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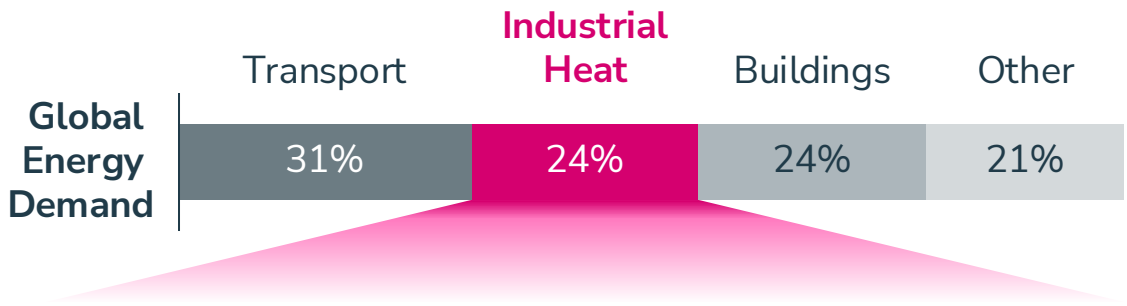
# Rondo Heat Batteries

## Pathway to Zero-Carbon Products & Biofuels

# Industry has a **heat challenge**

## INDUSTRIAL HEAT




- Food & Beverage
- Chemicals
- Paper
- Alumina refinement
- Mining (e.g., nickel, lithium)
- Textiles
- Refining, Bio-fuels, E-fuels
- Auto, Tires, EV batteries
- Other (CPG, Pharma, etc.)
- Steel
- Cement
- DAC & CCUS

## THE CHALLENGE

**Fossil fuels have historically been the best solution**

- **Lowest cost** source of energy
- Deliver **continuous** heat, on demand

**Yet there are problems with burning fossil fuels for heat**

- Creates **25%** of global GHGs; **major scope 1 source** for industrials
- **Risk of spikes** in fossil fuel prices**;** price on carbon is expected to **increase**

"I want to **save money** on heat and **drop the emissions!**"

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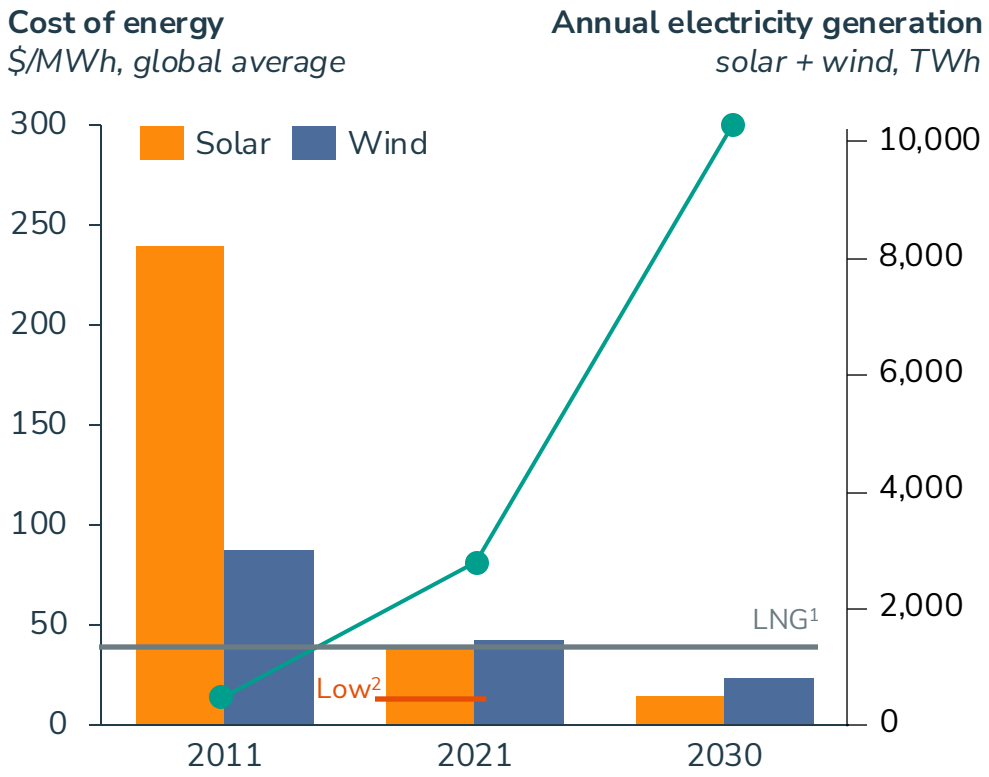
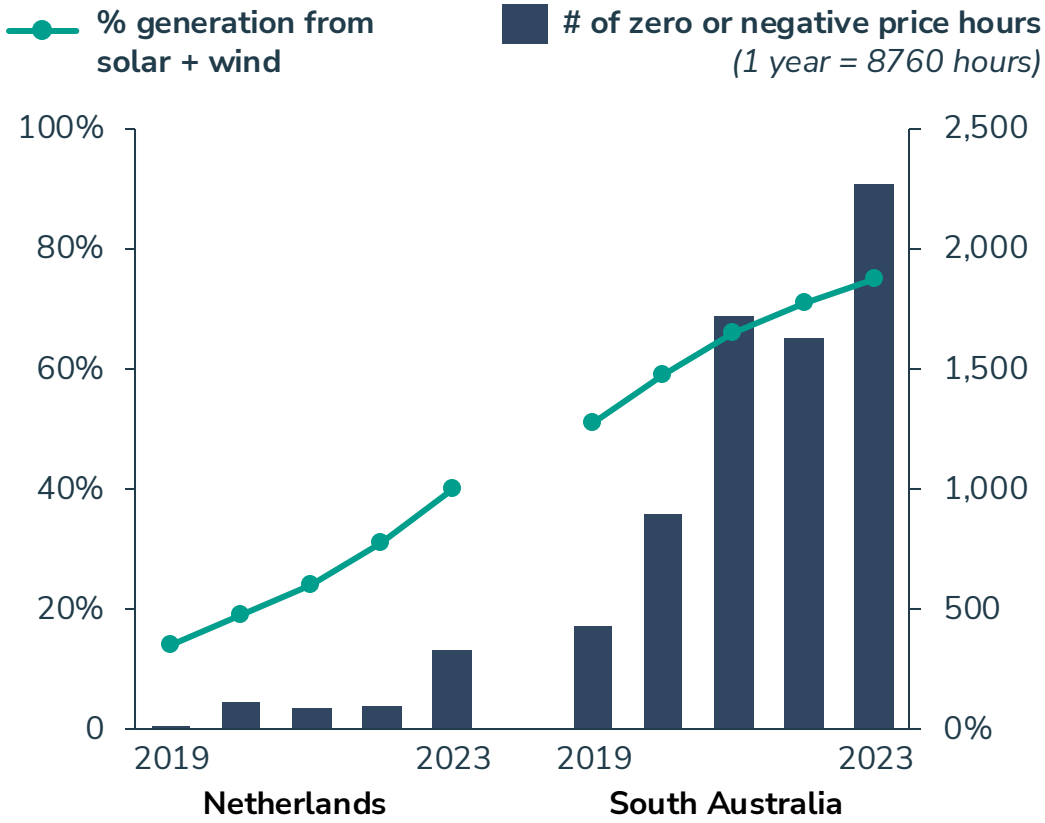
# The world is changing: we have a **new lowest cost energy**

**Solar and wind** scale-up is driving down costs.
Energy cost is now **below natural gas.**




In electricity systems worldwide, more solar & wind is creating
**low (<$20/MWh) and even negative prices for many hours**




The barrier is that **low-priced electricity** is only available **6-8 hours per day**

Notes: [1] LNG prices in 2024 c.$40/MWh. [2] Lowest prices for solar are already < $20/MWh. Sources: IEA, BNEF, RMI

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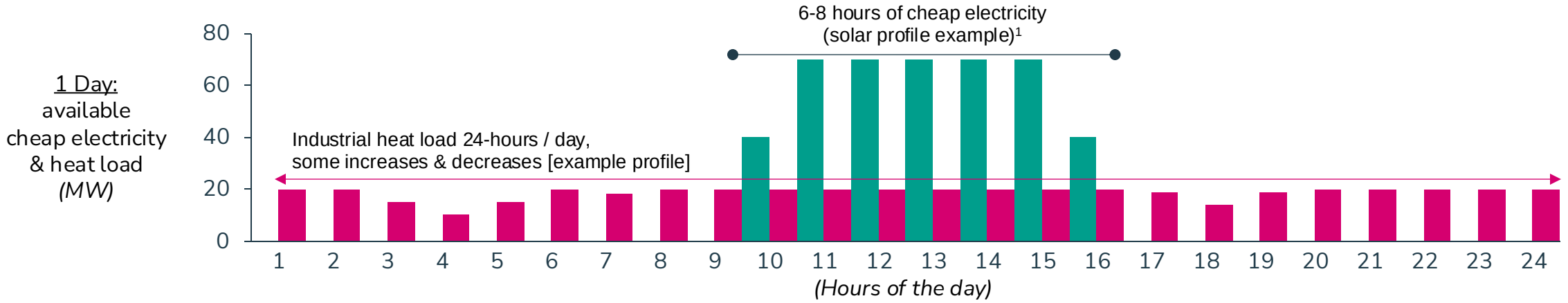
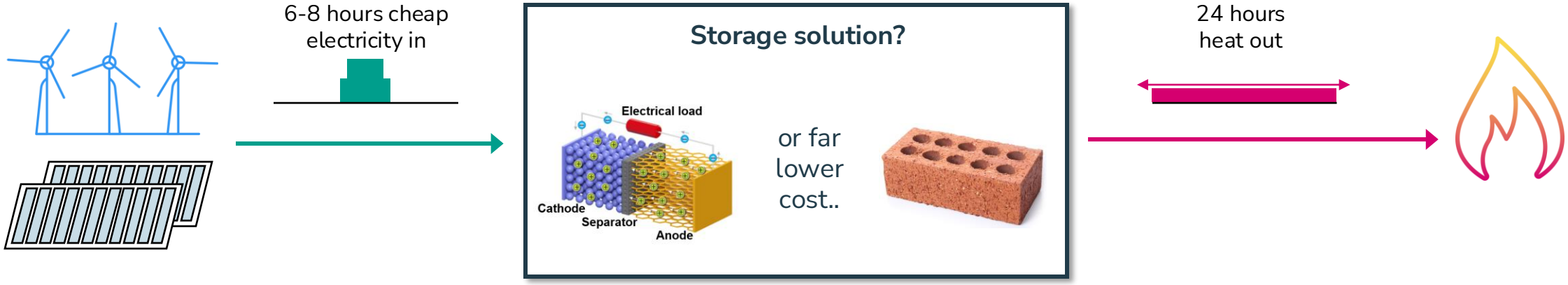
# To capitalize on this, we need **low-cost energy storage**

**The challenge:** cheap electricity available 6-8 hours per day, industrial processes need heat 24-hours / day




**The path:** heat storage is 5x cheaper than electricity storage. The answer is to convert to heat, store energy as heat, deliver as needed.




Notes: [1] In wind-heavy systems, such as NW-Europe or Mid-West US, the cheapest hours will be overnight when wind is producing and demand dips, e.g., midnight to 6am.

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# Meet the Rondo Heat Battery

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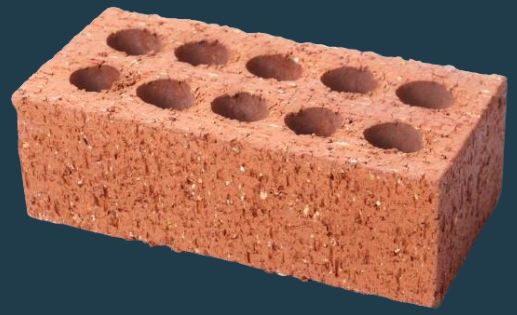

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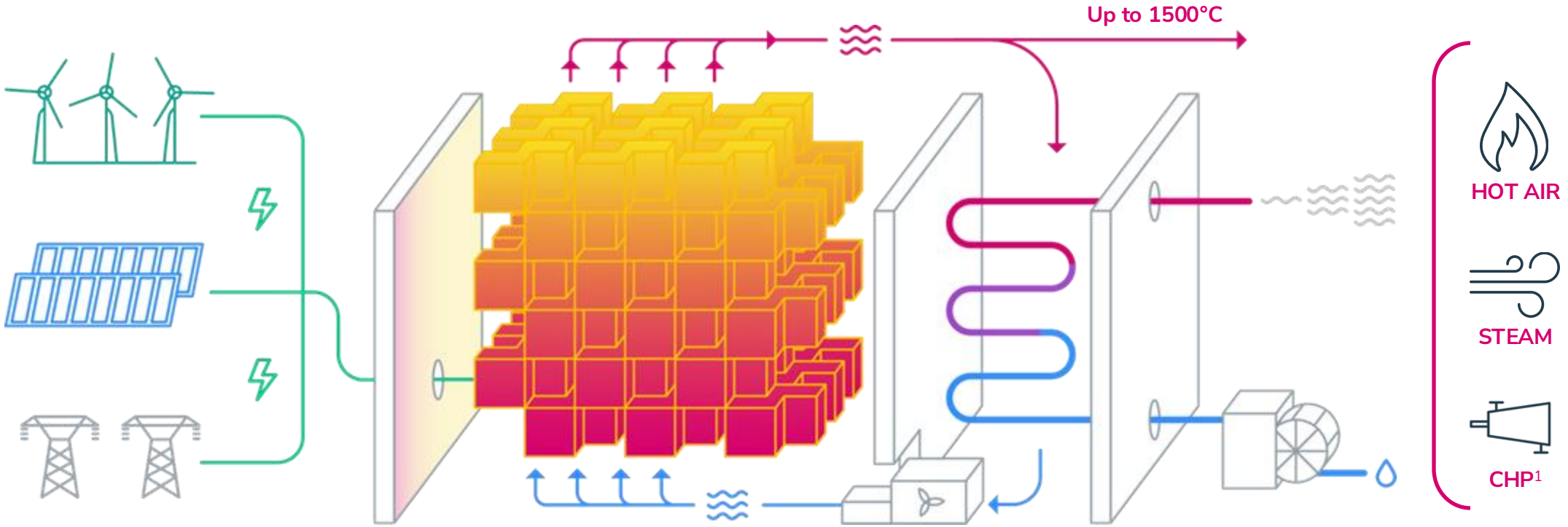
# Here is **how it works**




### 1 CHARGE 6-8 hours / day

The Rondo Heat Battery charges with **intermittent electricity** from local wind & solar or from the grid

### 2 STORE for hours or days

Electricity powers radiant heaters with zero loss; refractory brick is rapidly and uniformly heated to **1100 - 1500°C**, and stores heat for hours or days

### 3 DISCHARGE 24 hours / day

The battery delivers **continuous superheated air** for use as process heat, steam, or electric power at over 98% total efficiency

**98% energy efficient** from electricity IN to heat/steam OUT

[1] Combined Heat & Power; high pressure steam can drive a steam turbine to produce electric power and low-pressure steam, providing 95% efficient combined heat and power

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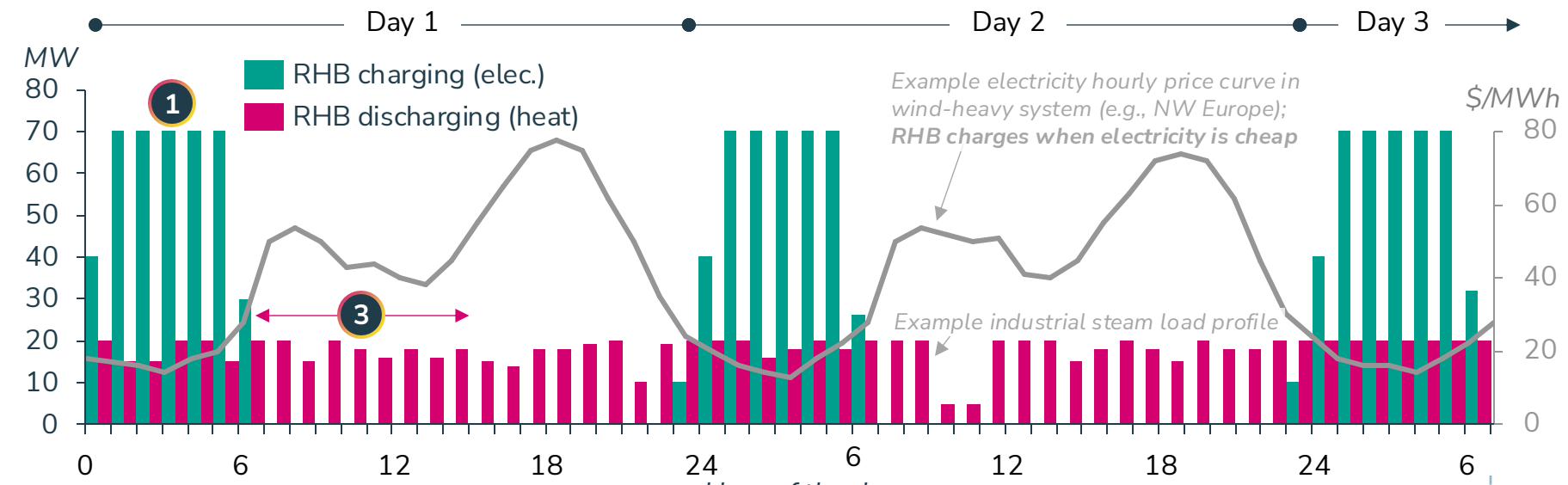
# 6-8 hours of cheap electricity turned into **baseload steam**

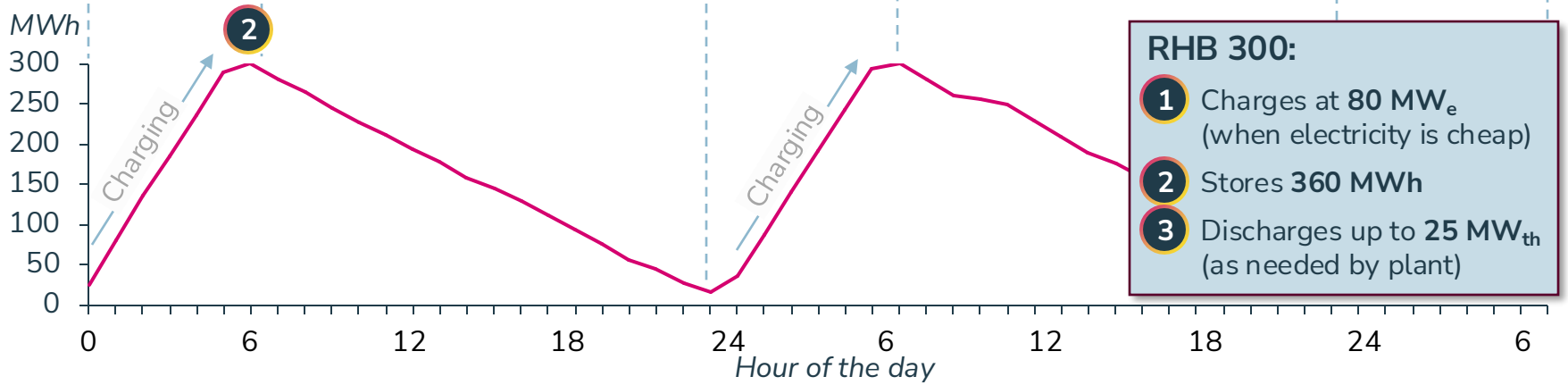
Rondo Heat Battery (RHB)
**CHARGE & DISCHARGE**

Example pattern for RHB300[1]




Rondo Heat Battery (RHB)
**STORAGE**

Energy stored in RHB



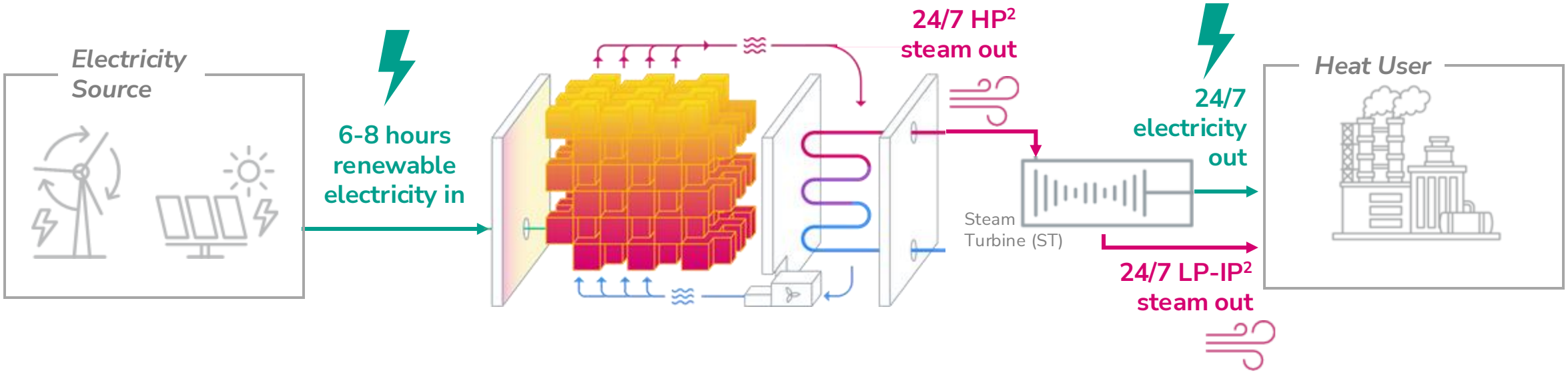

**RHB 300:**

1. Charges at **80 $MW_e$** (when electricity is cheap)
2. Stores **360 MWh**
3. Discharges up to **25 $MW_{th}$** (as needed by plant)

Notes: [1] RHB300 is a product size that refers to 360 MWh of energy storage capacity. See later slide for more information on product sizes.

# Rondo Heat Batteries can also drive a steam turbine to deliver **zero-carbon combined heat and power (CHP)**




High pressure steam drives a steam turbine to produce electric power and low-pressure steam

**Low-cost intermittent wind and solar power** → **95% round trip energy efficiency[1]** → **24/7 clean steam and electricity** (CHP: combined heat and power)

Notes: [1] 95% efficiency achieved when ratio of steam to electricity out is c. 4:1, e.g., 16MW baseload steam and 4MW baseload electricity served from RHB300 with ST.. [2] The steam immediately exiting the RHB is High-Pressure (HP) steam (e.g., 100bar), and the steam exiting the ST is low- or intermediate-pressure steam (e.g., 10 bar).

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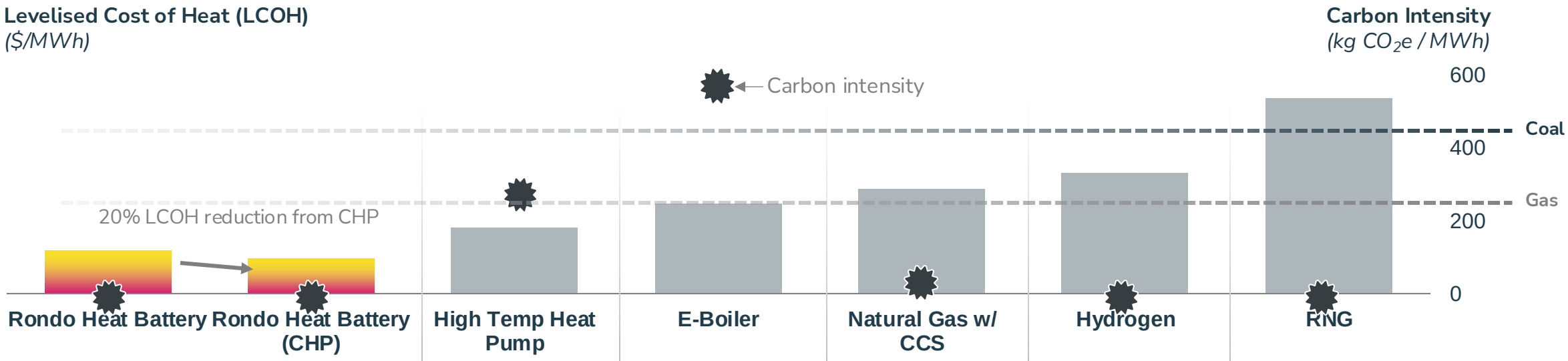
# Above 100°C, RHBs can **save money** and are **zero-carbon**




**CHALLENGES WITH OTHER SOLUTIONS**

**High Temp Heat Pump**

**Limited max temperature** <100°C proven

**24/7 baseload power**; scope 1+2 emissions similar to fossil fuels

Limited in scale

**E-Boiler**

Limitations in steam discharge conditions

**24/7 baseload power** leading to:

- Far higher cost of electricity
- Scope 2 emissions

**Natural Gas w/ CCS**

CCS is heavily **geographically limited**

Intrinsically **raises operating costs** by at least 30% versus no-capture

**Hydrogen**

**~3x CapEx** to produce gas or **prohibitively expensive to buy**

**50% efficiency** from source power to thermal energy

$NO_x$ / local permitting

**RNG**

**Limited supply** (waste product)

Trades at nearly a **5x premium** to fossil natural gas

$NO_x$ / local permitting

Sources: NREL; EIA; Industrial Heating; Agora Industry; Internal figures and analysis. Representative of US Mid-West

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# Modular product sizes to **fit your heat load**

| | RHB100 | RHB300 |
|---|---|---|
| |  |  |
| 1 CHARGE | **20** $MW_{ac}$<br>*Configurable up to 24 MWac* | **80** $MW_{ac}$ |
| 2 STORAGE | **100** MWh | **360** MWh |
| 3 DISCHARGE | **7** $MW_{th}$ | **25** $MW_{th}$ |
| EMISSIONS SAVED[1] | **15k** $tCO_2e$ / year<br>= 3,500 EVs | **55k** $tCO_2e$ / year<br>= 12,000 EVs |

[1] Based on avoided natural gas usage to generate the same volume of discharge heat

 

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# Calgren Renewable Fuels, Pixley, March 6, 2023

# Rondo creates value across many industries

## Food & Beverage:

- Helping industry **create distinguished net-zero products** by using zero-carbon steam & power
- For example: Rondo is installing RHB's at **Diageo's Bulleit Bourbon Facility** in Shelbyville, KY

DIAGEO

BULLEIT BOURBON

## Biofuels & SAF:

- **Biorefineries can monetize reductions in carbon intensity (CI)** via low carbon fuel markets, carbon markets & federal incentives
- Rondo's zero-carbon steam & power can **remove CI points from energy inputs**
- CI from energy is typically **40-50%** in biofuel & SAF production
- Rondo has been running at Calgren's biorefinery since early 2023

CALGREN Renewable Fuels



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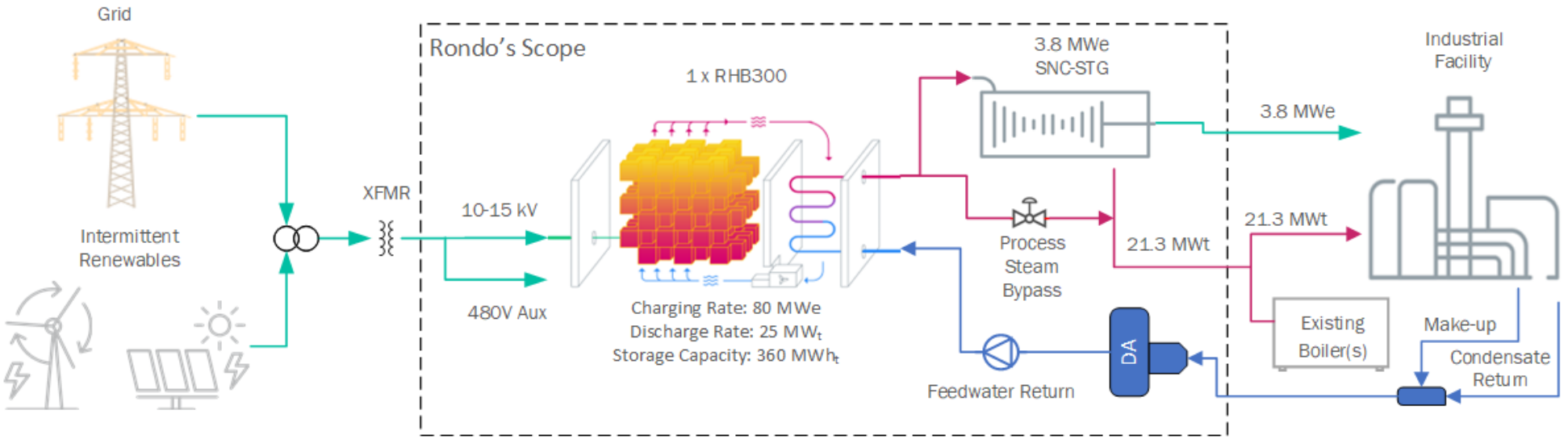
# Case Study: Zero-carbon CHP for SAF Production

## Illustrative Case Study: SAF project in US Midwest, charged from grid




### RHB300 in CHP configuration

- Delivering up to **85,000 lb/h or 25 MW thermal** of steam, up to 600 degrees C and 160 bar
- Intermittently charged from the grid for average of **6 hours per day** at a rate up to **80 $MW_{AC}$**
- Steam turbine delivers up to **3.8 MW of electricity**



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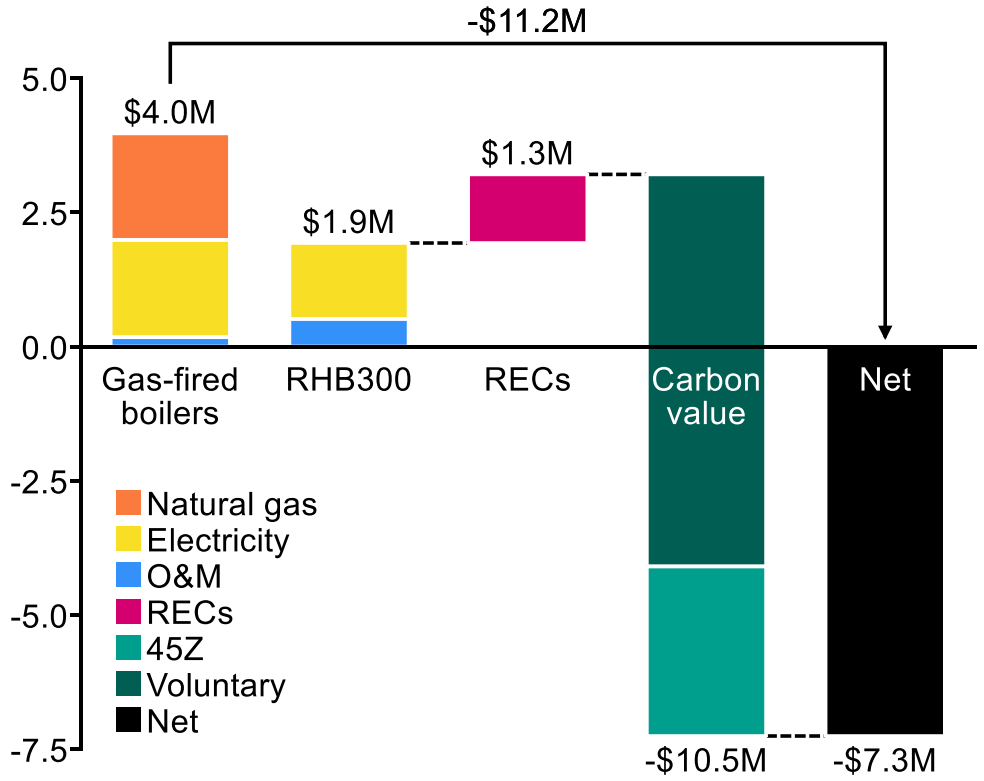
# Case Study: Driving paybacks in under 5 years

**Energy operating cost in 2028, RHB300 vs. gas boilers**
*Millions of USD$*




**Illustrative Case Study for SAF Producer in US Midwest**

- Using cheap intermittent power from the grid, electricity prices are cheaper than natural gas during 6-8 hours per day
- CI reductions create significant value in carbon markets & with federal incentives (45Z)
- RECs are additionally purchased to match electricity charged from the grid



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# It starts with a **commercial and technical site assessment**

*First step*

Non-binding Term-sheet

Contract

| Site assessment | Pre-FEED | Pre-Construction | Construction | Operation |
|---|---|---|---|---|
| *2 months* | *2-4 months* | *3-8 months* | *6-12 months* | ***20+ years*** |
| ▪ Evaluate based on **site-specific data:**<br>– Heat Load<br>– Electricity costs for cheapest 6-8 hours<br>– etc.<br>▪ **Produce proposal: technical & commercial**<br>– Integration into site processes<br>– Levelized Cost of Heat | ▪ Detailed plans & costs<br>▪ Confirm detailed specifications (e.g., water, steam) and tie-in locations | ▪ Detailed Engineering<br>▪ Permitting<br>▪ Long-lead item purchasing | ▪ Foundation<br>▪ Brick stacking<br>▪ Wires, E-house and boiler<br>▪ Commissioning |  |

 

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# Thank you

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