Calor-e

Versatile, Durable, Smart

Unda Engineering Inc.

Unda Mühendislik San. ve Tic. A.Ş.

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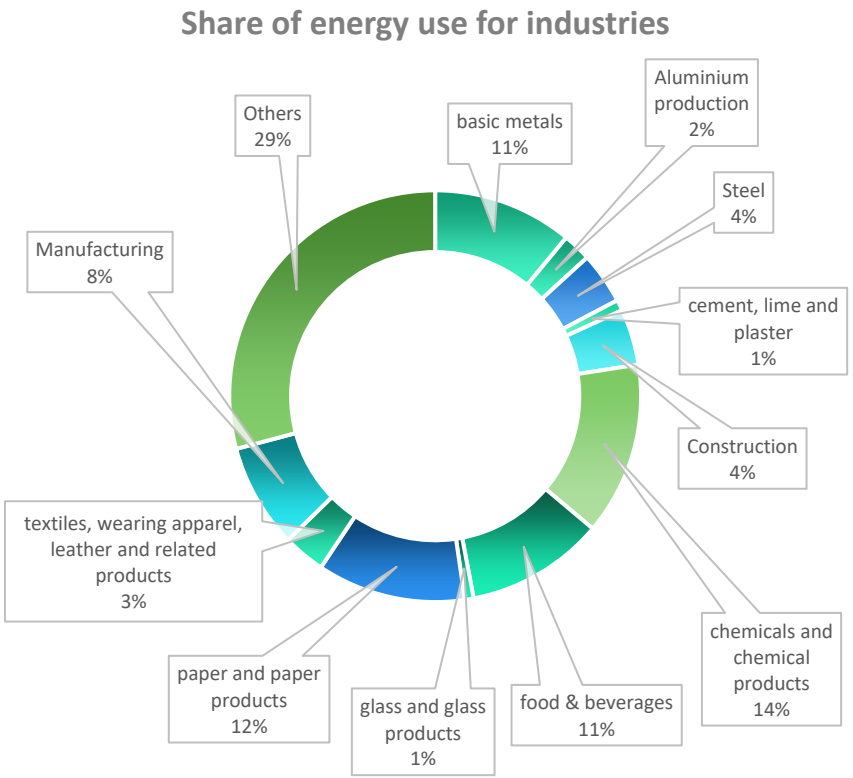
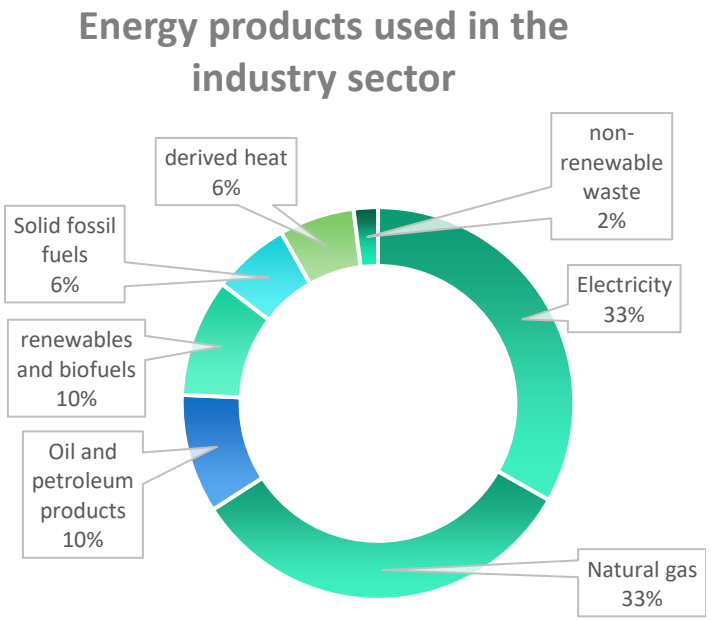
Challenge - Industry

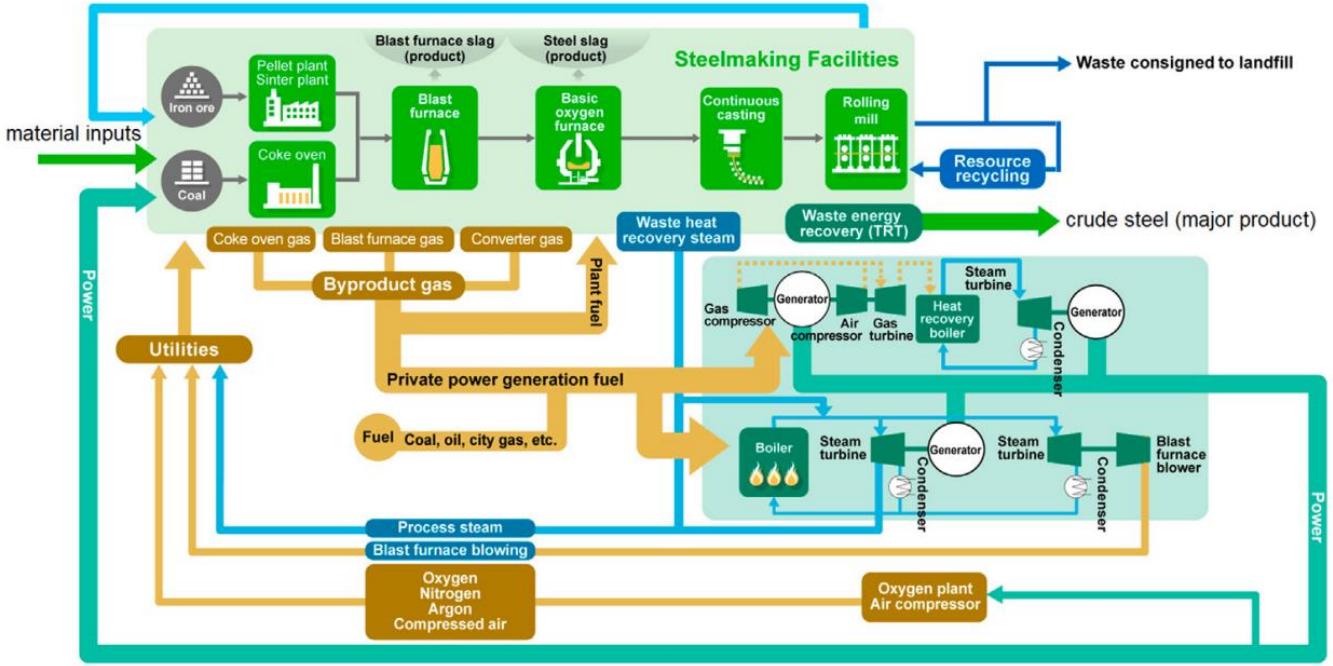




Half of this demand occurs for thermal energy for temperature <400 °C.

Eurostat, Disaggregated final energy consumption in industry - quantities by NACE Rev. 2 activity [NRG_D_INDQ_N__custom_7786906]

Steel Emission and process flows



Sun, Wenqiang, et al. "Material and energy flows of the iron and steel industry: Status quo, challenges and perspectives." *Applied Energy* 268 (2020): 114946.

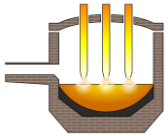
Emission Source	Emission intensity (tCO2/t steel)	Alternative
Lime	0.04	Cement paste
Carbon Electrolyte	0.007	New materials
Coal	0.043	Biogas, Hydrogen
Gas	0.01 – 0.09	Biogas, Hydrogen, Induction heating

Clean steel opportunities

Iron electrolysis

Iron

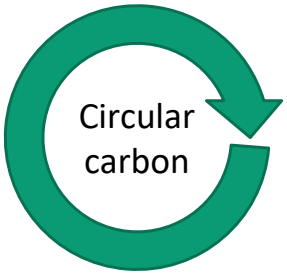
Hydrogen



BAF

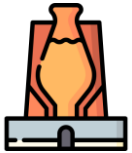
Water electrolysis

Heat



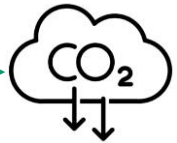
Heat

carbon



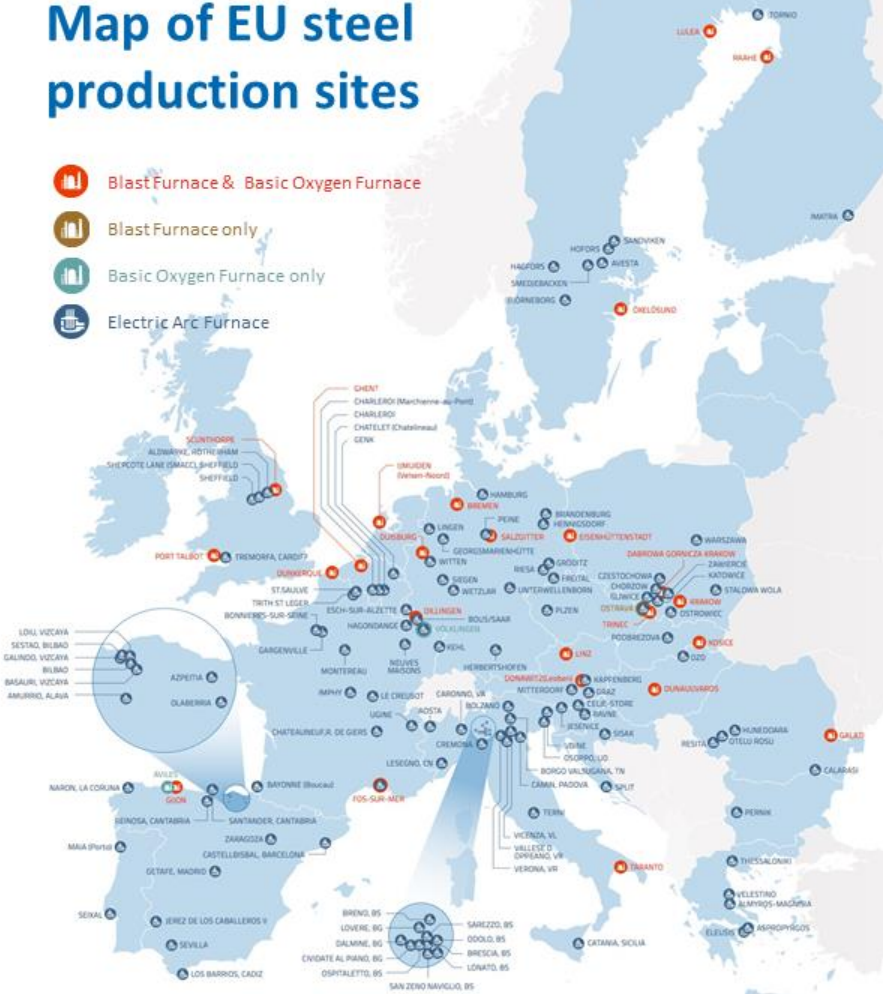
BOF

carbon



Alternative Fuels
Methanol, etc.

Map of EU steel production sites



Blast Furnace & Basic Oxygen Furnace

Location	Hot Metal Capacity ('000 tonnes/ year)	Finished Steel Capacity ('000 tonnes/ year)	No. of furnaces
AUSTRIA			
DONAWITZ (Leoben)	1370	1570	2
LINZ	4340	6000	3
BELGIUM			
GHENT	4430	5000	2
CZECH REPUBLIC			
OSTRAVA	3200		3 – BF only
TRINEC	2100	2400	2
FINLAND			
RAAHE	2400	2600	2
FRANCE			
DUNKERQUE	6800	6750	3
FOS SUR MER	5160	5100	2
GERMANY			
BREMEN	3960	3800	2
DILLINGEN	4790	2760	2
DUISBURG	11600	11560	4
EISENHÜTTENSTADT	2340	2400	2
SALZGITTER	4800	5200	3
VÖLKLINGEN		3240	BOF only
HUNGARY			
DUNAUJVAROS	1310	1650	2
ITALY			
TARANTO	9590	11500	4
NETHERLANDS			
IJMUIDEN (Velsen-Noord)	6310	7500	2
POLAND			
DABROWA GORNICZA	4500	5000	2
KRAKOW	1310	2600	1
ROMANIA			
GALATI	3250	3200	2
SLOVAKIA			
KOSICE	2850	4500	2
SPAIN			
AVILES		4200	BOF only
GIJON	4480	1200	2
SWEDEN			
LULEA	2200	2200	1
ÖXELÖSUND	1800	1700	2
UNITED KINGDOM			
PORT TALBOT	4770	4900	2
SCUNTHORPE	3590	3200	3

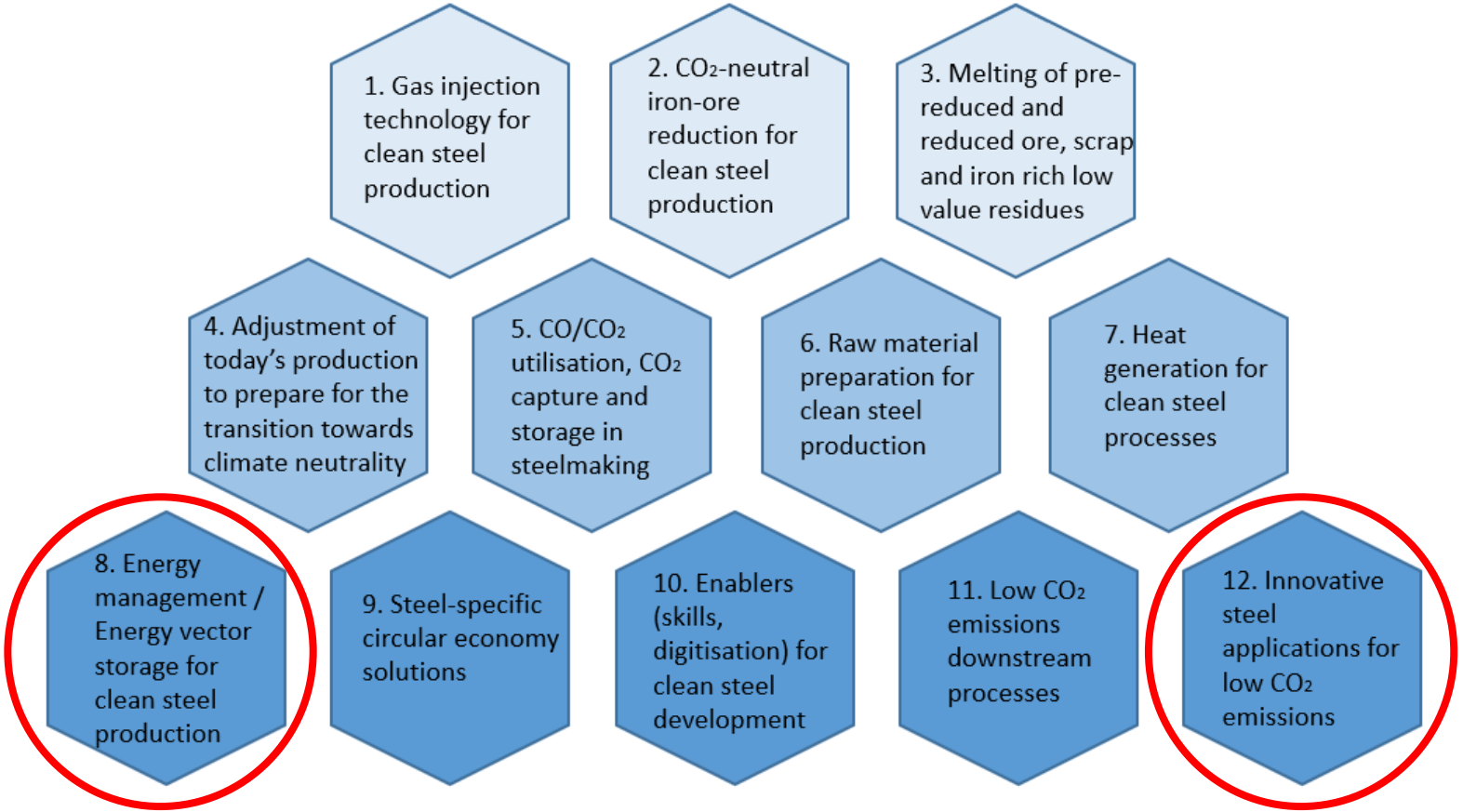
Electric Arc Furnace

Location	Capacity ('000 tonnes/ year)	No. of furnaces
AUSTRIA		
GRAZ	365	1
KAPFENBERG	180	1
MITTERDORF	300	1
BELGIUM		
CHARLEROI	850	1
CHARLEROI (Marchienne au Pont)	350	1
CHATELET (Chatelineau)	1000	1
GENK	1200	2
BULGARIA		
PERNIK	1000	2
CROATIA		
SISAK	350	1
SPLIT	185	1
CZECH REPUBLIC		
OSTRAVA	120	1
PLZEN	150	2
FINLAND		
IMATRA	360	1
TORNIO	1300	2
FRANCE		
BAYONNE (Boucau)	1200	1
BONNIERES SUR SEINE	550	1
CHATEAUNEUF,R. DE GIERS	100	1
FOS SUR MER	480	1
GARGENVILLE	700	1
HAGONDANGE	460	1
IMPHY	90	1
LE CREUSOT	150	1
MONTEREAU	720	1
NEUVES MAISONS	800	1
ST.SAULVE	730	1
TRITH ST LEGER	800	1
UGINE	250	2
GERMANY		
BOUS/SAAR	350	1
BRANDENBURG	1800	2
FREITAL	90	1
GEORGSMARIENHÜTTE	1100	1
GRÖDITZ	100	1
HAMBURG	1100	1
HENNIGSDORF	1000	2
HERBERTSHOFEN	1180	2
KEHL	2500	2
LINGEN	620	1
PEINE	1000	1
RIESA	900	1
SIEGEN	600	1
SIEGEN	150	1
UNTERWELLENBORN	1100	1
VÖLKLINGEN	300	1
WETZLAR	400	1
WITTEN	480	1

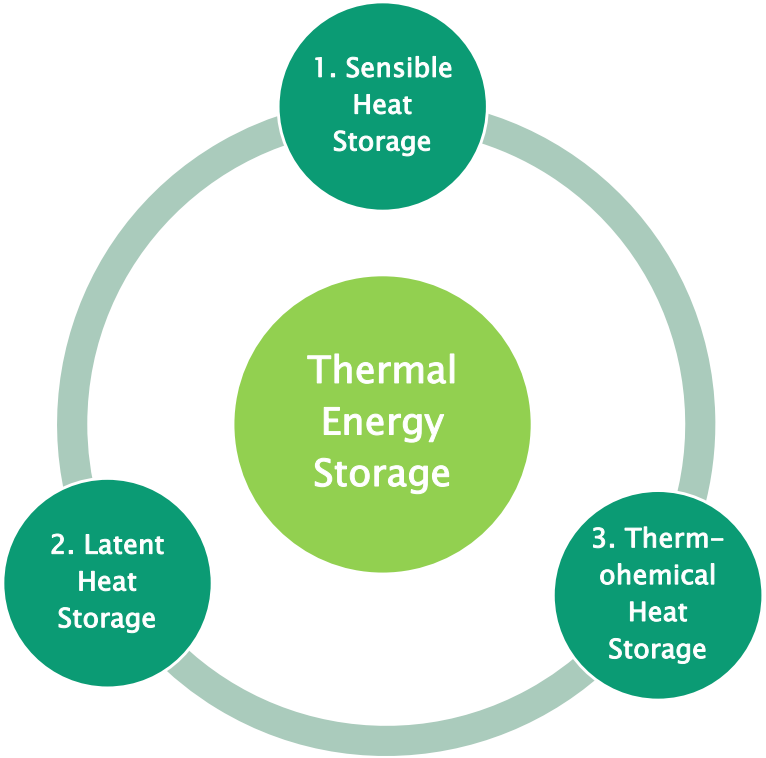
Location	Capacity ('000 tonnes/ year)	No. of furnaces
GREECE		
ALMYROS MAGNISIA	1200	1
ASPROPYRGOS	400	1
ELEUSIS	800	1
THESSALONIKI	600	1
VELESTINO	450	1
HUNGARY		
OZD	400	1
ITALY		
AOSTA	260	1
BOLZANO	200	2
BORGO VALSUGANA, TN	600	1
BRENO, BS	100	1
BRESCIA, BS	1200	2
BRESCIA, BS	650	1
CAMIN, PADOVA	600	1
CARONNO, VA	780	1
CATANIA, SICILIA	500	1
CIVIDATE AL PIANO, BG	250	1
CREMONA	3850	2
DALMINE, BG	700	1
LESEGNO, CN	600	1
LONATO, BS	1100	1
LONATO, BS	600	1
LOVERE, BG	150	1
ODOLO, BS	900	1
OSOPPO, UD	2200	1
OSPITALETTO, BS	150	1
SAN ZENO NAVIGLIO, BS	800	1
SAREZZO, BS	540	1
TERNI	1450	2
UDINE	500	1
UDINE	770	1
VALLESE D. OPPEANO, VR	450	1
VERONA, VR	1250	2
VICENZA	170	1
VICENZA, VI	1200	1
LUXEMBOURG		
ESCH SUR ALZETTE	2250	2
POLAND		
CHORZOW	145	1
CZESTOCHOWA	800	1
GLIWICE	250	1
KATOWICE	65	1
OSTROWIEC	900	1
STALOWA WOLA	240	1
WARSZAWA	750	1
ZAWIERCIE	1340	2
PORTUGAL		
MAIA (Porto)	600	1
SEIXAL	1100	1

Location	Capacity ('000 tonnes/ year)	No. of furnaces
ROMANIA		
CALARASI	470	1
HUNEDOARA	550	1
OTELU ROSU	830	1
RESITA	450	1
SLOVAKIA		
PODBREZOVA	350	1
SLOVENIA		
CELJE STORE	150	1
JESENICE	500	1
RAVNE	140	1
SPAIN		
AMURRIO, ALAVA	150	1
AMURRIO, ALAVA	360	1
AZPEITIA	800	1
BASAURI, VIZCAYA	740	1
BILBAO	1100	1
CASTELLBISBAL, BARCELONA	2400	2
GALINDO, VIZCAYA	400	1
GETAFE, MADRID	600	1
JEREZ DE LOS CABALLEROS II	1300	1
LOIU, VIZCAYA	130	1
LOS BARRIOS, CADIZ	1200	3
NARON, LA CORUNA	700	1
OLABERRIA	2450	1
REINOSA, CANTABRIA	240	1
SANTANDER, CANTABRIA	750	1
SESTAO, BILBAO	2000	2
SEVILLA	1300	2
ZARAGOZA	500	1
SWEDEN		
AVESTA	500	1
BJÖRNEBORG	95	1
HAGFORS	120	1
HOFORS	500	1
SANDVIKEN	200	1
SMEDJEBACKEN	480	1
UNITED KINGDOM		
ALDWARKE, ROTHERHAM	1220	2
SHEFFIELD	150	1
SHEPCOTE LANE (SMACC), SHEFFIELD	500	1
TREMORFA, CARDIFF	1200	1

Priorities for Green Steel



Thermal storage



	Storage duration use case		
	Hours	Days	Weeks
Sensible Heat			
Graphite			
Ceramics, silica, and sand			
Molten Salts			
Concrete			
Rocks			
Steel			
Underground water			
Water			
Latent Heat			
Microencapsulated metals			
Inorganic salts and eutectic mixtures			
Sodium			
Other liquid metals			
Molten aluminium alloy			
Paraffin waxes, fatty acids			
Salt hydrates			
Salt-water mixtures			
Ice			
Liquid air			
Thermochemical Heat			
Chemical Reaction Storage			
Absorption			

https://ease-storage.eu/publication/thermal-energy-storage/

Thermal storage opportunities for steel

Carbon Direct Avoidance (CDA)

Improve energy and resource efficiency

Cost reduction

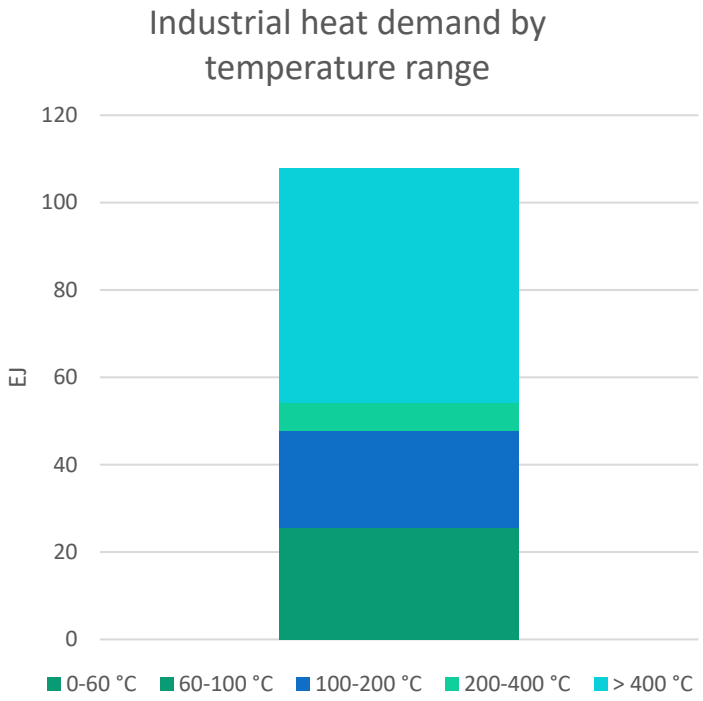
Application	Examples
Heat-to-Heat	Waste Heat recycling
Heat-to Power	Waste heat Recovery
Power-to-Heat	Decarbonization of industrial process
Power-to-Heat-to-Power	Decarbonization of industrial energy and heat

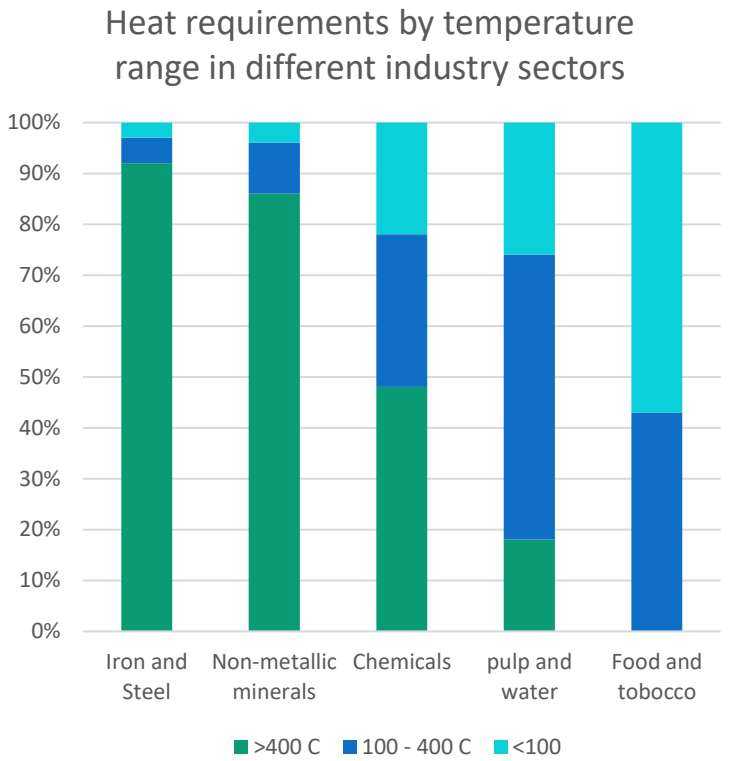
Waste heat outputs

Operation	Heat Type	Temperature (°C)
Sintering	Sinter flue gas	350–370
	Stack exhaust	300–400
	Sinter	700–800
Coking	Flue gas	250–270
	Coke	1000–1150
	Coke oven gas	650–1000
Iron making	Blast furnace slag	1450–1550
	Blast stove exhaust	200–300
	Blast furnace gas	200–500
	Cooling water from blast furnace	35–50
Steelmaking-Basic Oxygen Furnace	Basic oxygen furnace slag	1400–1800
	Linz-Donawitz gas	1600–1800
Steelmaking- Electric Arc Furnace	Exhaust gases with recovery	200–210
Casting	Steel latent heat	1200–1250
	Steel	1250–1650
Hot rolling	Hot rolled steel	800–1000
	Reheat exhaust	700–750

Innovative Steel Applications for low CO2 emissions

Challenge Industry



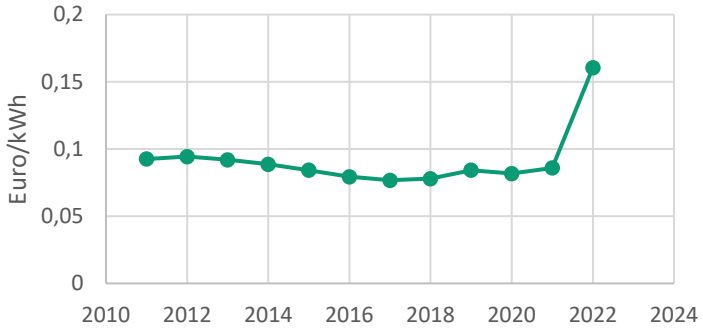


(2019a), World Energy Outlook 2019.

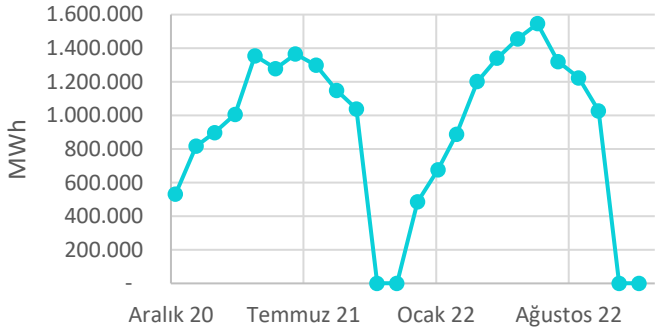
A Landscape Review of the Global Renewable Heating and Cooling Market

Challenge – Electrical grid

EU – Average non-household electricity prices



Monthly un-licenced and off-demand renewable power generation (Turkey)



Industrial heat

- Emissions
- Energy security (fossil fuel availability)
- Variable and increasing prices

Electrical grid

- Increased renewables increase grid stability problems
- Overloading of existing transmission lines
- Demand and supply mismatch

How to solve both problems?

Electricity

Calor-e
Versatile, Durable, Smart

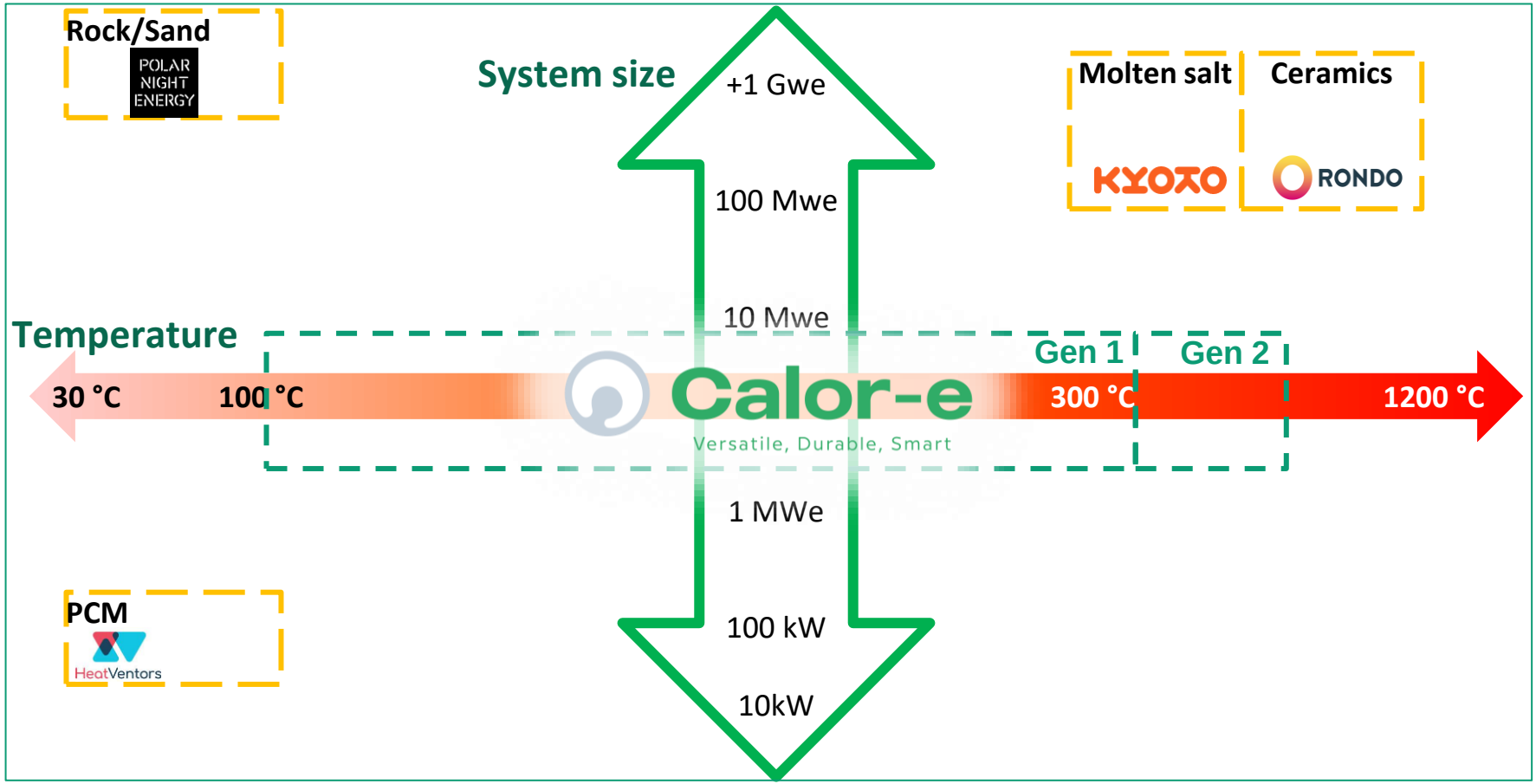
Heat

- Low cost / of demand renewables
- Renewable energy on site

Intraday storage
- Charge when its cheap
- Heat when you need

- Heat on demand
- High temperatures up to +400 °C

A solution for an unaddressed problem



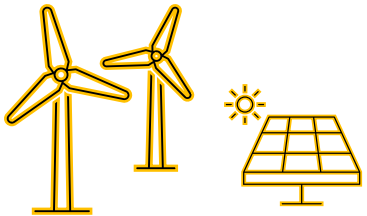
Calor-e; durable and fully recyclable

Technology

- Storing heat in Steel (0.6 – 1 MWe / unit)
- Fast response and charge (50-500 kW)
- Variable discharge (10-1000 kW)
- Transfer with **conventional heat transfer fluids**

Merits

- Made from conventional materials
- Does not lose capacity with discharge
- Fully recyclable
- Modular and scalable
- 98% electricity to heat efficiency



Off-demand / low-cost renewable power

High temperatures up to +400 °C

Low-Medium Industrial Heat

Sectors:

- Food and beverages
- Chemical
- Agriculture
- Textile
- Paper
- Metals

Operations:

- Pasteurizing (60 – 80 °C)
- Drying (70 – 200 °C)
- Tempering (150 – 200 °C)
- Boiling / Steam (100 – 250 °C)
- Distillation (140 – 150 °C)
- Bleaching (130 – 150 °C)

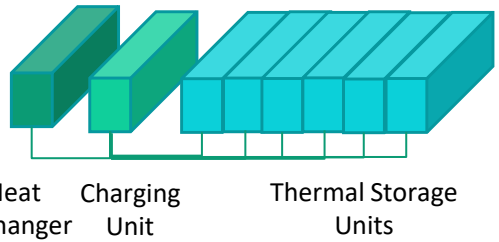
Office Heating

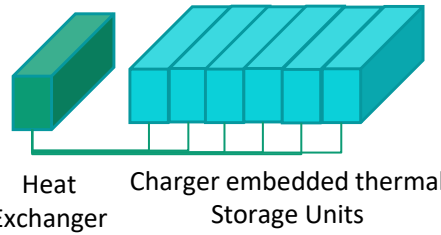
Calor-e Units

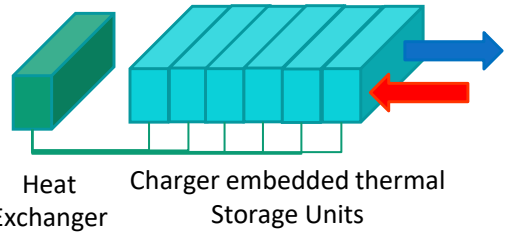
Calor-e Gen1	Calor-e Gen2	Calor-e Hybrid
• Upto 400 °C Storage temperature	• +700 °C storage temperature • Up to 400 °C discharge temperature	• Charged by both electricity and excess heat

Single Unit use

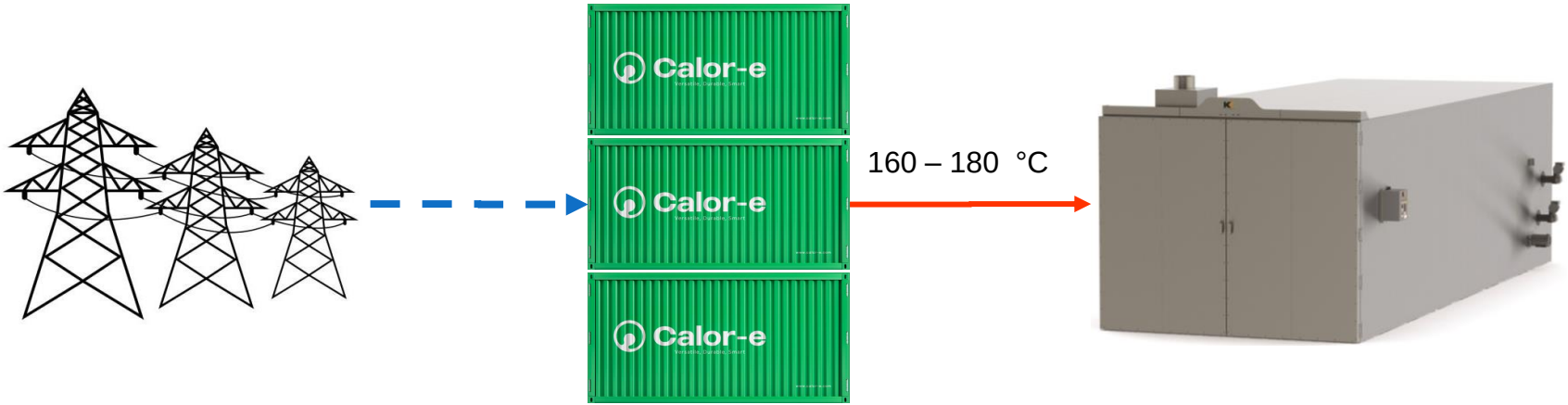
Multi Unit use







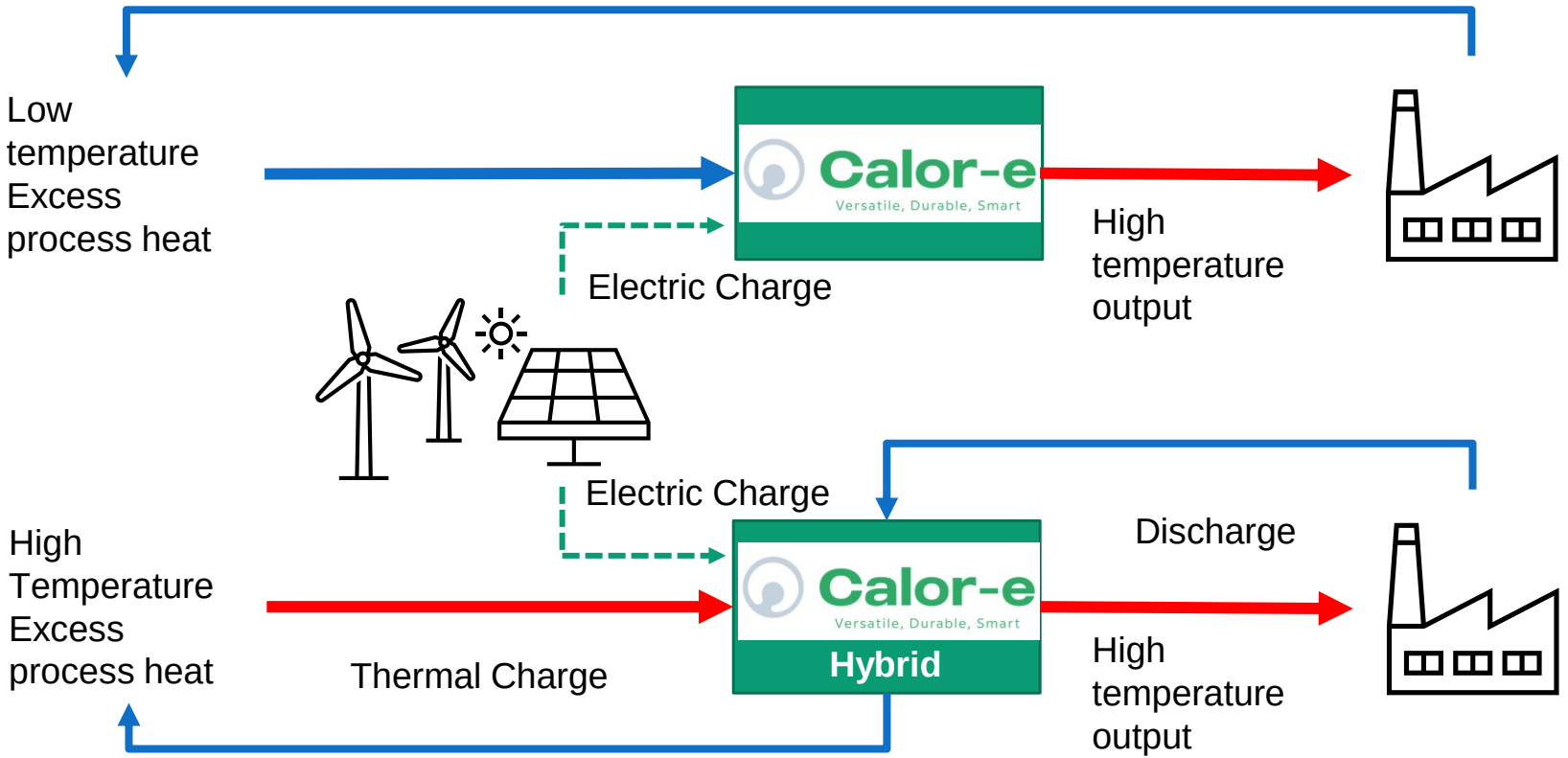
Medium temperature low demand case: Calor-e + Grid integration



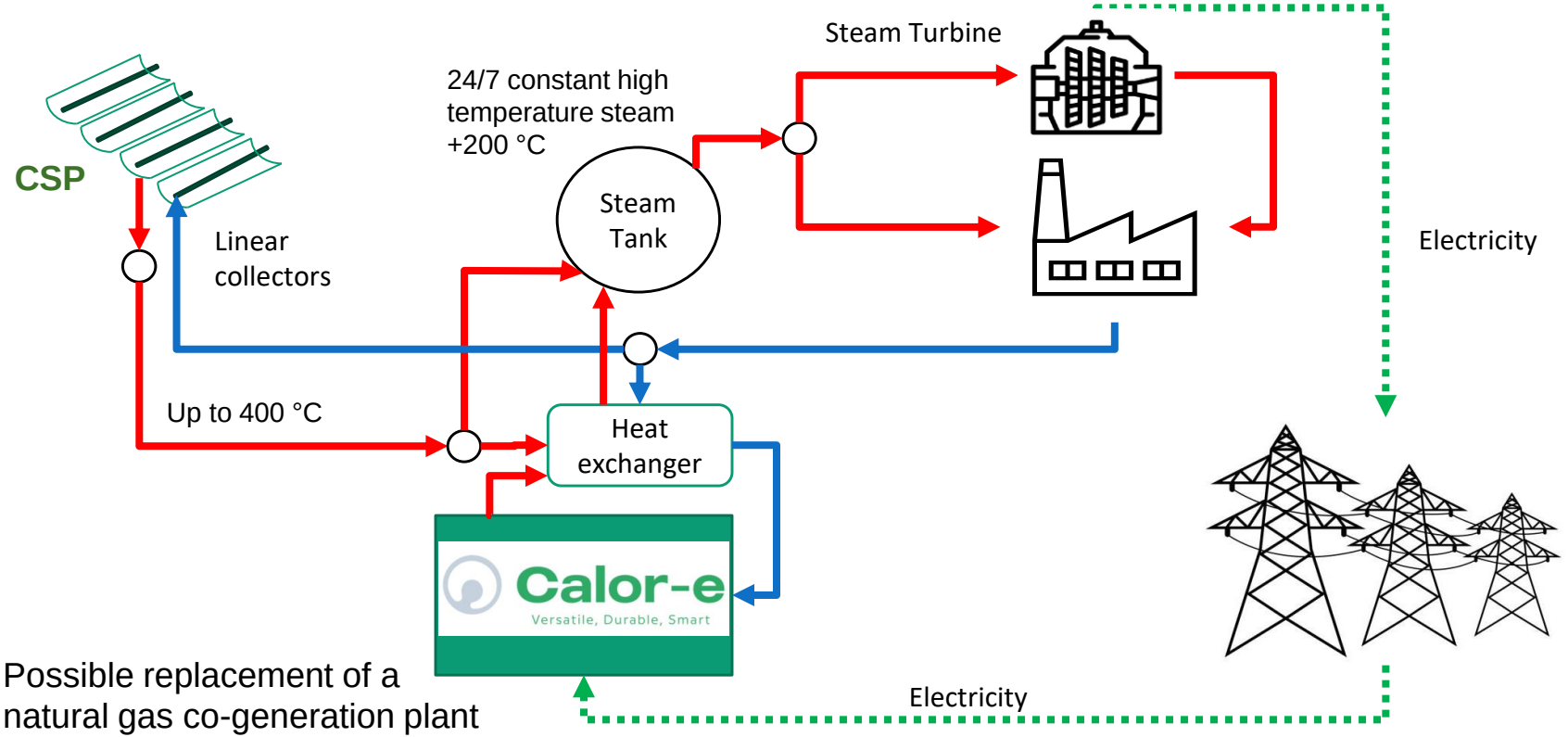
Electrostatic Powder Coating Oven burner to heat up the system to 160 – 180 °C

- 3 operations daily, 260 days work annually
- Natural gas burner is replaced by 3 x 1MWh(e) Calor-e unit
- Prevents up to 638 tons CO_2 emissions /year

Medium Temperature Case: Calor-e + Heat recovery



Medium Temperature Case: Calor-e + CSP (Direct Steam Generation) - Sectoral integration & Grid Flexibility



Possible replacement of a natural gas co-generation plant

System Impact

Calor-e thermal batteries

- Fast response capacity for multiple charge/discharge through the day
- Low parasitic loads
- Low energy loss
- lifetime of 25 years
- low environmental footprint
- 100% recyclable with conventional methods

Each 1 MWe unit

- + 3.500 tons CO_2 emission reduction in average in its lifetime

Environmental Assumptions	
Use cycle per day	2
Annual use	260 days
Unit life time	25 years
Replaced heat source(s)	Coal and natural gas

One 1 MWe unit reduced emissions = **100** 

Average target customer reduced emissions = **1000** 

Calor-e business impact for 2030 = **39,500** 

Thank you

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