storage
All-in-one equipment	Differently to e-boilers to be combined, MGTES is fully integrated to operate seamlessly, with long life (+ 30 years)
Magaldi's quality	Magaldi is worldwide known for its BAT mindset and top dependable technologies

1. Detailed data on MGTES system sizing, performance and costs are available when discussing specific applications



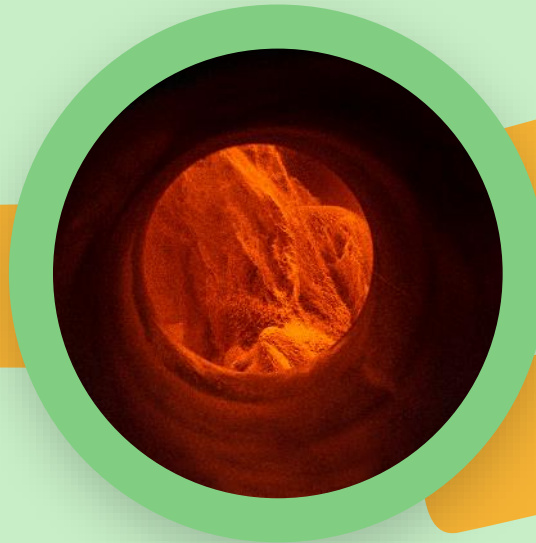
The role of Thermal Energy Storage to address the challenges of industrial heat

Decarbonize heat generation



Storing energy from renewable sources as **heat and releasing steam** with >90% efficiency 24/7

Optimize heat generation costs



Enabling **price arbitrage** across **energy sources** (gas vs. power) and **time windows** (high vs. low power demand)







Capture grid balancing value pools



Tailoring power demand in **input** to system needs, contributing to ensure power **grid stability and adequacy**

Main value pool addressable today

Comparison of different decarbonization technologies

Technology	 Heat Pump	 E-Boiler (P2H)	 TES	 BESS + P2H	 Bio Energy	 Green H2 (derivatives)
Temperature	<150 C	< 500 C	150-1300 C	< 500 C	up to 1200 C	> 1200 C
Energy Efficiency	up to 300%	~98%	~95%	~80%	~33%	<67% (lower for der.)
Availability (h/y)	>8000 h	~ 1000 h	>8000 h	~ 2000h	>8000 h	>8000 h
Storage Lifetime	n/a (no storage)	n/a (no storage)	> 20 y	~ 10 y	n/a (tank)	n/a (tank)
Cost LCOS	n/a (no storage)	n/a (no storage)	10-20 €/MWh	100-150 €/MWh	< 10 €/MWh	< 10 €/MWh
Cost LCOH	60-90 €/MWh	60-90€/MWh	60-90 €/MWh	150-200 €/MWh	~ 150 €/MWh	> 200€/MWh
Integration						
Land Use						
TRL	8-9	9	8-9	9	8-9	7
Supply Chain Resilience						

LCOS Levelized Cost of **Storage**
 LCOH Levelized Cost of **Heat**
 TRL Technology Readiness Level (1-9)

CoP: Coefficient of Performance
 TES: Thermal Energy Storage
 BESS: Battery Energy Storage System
 RFNBO: Renewable Fuels of Non Biological Origin (H2 and derivatives)

- E-boilers are only opportunistic decarbonization (~1000h/y)
- Heat Pumps performs well at low temperatures (high CoP)
- **TES are the ideal solution in temperature ranges 150-400 °C**
- Biogas or RFNBO are expensive solutions, but able to cover temperature ranges > 600°C (combustion)

MGTES – First Industrial Application

Enel X and **Magaldi Group** joined forces to implement a ~ 7,5 MWh MGTES system, within Q2 2025, for the continuous production of **green steam** at 190° at a plant of I.GI, a vegetable oil refinery, that supplies **Ferrero**, with headquarters in the Industrial Development Area of Buccino (Italy).

March 29, 2023

Enel X and Magaldi Group join forces to decarbonize industrial processes



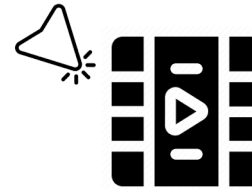
BUCCINO SA



enel x



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Potential grid services in P2H configuration









MGTES modes of operation

Modes	Electric heaters	Steam line	Fluidization line	Possible actions on electric heaters	Active power reserve*	OPERATION MODES
Warm stand-by	OFF	OFF	OFF	Startup < 2 min. Fluid bed activation < 2 min.	Down-regulation	
Charge	ON	OFF	ON	Quick shutdown Bed already fluidized	Up-regulation	
Discharge	OFF	ON	ON	Quick startup Bed already fluidized	Down-regulation	
Charge + Discharge	ON	ON	ON	Quick modulation Bed already fluidized	Up and Down regulation	SYSTEM SHUT DOWN
Cold-stand-by	OFF	OFF	OFF	n/a	n/a	

* «Up» and «down» refers to the frequency variation

Potential grid services in P2H configuration

Service*	Response time		Duration		MGTES P2H
	Enabled Units (traditional)	UVAM (virtual power plant)	Enabled Units (traditional)	UVAM (virtual power plant)	
Fast reserve	< 1sec	< 1sec	15 min	15 min	
Primary regulation**	30 sec	n.a.	15 min	n.a.	
Secondary regulation	All band in 200 sec Continent 100 sec Islands	All band in 200 sec Continent 100 sec Islands	2 h	1 h	
Tertiary regulation	15 min (> 10 MW)	15 min (> 1 MW)	2 h	2 h	
Congestion resolution	15 min (> 10 MW)	15 min (> 1 MW)	Unlimited (thermal) 4 h (hydro)	2 h	
Balancing	15 min (> 3 MW)	15 min (> 1 MW)	Unlimited (thermal) 4 h (hydro)	2 h	

* Italian grid transmission regulation

** 50% of power in 15 s


Able to provide the service



Able to provide the service but unable due to current regulations and/or technological limitations

Potential grid services in P2H configuration

	Grid resources	THERMO-ELECTRIC	Non-Progr RES	USER	PHS	BESS	MGTES P2H (TES)
<div>✓</div> <div>Able to provide the service</div>	Regulation services						
<div>—</div> <div>Able to provide the service but unable due to current regulations and/or technological limitations</div>	Fast reserve	—	✗	✗	✗	✓	—
	Primary regulation	✓	✗	✗	✓	✓	—
	Secondary regulation	✓	— ↓	— ↑	✓	✓	✓
	Tertiary "ready"	✓	✗	✗	✓	—	✓
	Tertiary "rotating"	✓	— ↓	— ↑	✓	✓	✓
	Tertiary "replacement"	✓	— ↓	— ↑	✓	✓	✓
	Congestion resolution	✓	— ↓	— ↑	✓	—	✓
	Balance	✓	— ↓	— ↑	✓	—	✓
<div>✗</div> <div>Unable to provide the service</div>							

Thermal energy storage is applicable globally and across multiple sectors



Sector heat demand Potential demand

		<div>Sector</div>													
Temper. range	MGTES Sweetspot	Agriculture/forestry	(Petro)Pharma chemicals	Buildings	Construction	Energy industry	Food & Beverage	Iron and Steel	Manufacturing	Mining	Non-ferrous metals	Non-metallic minerals	Water desalination	Refining	
<150°C	Combination with water and heat pumps														
	Significant storage capacity with DeltaT > 400°C	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	
150-350°C	Uniquely positioned given the fluidized sand bed														
	Optimal operational range 170-300°C and 10-12 bars	✓	✓		✓	✓	✓			✓		✓	✓	✓	
350-500°C	In combination with Cogen applications														
	Lower storage capacity, higher pressures up to 50 bars		✓			✓	✓					✓		✓	