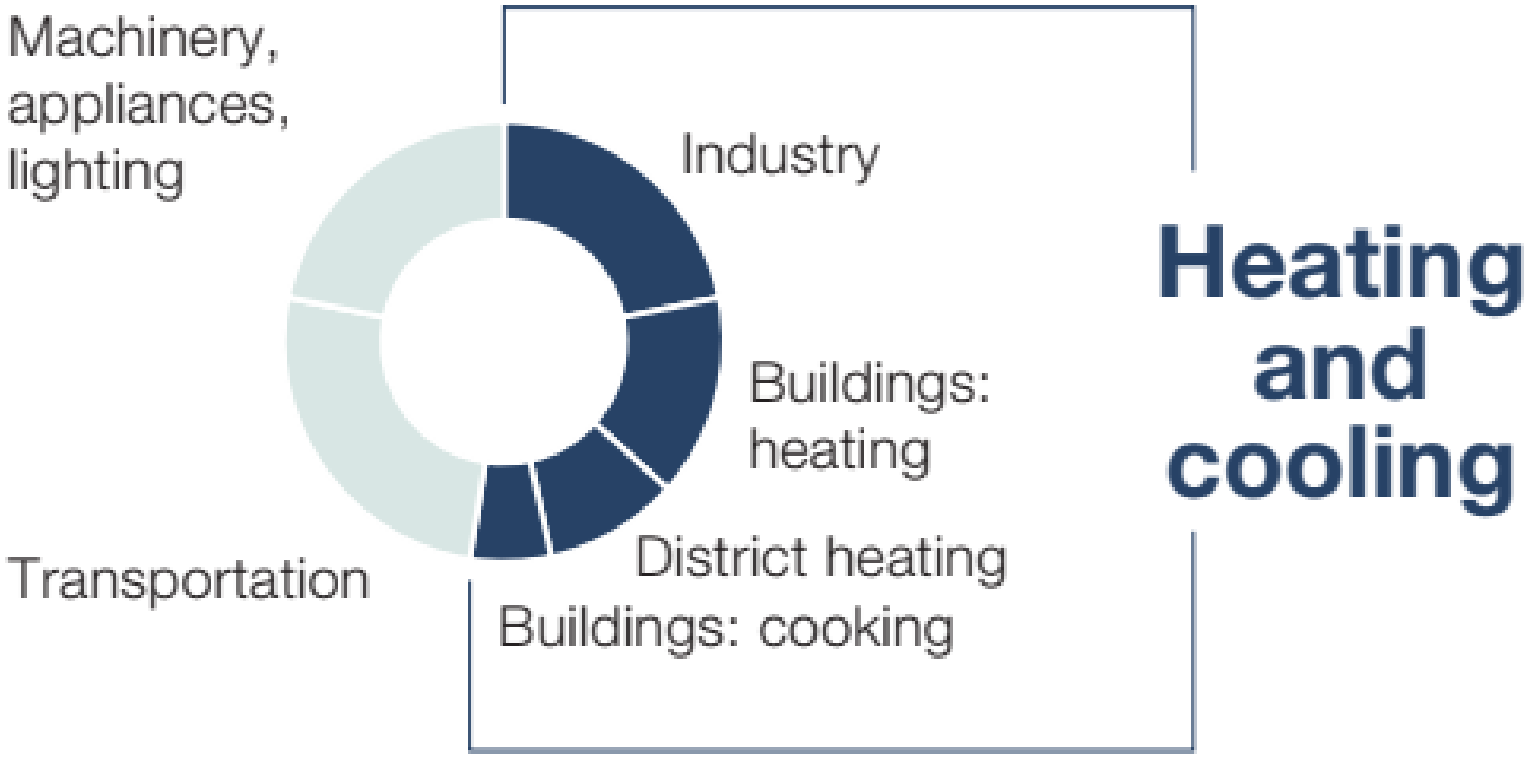
THERMAL STORAGE AND THE HEATING SECTOR – A OFTEN OVERLOOKED POTENTIAL

A. Vandersickel, DLR & University Stuttgart

What about heating?

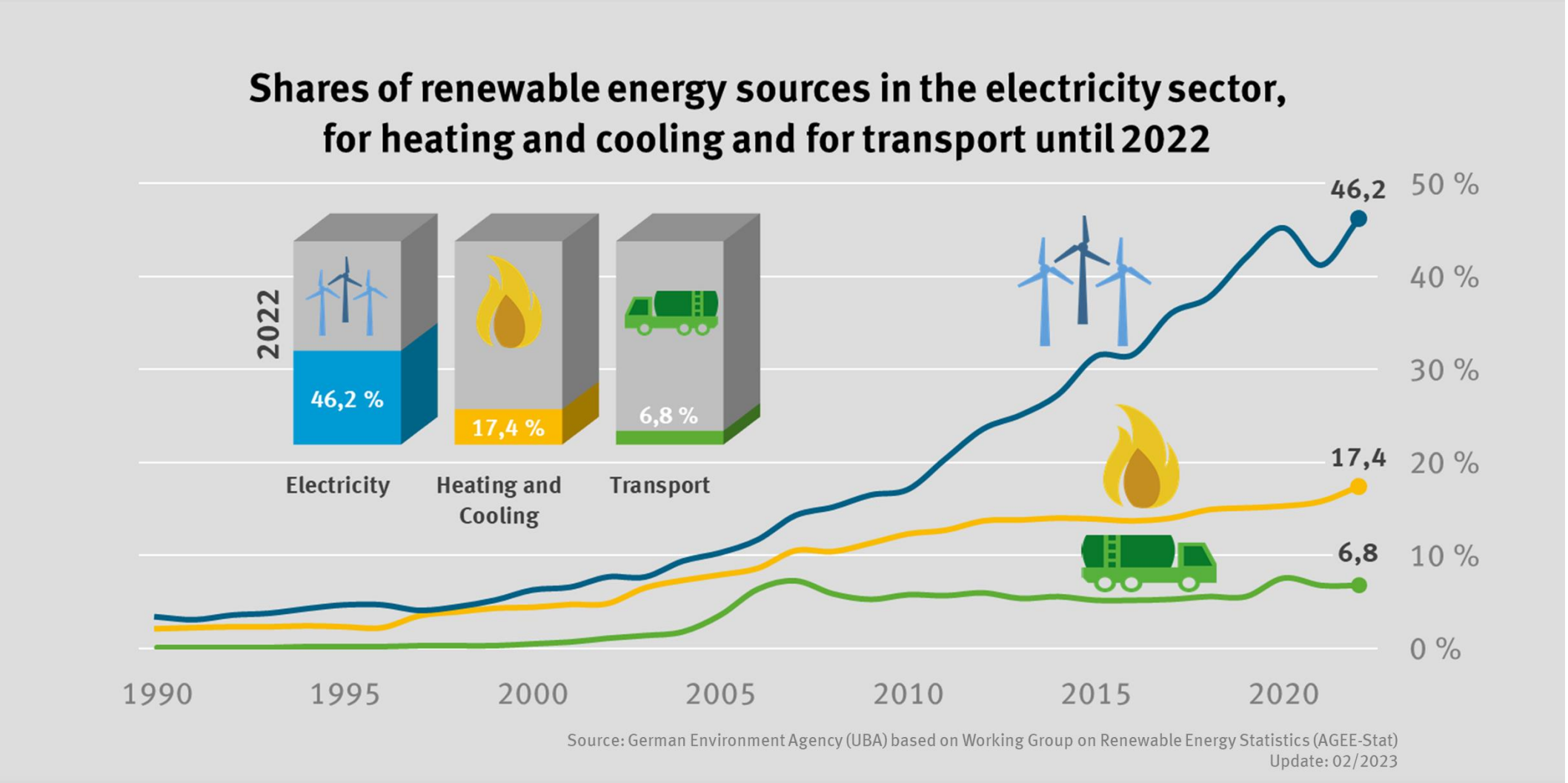
The future energy system is not power only

Global final energy consumption by sector



Net-zero heat Long Duration Energy Storage to accelerate energy system decarbonization, LDES 2022

The ‚Heat' transition has only started

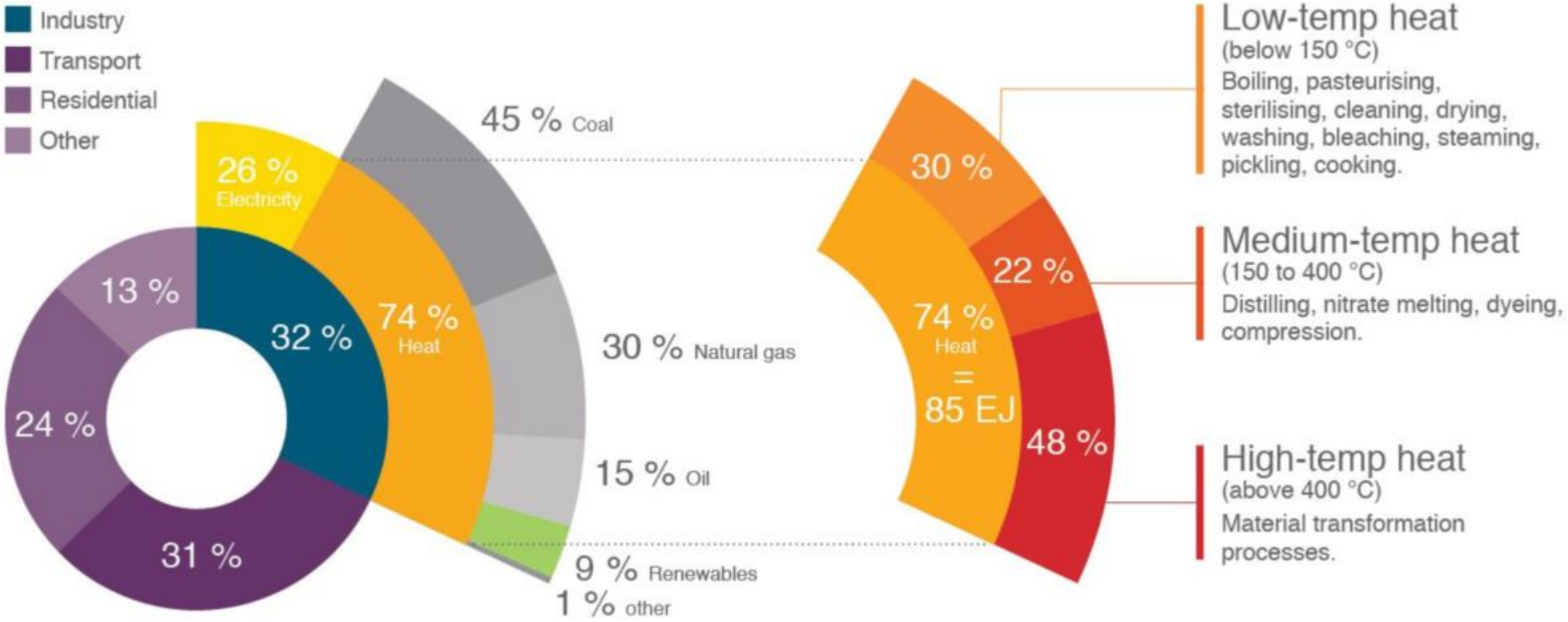


www.umweltbundesamt.de
Grzegorz Polak / Fotolia.com

7 Terrible Effects of Industrial Pollution | Earth Eclipse

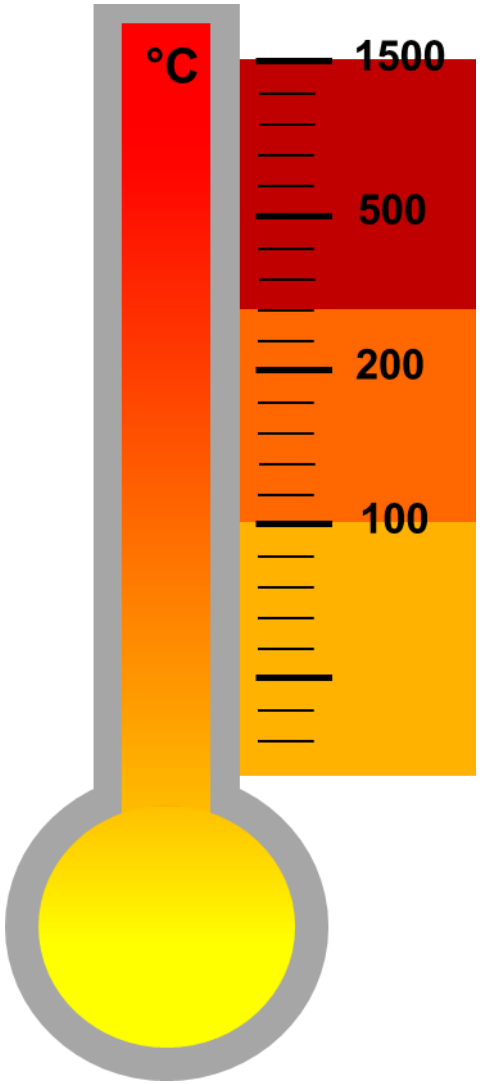
The Challenge: Heat ist not Heat !

The Challenge: Heat is not Heat !



graph: Solar Payback, www.solar-payback.com (2022), World Data Source: Source: IEA; Total Final Energy consumption 2014: 360 EJ

What technogy options do we have?



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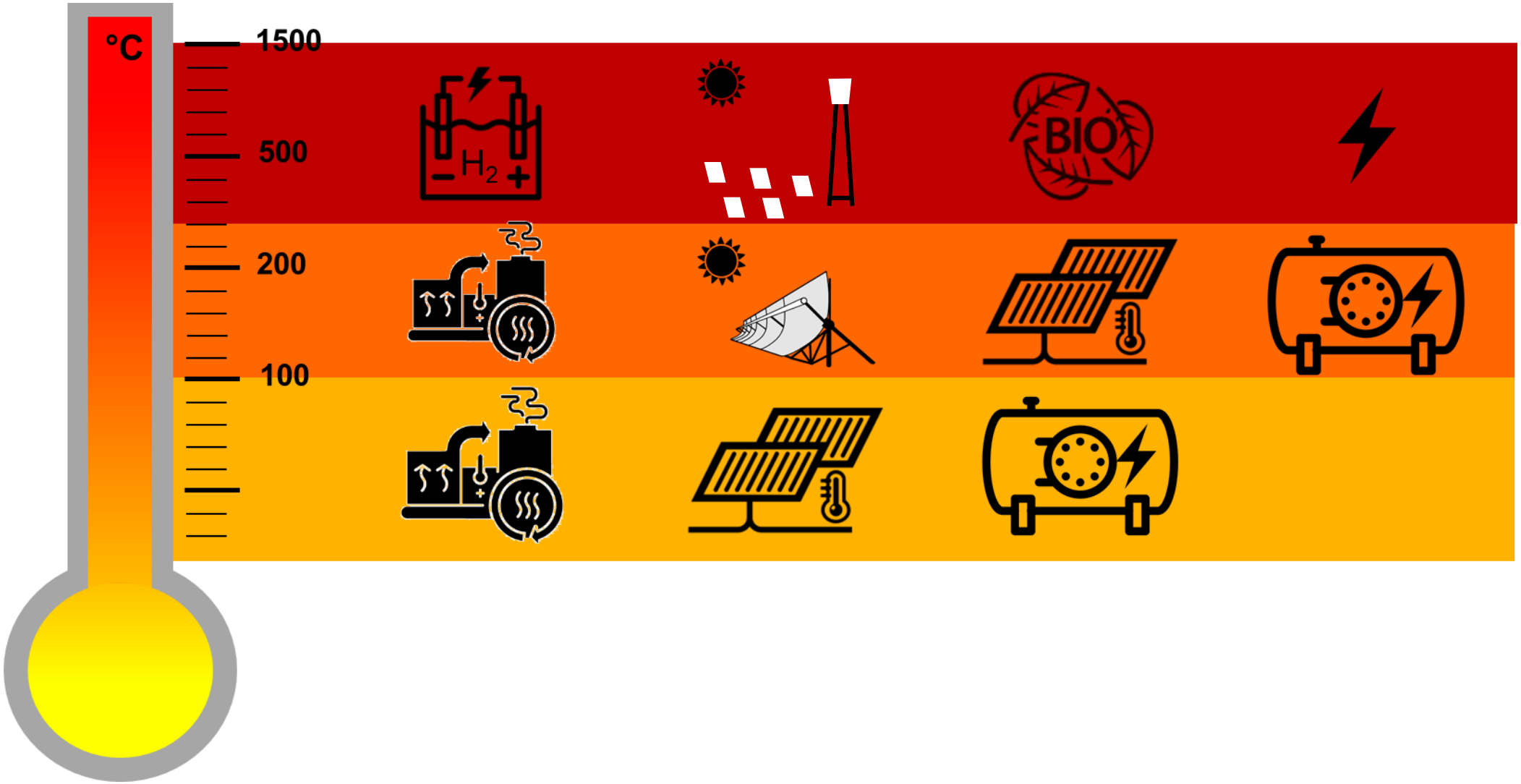
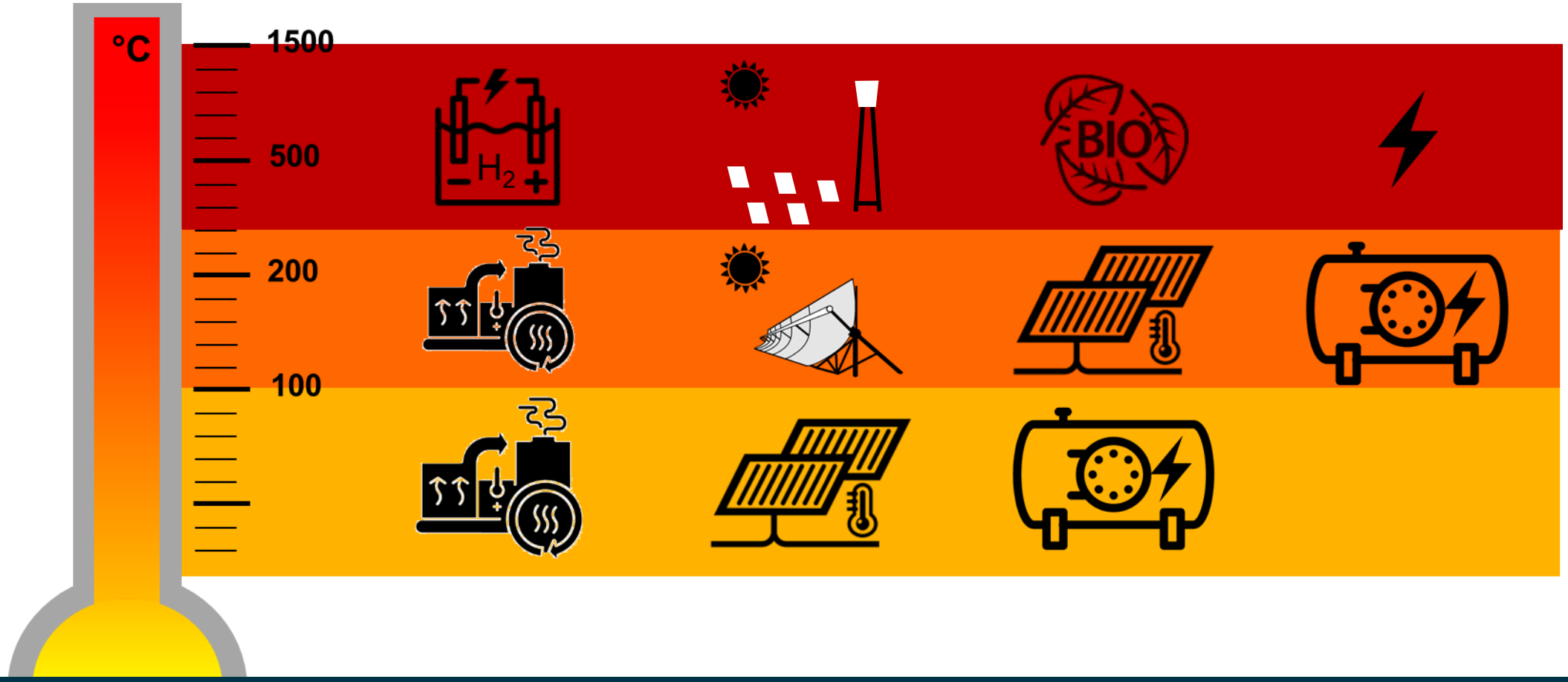


What technogy options do we have?
Electrification as Key Enabler



By 2050 > 60 % electrification both in Buildings & Industry ~ IEA Net Zero by 2050

Thermal storage will be a Key Technology
to master the decarbonisation of the heating sector

Reliable on-demand Heat

Thermal storage is the key to heating on demand from intermittent renewable energy

Affordable Grid Stability

In combination with Power-to-Heat, thermal storage supports the integration of high shares of RE

Reduced Heat demand

Thermal storage enables the recuperation of waste heat reducing the size of the heating challenge

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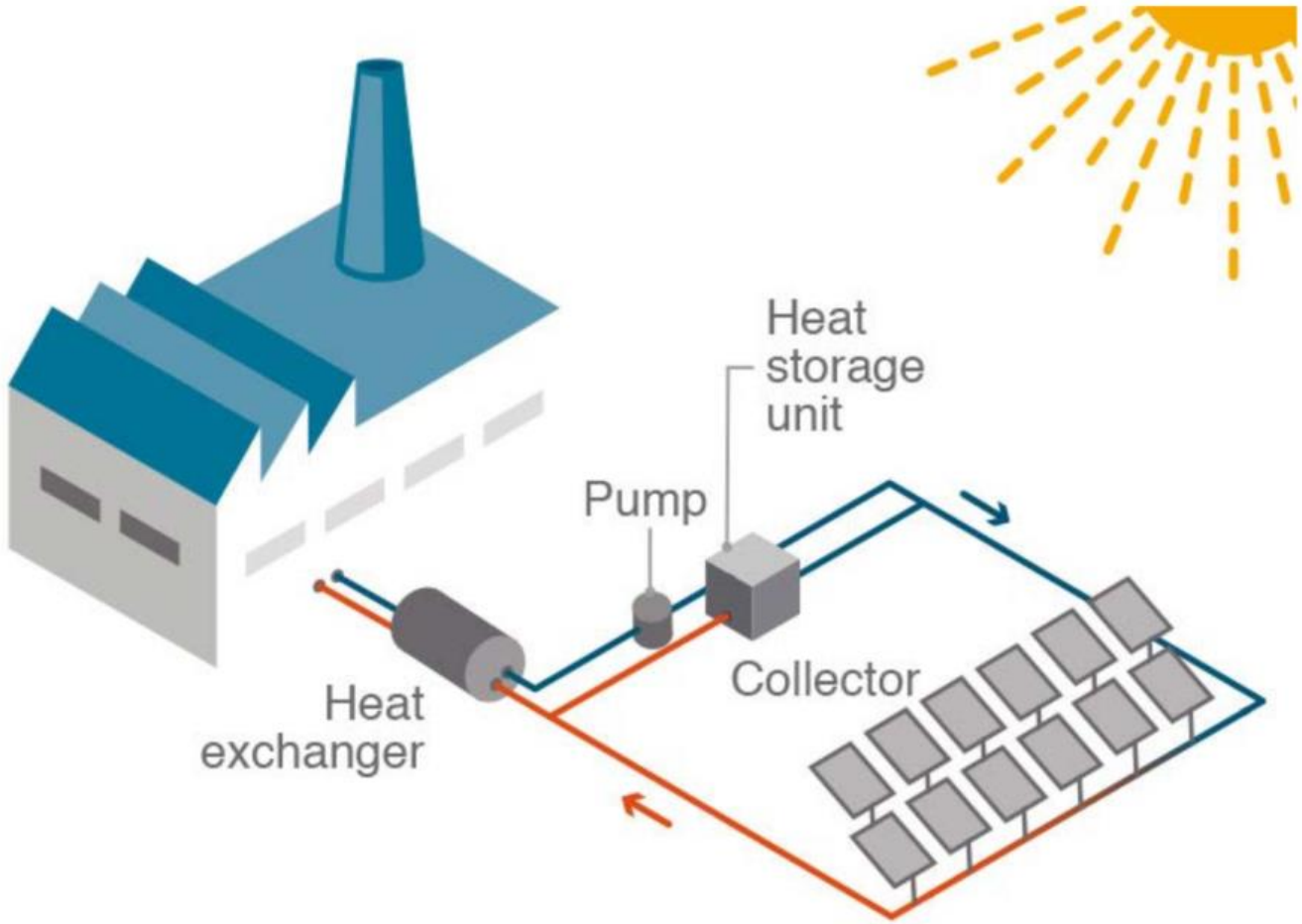
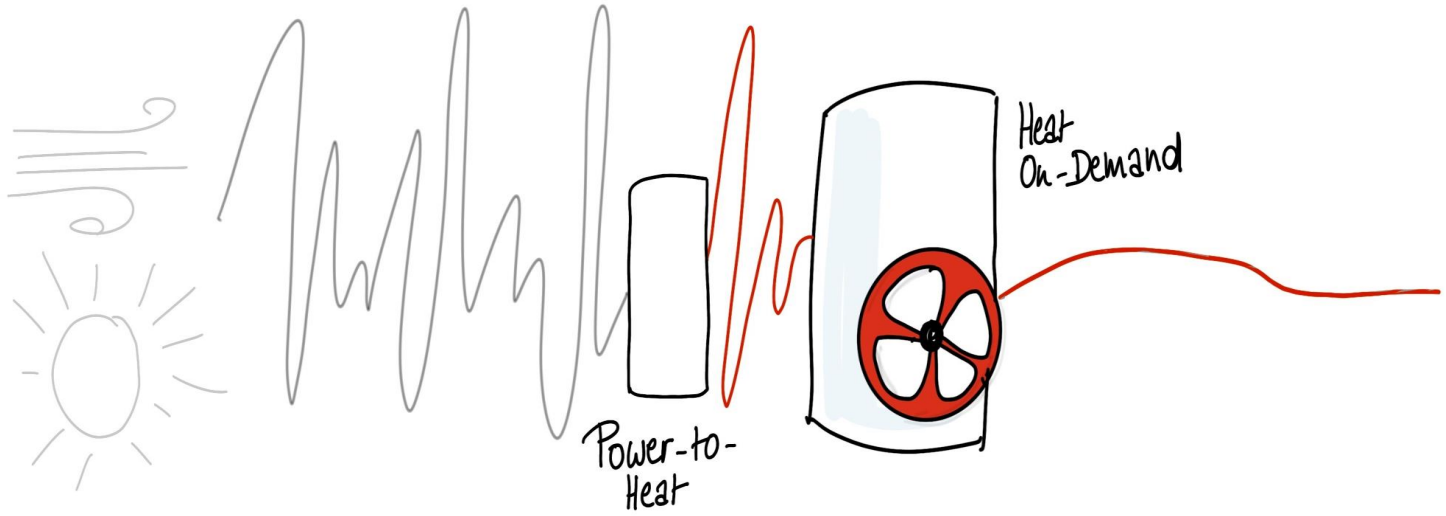
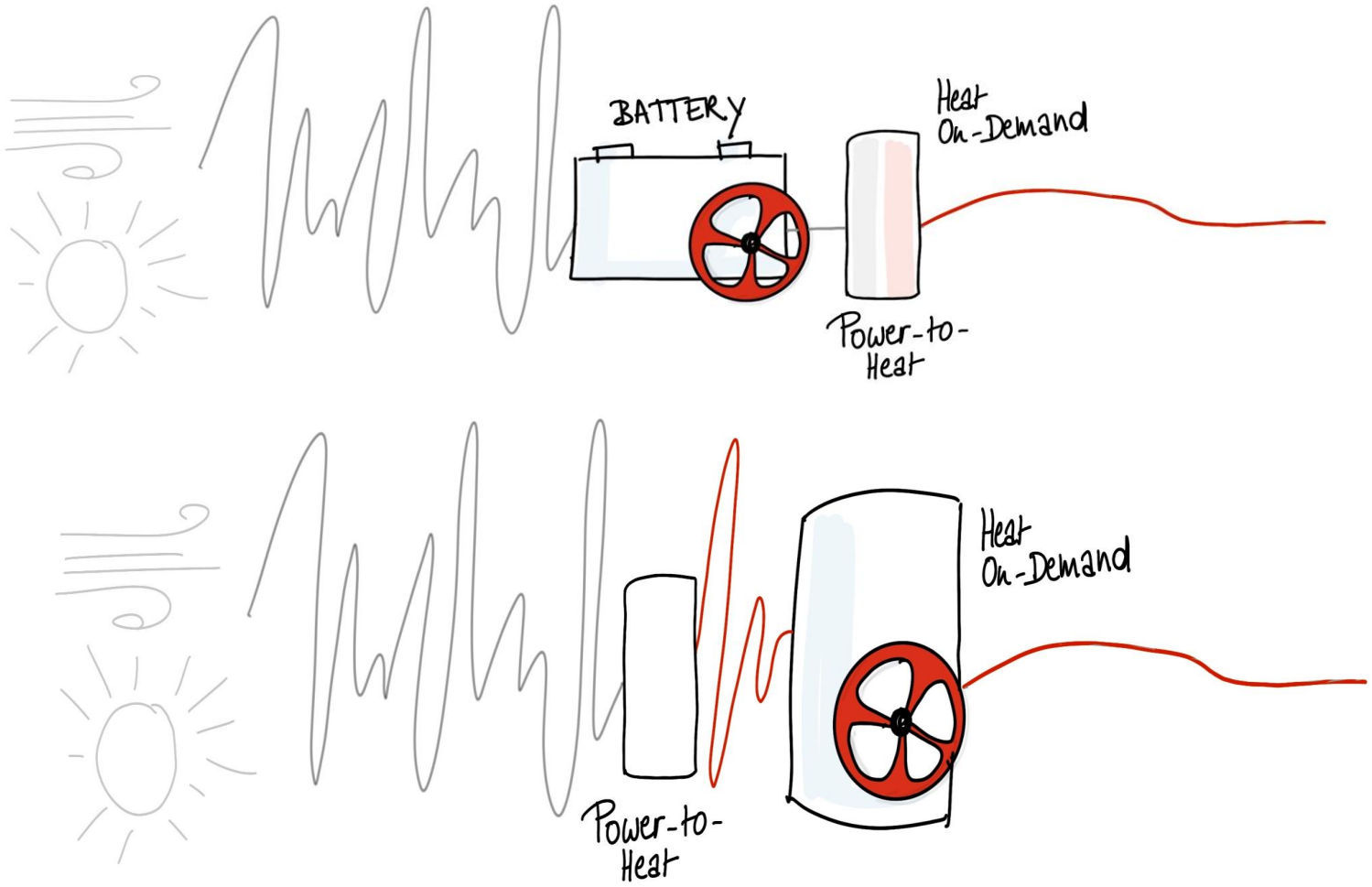
Heat-on-Demand from solar thermal
from 60°C beyond 1000°C



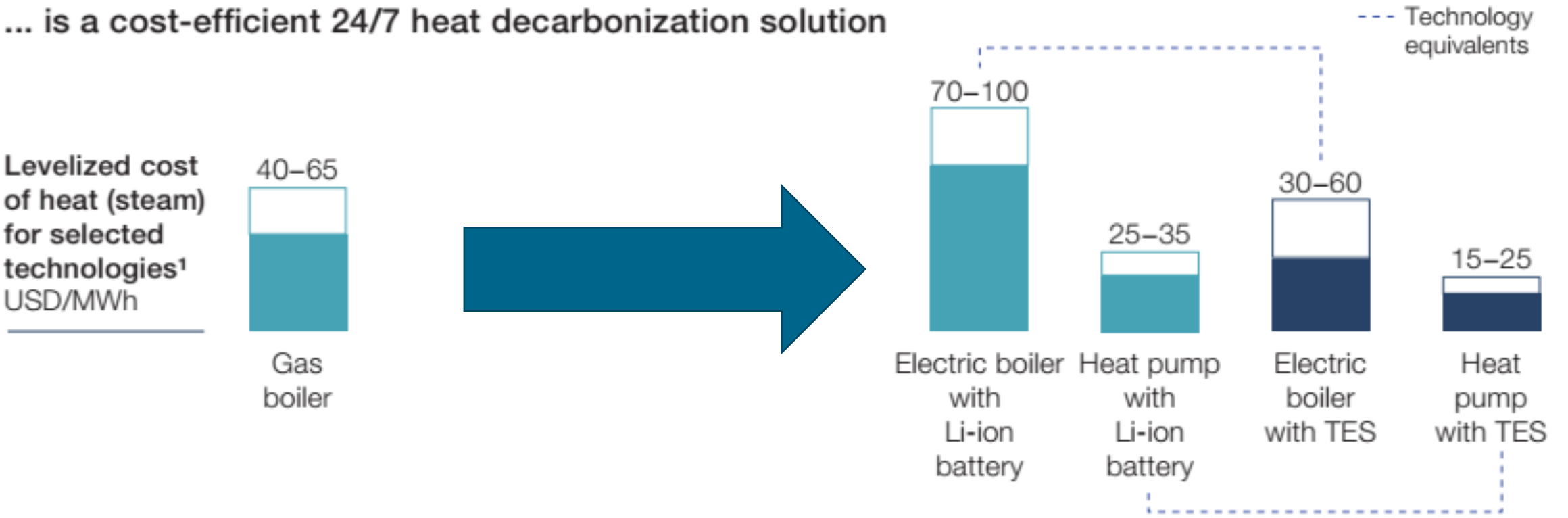
Heat-on-Demand from renewable electricity



Heat-on-Demand from renewable electricity



Thermal Storage with Power-to-Heat



TES makes storing heat more cost-efficient than storing power for heat applications

TES requires less (no) critical materials than storing power

Adapted from Net-zero heat Long Duration Energy Storage to accelerate energy system decarbonization, LDES 2022

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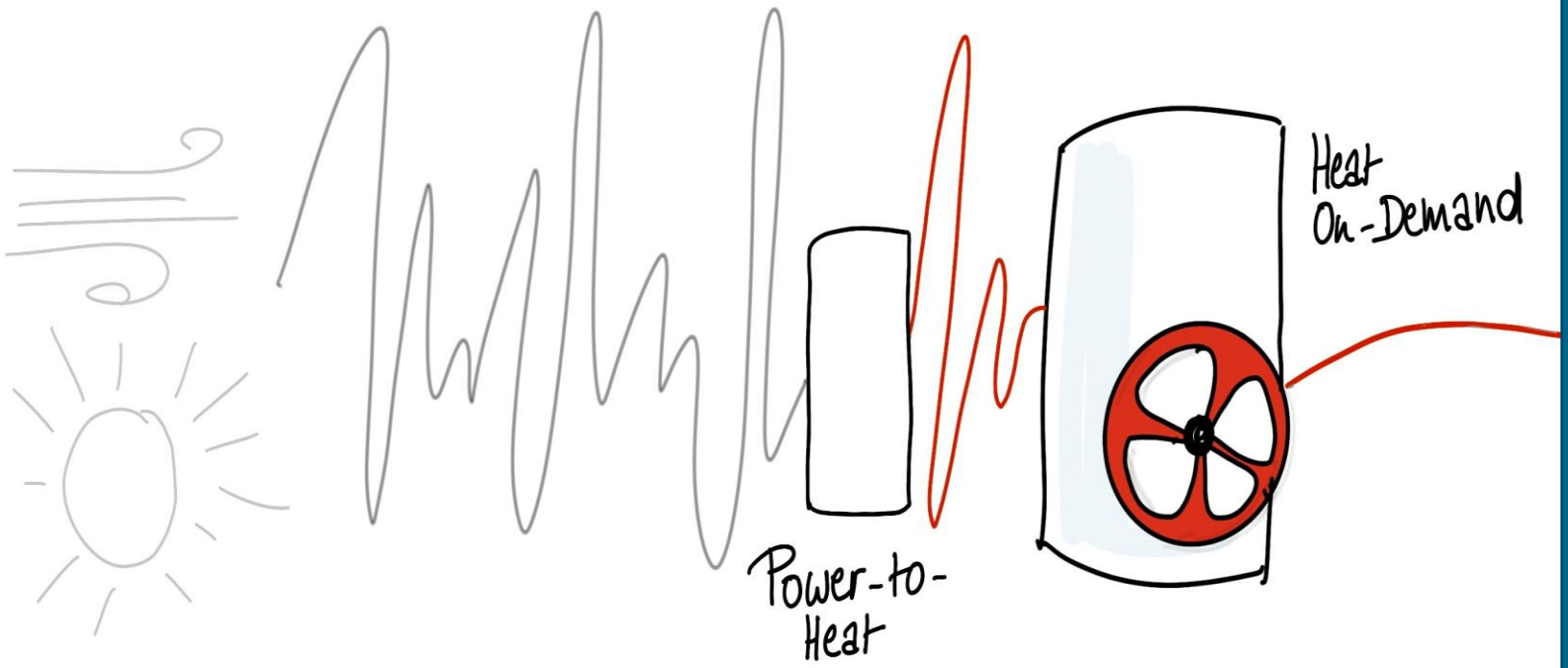
Flexible Sector Coupling with Power-to-Heat
High flexibility through a thermal storage



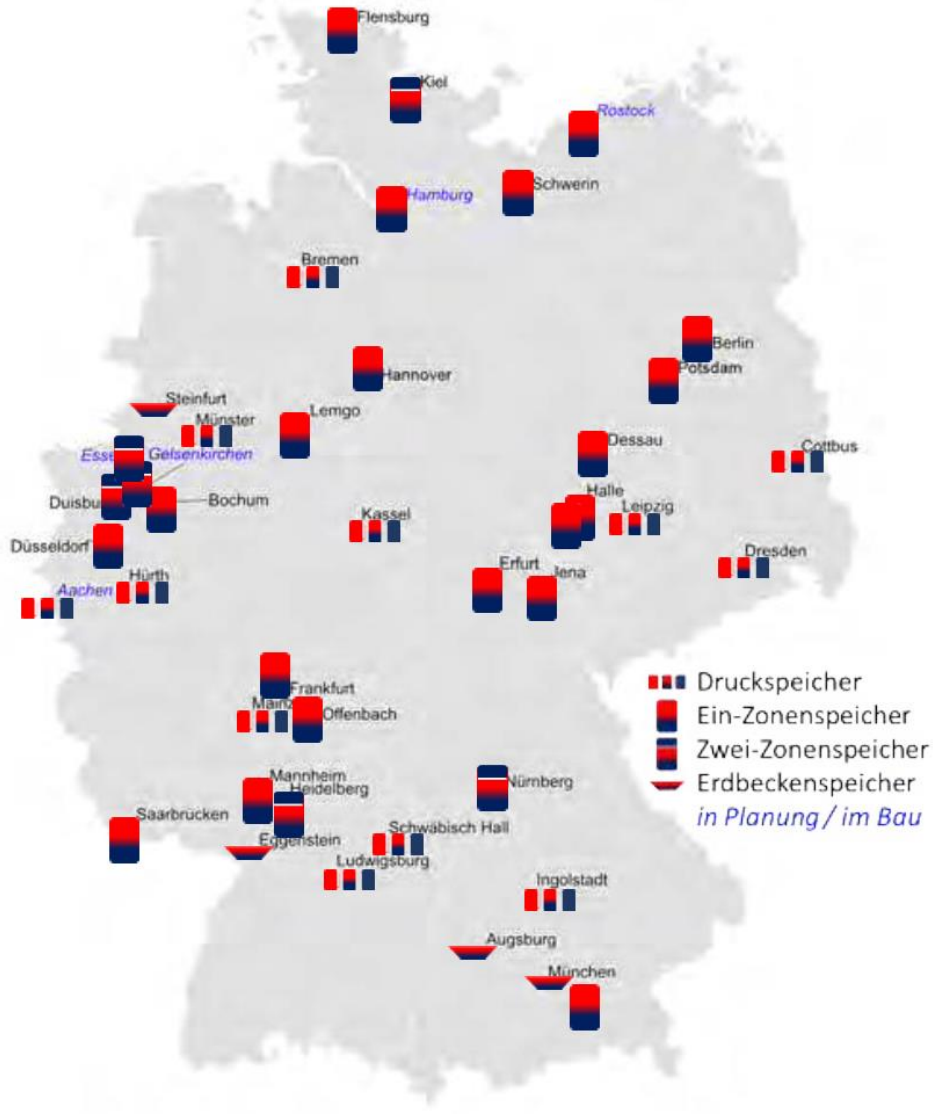
Storage supported PtH:

- Enables a cost-effective integration of large shares of RE (load Shifting)

Power-to-Heat for districts

Heat storage & Elektroboiler

- to flexibilise CHP
- Minimise heating costs, e.g. by acting in the control energy markets



BWK BD. 73 (2021) Energiespeicher – Stenzel et al.

Flexible Sector Coupling with Power-to-Heat
High flexibility through a thermal storage

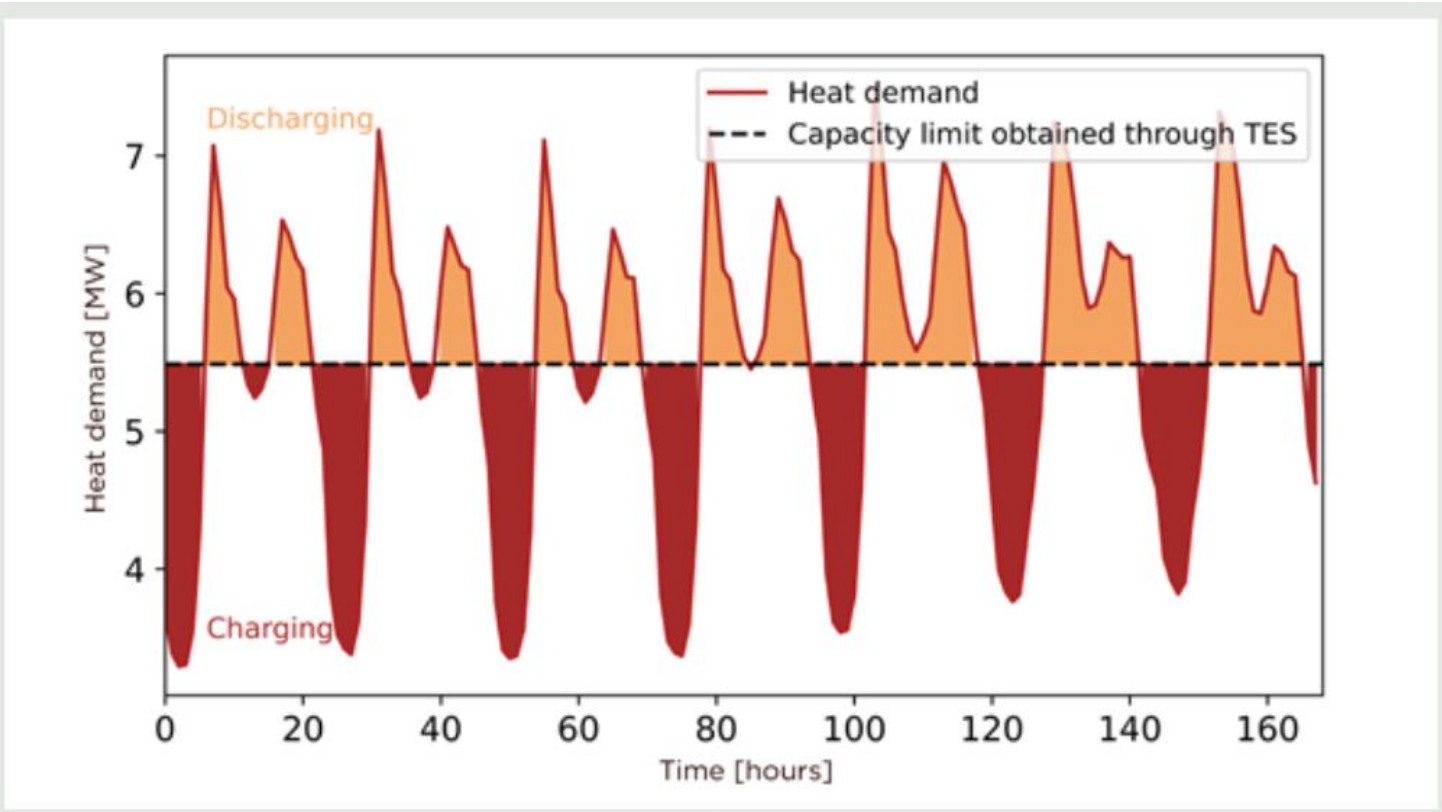
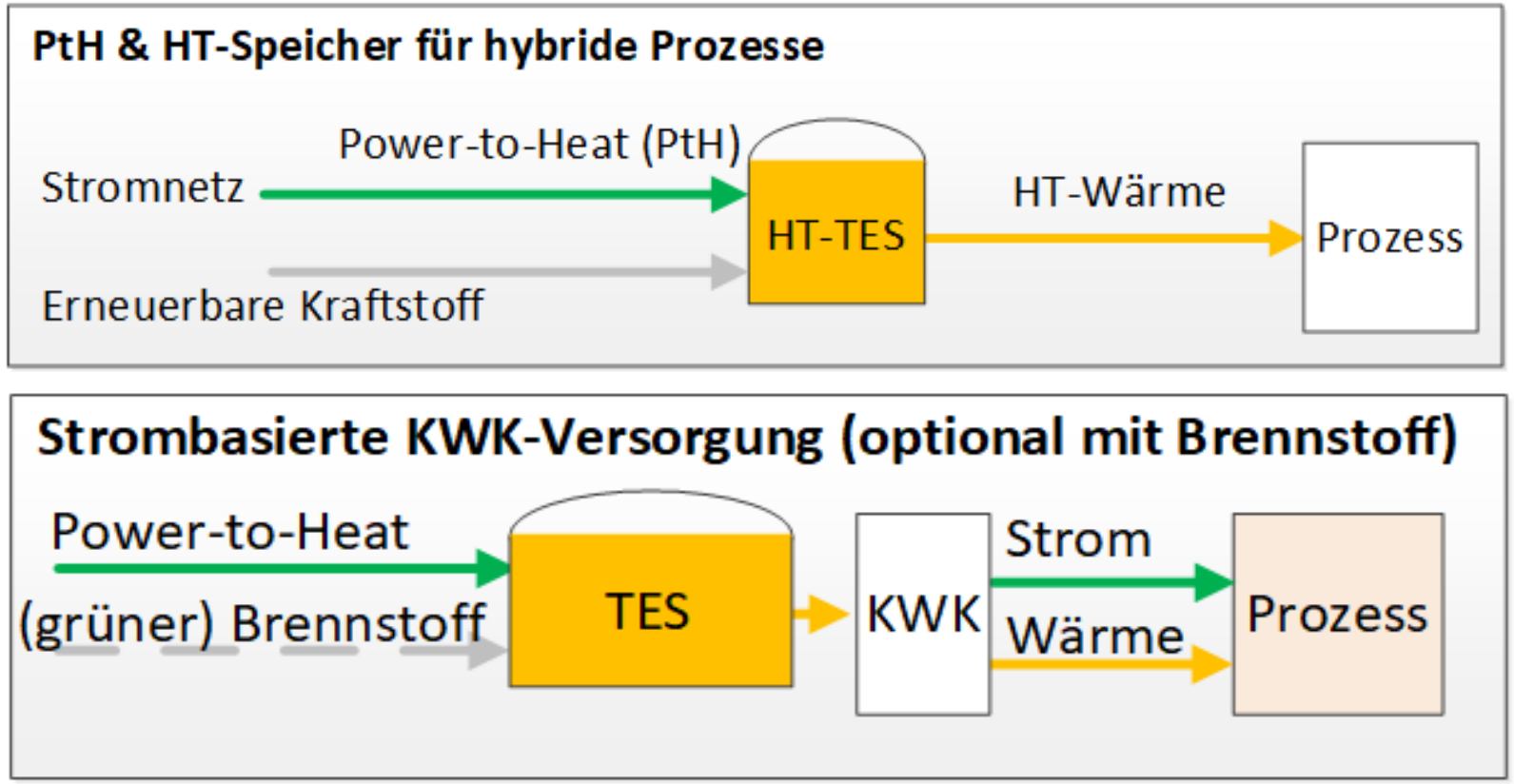


Figure 2 Peak shaving with TES: charging during low-demand periods and discharging during high-demand periods (©SINTEF).

Storage supported PtH:

- Enables a cost-effective integration of large shares of RE (load Shifting)
- Reduced required transmission capacity & provides grid relief

Flexible Sector Coupling with Power-to-Heat
Thinking one step further….



Carnot-Battery for affordable mid-to-long term storage & flexible heat supply and integration

Thermal storage will be a Key Technology
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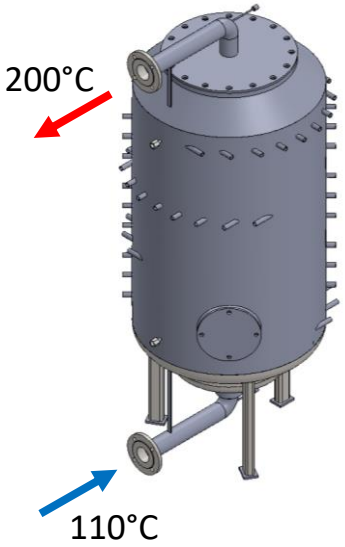
Thermal storage enables the recuperation of waste heat reducing the size of the heating challenge

Heat Recuperation to reduce the required heat demand

GIEßEREI

Prototyp im Labormaßstab mit Thermoöl als WT

- Anwendung: Wärmerückgewinnung Kupolofen zur Unterstützung der Lacktrocknung
- Volumen: 700 Liter
- Größe: Ø = 0,8 m, H = 2 m
- Temperatur: 100 °C – 215 °C



- ✓ 6700 Aufheiz-/Abkühlzyklen abgeschlossen
- ✓ Demonstrator geplant (3,6 MWh)
- ✓ Einsparungen > 50% des Wärmebedarfs für die Lacktrocknung

ZAE BAYERN

SCHLEIFSCHEIBEN-HERSTELLUNG

Demonstration im Pilotmaßstab mit Luft als WT

- Anwendung: Zwischenspeicherung Abwärme aus der Herstellung keramischer Schleifscheiben bis zur Reintegration in den Prozess
- Speicherkapazität: **900 kWh**
- Größe: 2m x 2m x 2m
- Temperatur: 200 – 450°C

Demonstrator beim Endanwender

- ✓ Speichereinbindung abgeschlossen
- ✓ Erste Tests laufen
- ✓ Einsparungen: 45 MWh/a (9,8 Tonnen CO2)

Fraunhofer ISE

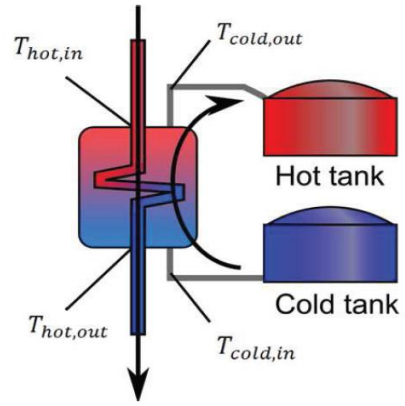
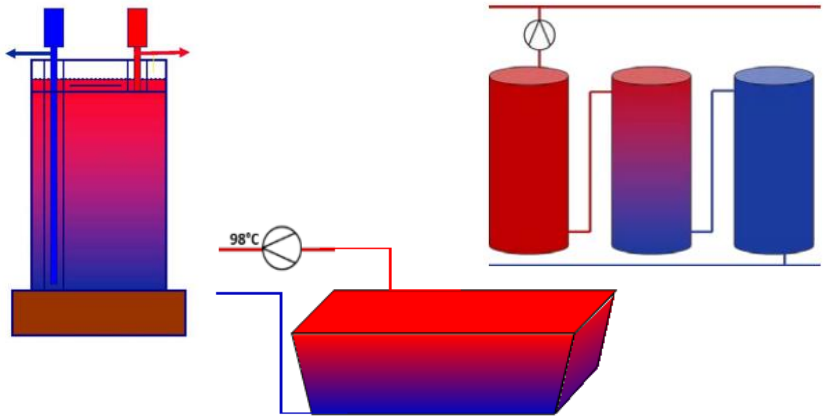
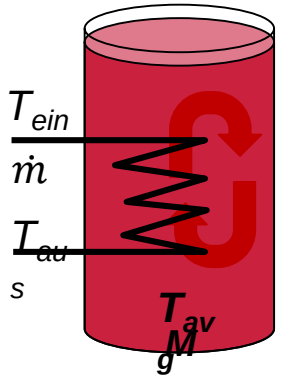
How can we store heat ?

What are relevant design criteria ?

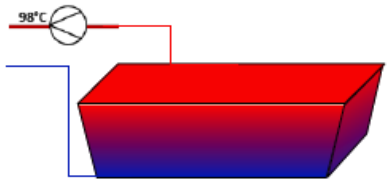
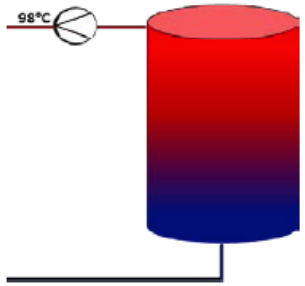
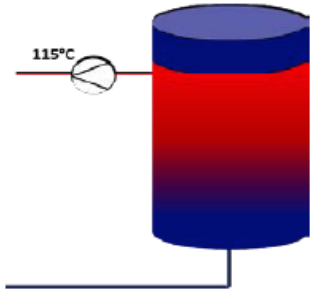
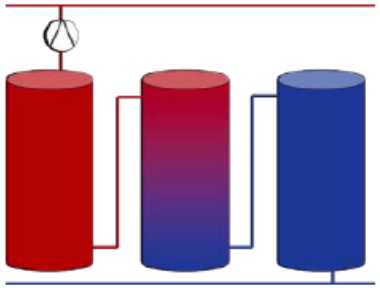
Heat Storage in the high temperature range
No „One-fits-it-all“ Solution

	Regenerator	Regenerator	Molten Salt	Ruths	Phase Change Material	Liquid Metal	Hot Water
Storage Material	Ceramics	Natural Rock	Nitrate Salt (molten)	Pressurized Water	Nitrate Salts, Aluminium	ZrSiO4	Water
Energy density *in kWh/m³*	75 - 200	75 - 200	75 - 200	bis 100	50 - 200	75 - 200	60-80
Max. Capacity	1000 MWh	23 MWh	4500 MWh	30 MWh	500 MWh	100 kWh	scalable
Typ. Temperatures	400-1600 °C	200-800 °C	170-560 °C	150-230 °C	130-330 °C	100-700 °C	< 100°C
Typ. Heat Transfer Fluids	Gases	Gases	Salt	Water/Steam	Steam	Lead/Bismuth	Water
Investment cost TES *in €/kWh*	15 – 40	-	15 – 70	70 – 300	40 – 80	Not known	25-30
Maturity (TRL)	6 – 9	4 – 5	4 – 9	8 – 9	4 – 5	3 – 4	9

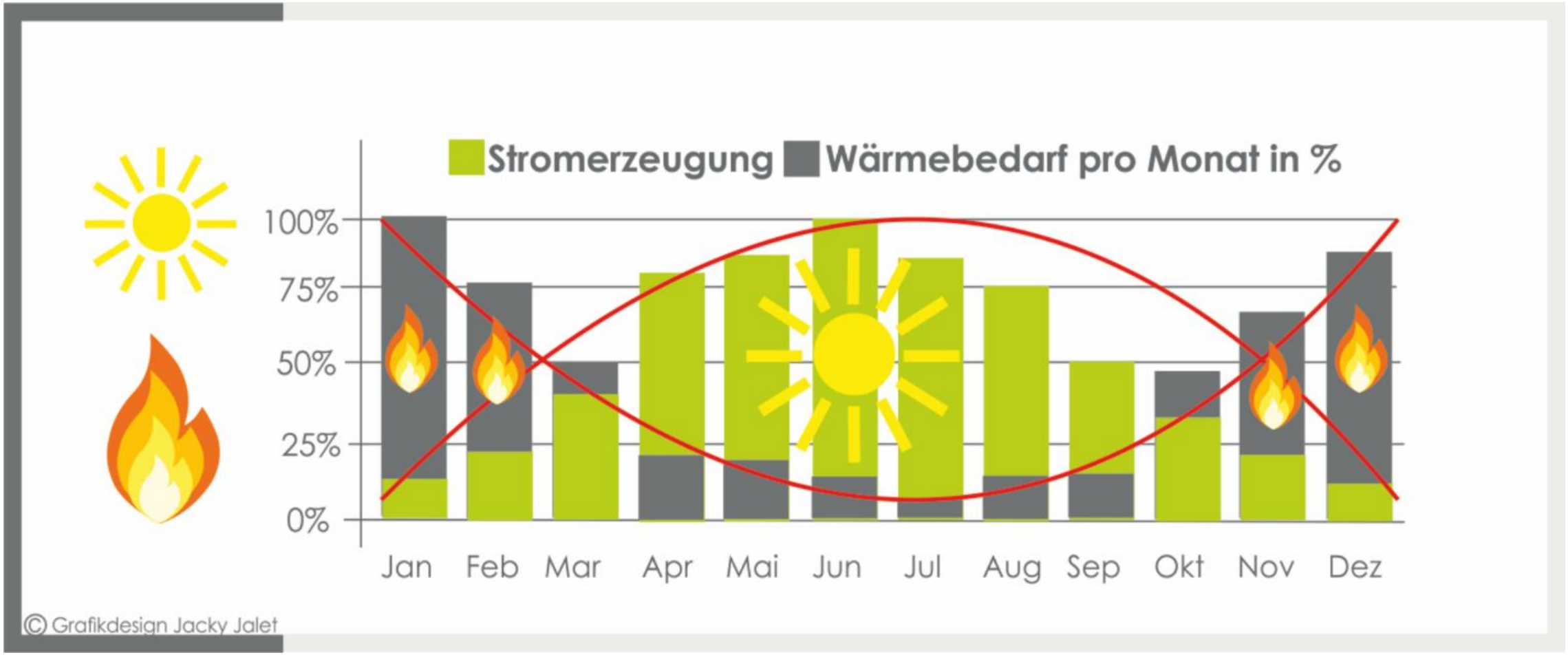
State of the Art – Water

2-Tank	1-Tank Thermocline Atmospheric – Pressurised	1-Tank Mixed
		

State of the Art – Water

	Drucklose Speicher			Druckspeicher
	Erdbeckenspeicher (Saisonalspeicher)	atmosphärischer Speicher	Atmosphärischer Zweizonenspeicher	
Prinzip				
Volumen (aktuell realisiert)	Bis 200.000 m³	Bis rd. 50.000 m³	Bis rd. 42.000 m³	Modular, Einzelbehälter bis 150 m³
Max. Temperatur	90°C (bei Solarwärme-speicherung)	98°C	abhängig von der Wasserauflastung	Bis ca. 140 °C
Spez. Kapazität (bei 60° Rücklauftemperatur)	35 kWh/m³	44 kWh/m³	> 44 kWh/m³	Bis ca. 90 kWh/m³
Kosten (ca.)	100-250 EUR/m³	300-500 EUR/m³	400-700 EUR/m³	800-1.200 EUR/m³

Seasonal storage – the holy grale of R&D?



Seasonal storage – the holy grale of R&D?
Power-to-Heat with thermochemical energy storage

Charging with electricity mainly in summer

Storage Material
$Ca(OH)_2$ /CaO

Seasonal Storage @ Ambient Temperature

CaO

$Ca(OH)_2$

$H_2O_{(g/l)}$

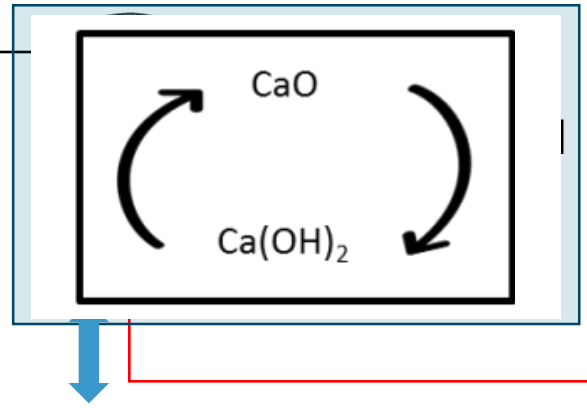
District heating

Seasonal storage – the holy grale of R&D?
Power-to-Heat with thermochemical energy storage

Charging with electricity mainly in summer

Storage Material
$Ca(OH)_2$ /CaO

Seasonal Storage
@
Ambient
Temperature

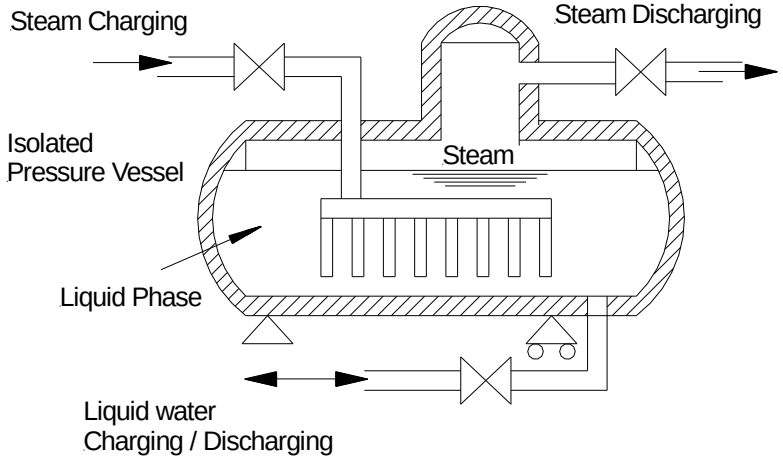


Scalable Reactor demonstrated for 5-10 cycles providing renewable heating & seasonal balancing in the electricity grid

Ruths-Storage or PCM-Storage
for steam generation

Ruths-Speicher

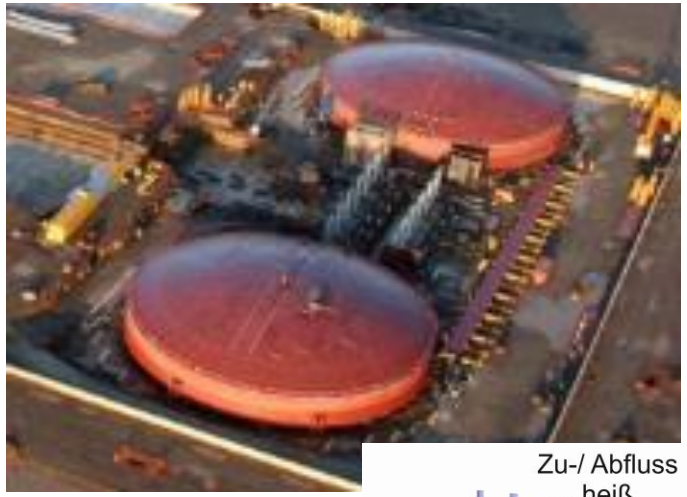
- Used in the process industry
- Supplies saturated steam
- 150 ºC / 5 bar bis 230 ºC / 30 bar
- Used as Power-Component
- TRL 9



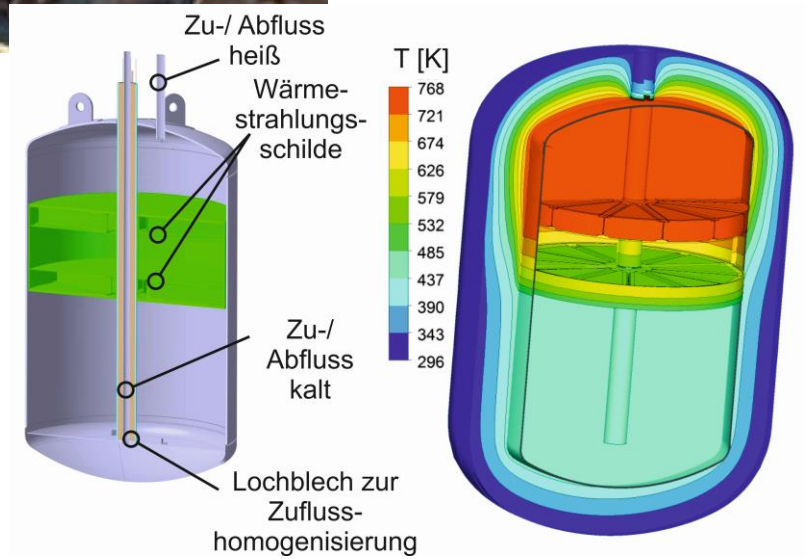
Challenge of Ruths-Storages:

- Pressure Slide → PCM-Storage for saturated & superheated steam

Liquid storage systems – 1-Tank/2-Tank Systems



2-Tank Solarsalz
Andasol

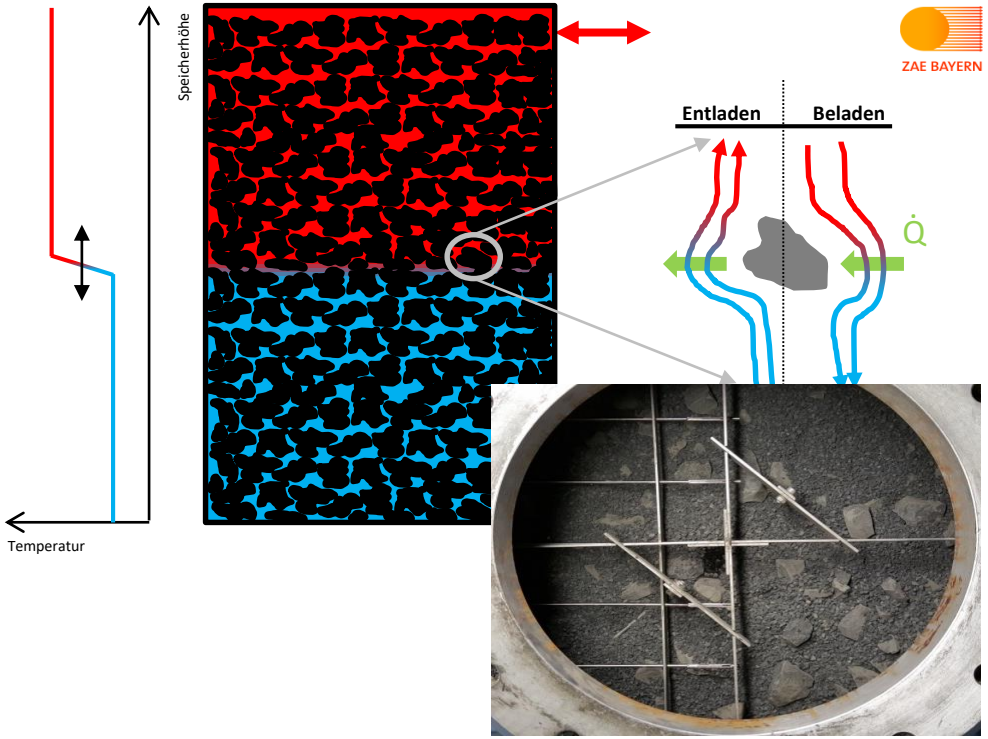


Thermokline mit
Flüssigen Natrium

- **Thermal Öl**
- Temperatur: 200 – 450°C
- TRL 4-5

- **Molten Salt**
- Used in solar power plants (TRL 9)
- Temperature: 170 – 560°C (600°C)
- Application: Solar power plants, industrial heat & Power-to-Heat

One-Tank Liquid Storage with filler



- **THERMAL OIL**
- Temperature: 200 – 450°C
- TRL 4-5

✓ Demonstration in kWh scale
No dust, no degradation of oil or solids

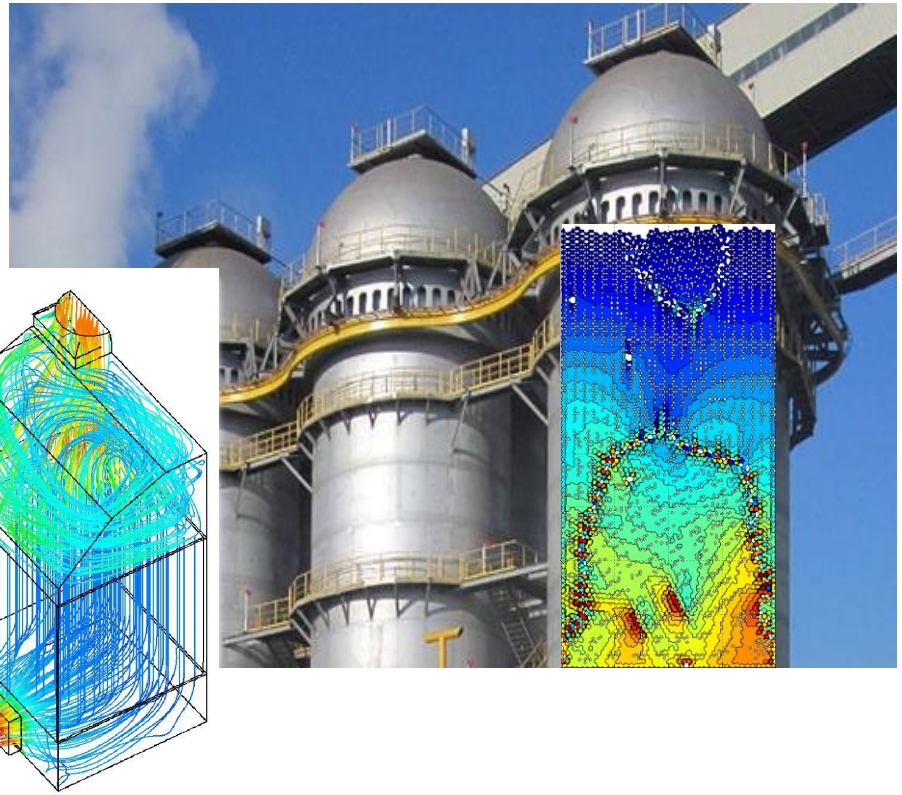
- **MOLTEN SALT**
- Temperature: 170 – 560°C
- TRL 4-5

✓ Demonstration in kWh/MWh Scale

- **LIQUID METAL**
- Stable far above 600°C
- High heat transfer coeff. → compact HXGer
- TRL 3-4

✓ „First-of-its-kind“ tested sucessfully

Solid Media Storage with gaseous HTF



Cowper-Storage in Steel Industry

REGENERATOR:

- Used in steel industry since 1860
- Short Cycle times of 30-180 min
- Temperature: 200 bis > 1000°C
- Application: Solar power plants, industrial heat & Power-to-Heat

TRL: Demonstrator in MWh – bis TRL 9
First Market-Products

Institute of Engineering Thermodynamics

Thermal Process Technology

Prof. Annelies Vandersickel

Thermal Power Plant Components	Thermal Systems for Fluids	Thermal Systems with Phase Change	Thermo-chemical Systems
Dr. Stefan Zunft	*Dr. Thomas Bauer*	*Dr. Andrea Gutierrez*	*Dr. Marc Linder*
			
Regenerator and solid state storage High temperature heat exchangers	Molten salt storage	Latent heat storage PXP storage	Thermochemical Storage Chemical Heat Pumps

About 60 people located in Stuttgart & Cologne

Thermal storage

- Is technically available in a wide T-range & entering the market
- Has large cost reduction potential with upscaling
- In many cases more cost effective AND environmentally friendly as eg. batteries

Power-to-Heat + Thermal storage offer the opportunity to simultaneously

- decarbonise the heating sector AND
- provide flexibility for a reliable and stable electricity system

BUT… still some Challenges

- Lack of visibility & awareness
- Lack of Know-How at Energy System Planers / Lack of independent Advice
- Reluctance on End-User side

Together we can tackle these challenges !

THANK YOU !