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Pullman Sydney Hyde Park
Australia

Reducing emissions for hard to abate industries

Thermal energy storage to enable industrial electrification

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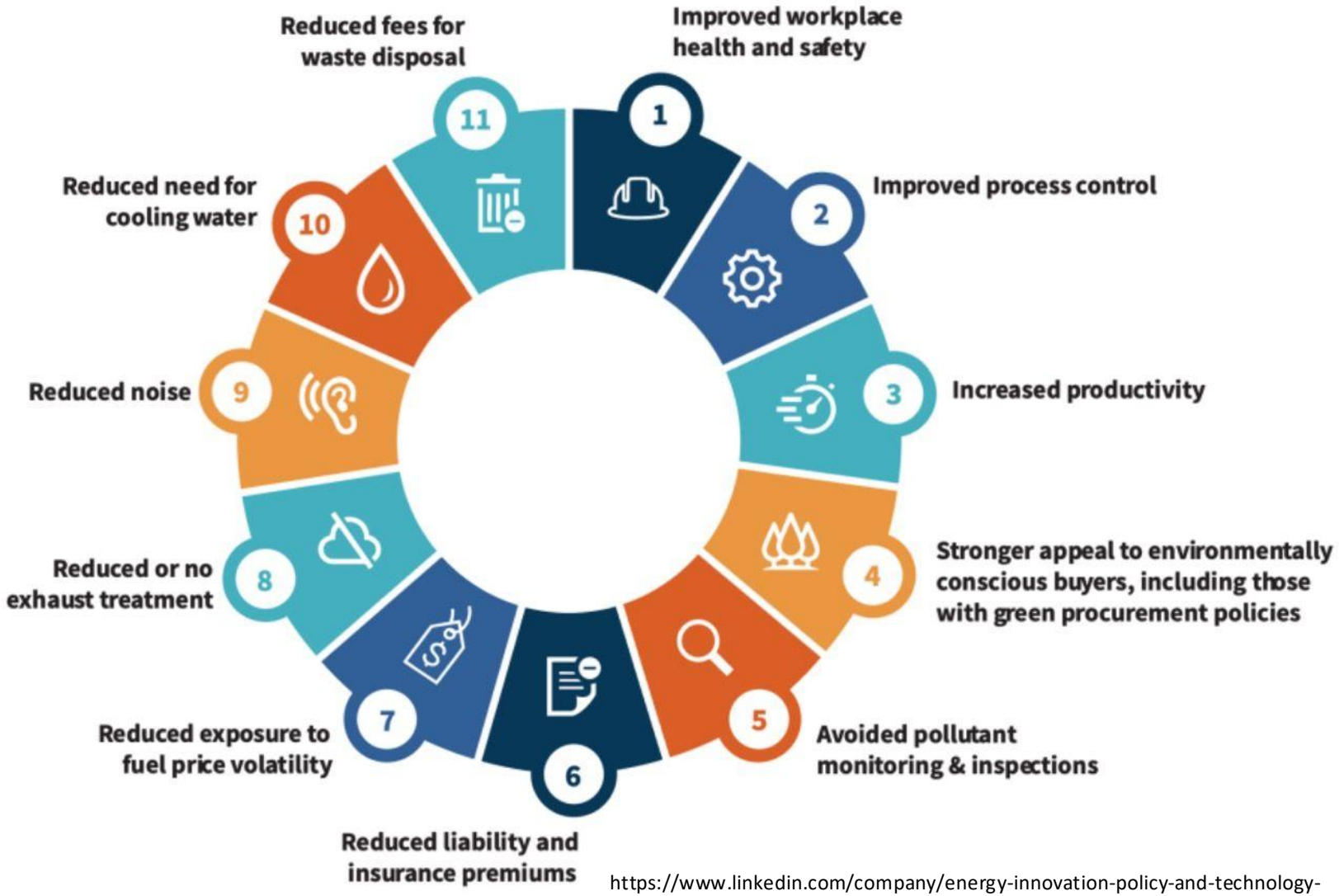
Drivers for electrification of process heating

- **Commercial** - Higher energy efficiency of electric processes, Productivity, quality, safety, local environment benefits
- **Gas constraints** and potential price escalation 2027/28, plus increasing renewable grid may reduce electricity:gas price ratio
- **Meet emission targets** – Supply chain demands for low C products

BENEFITS OF ELECTRIFICATION FOR INDUSTRIAL FIRMS



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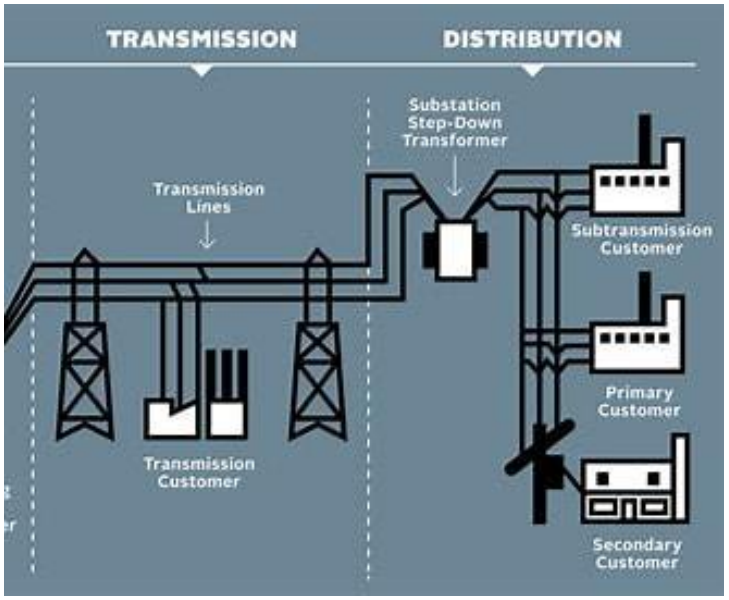
Industrial Electrification Meets Grid



Electrification of process heating creates an intersection of operational process needs and the dynamics of the electricity supply sector – energy generation, transmission and distribution

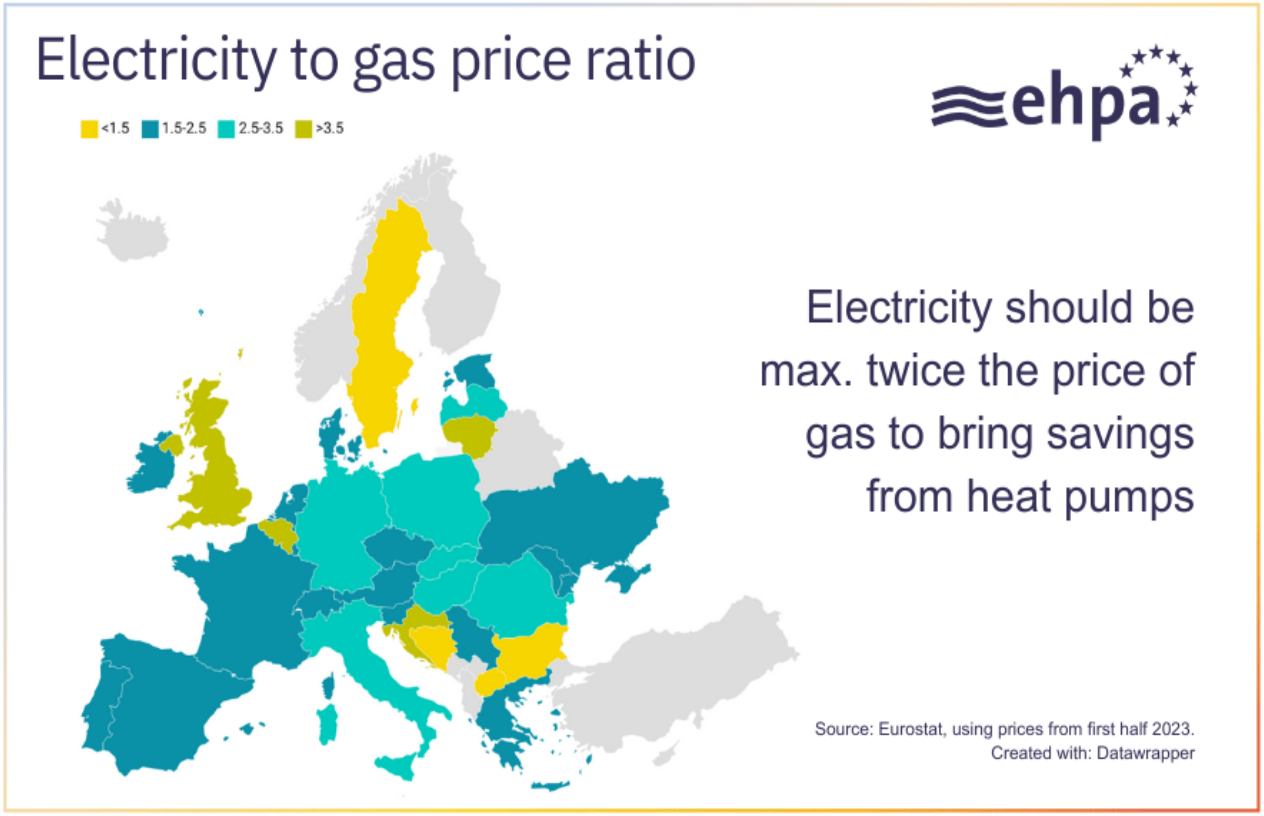
Load flexibility key to:

- Reduce capital cost for connection of new loads, and economic operation of electric heating for industry.
- Improve grid utilization.

DNSP Readiness for Electrification

- Limited visibility of potential new electrified industrial loads for planning
- Cumbersome, slow and costly processes for connection of new loads and system augmentation
- Limited availability of flexible/dynamic tariffs
- Need load flexibility incentives and variable connection charges. Thermal storage likely to be an important source of load flex.

Relative electricity and fuel prices critical for success of electrification



NSW = 2.5-3 for larger users

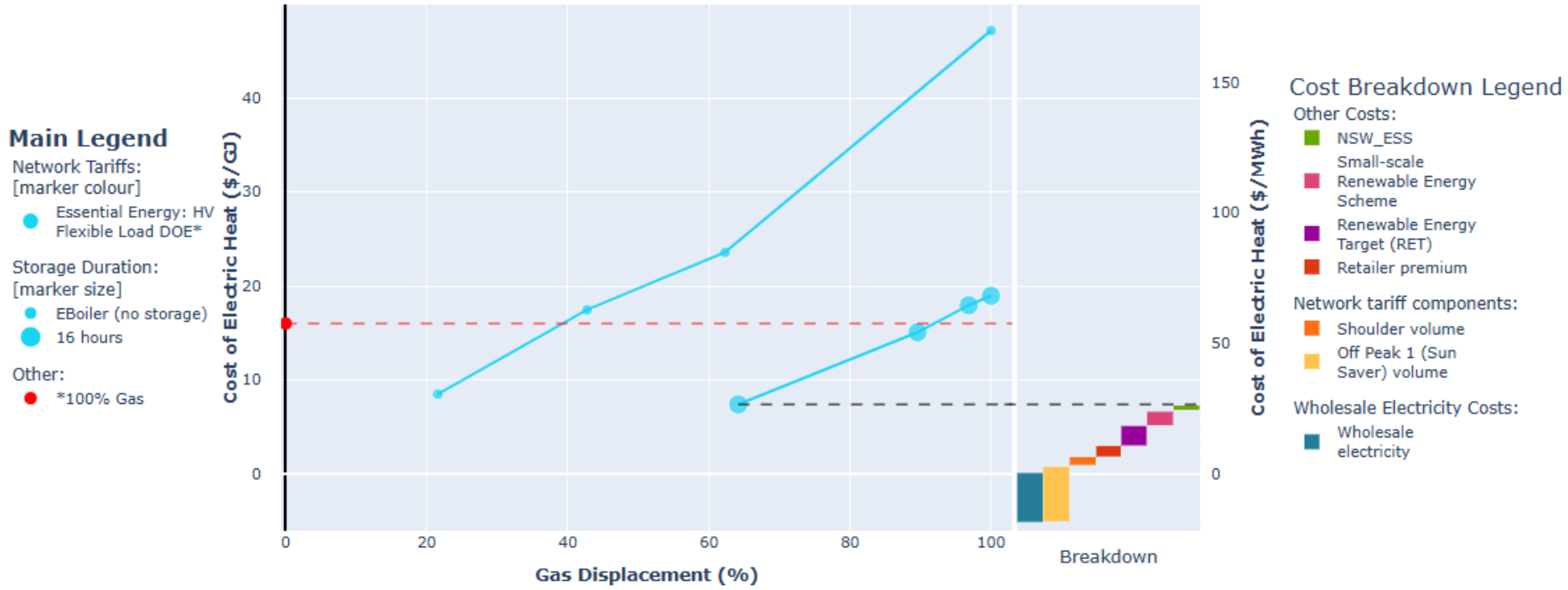
BUT can be <2 if:

*** Industry accesses variable electricity prices (wholesale energy + dynamic network pricing) and invest in significant thermal storage**

* Remove environmental levies for net zero electrification projects.

ETES = resistance heating = 90-95+ % efficiency
Requires >1:1 price ratio with gas: i.e. must leverage low cost grid power in middle day or on-site solar PV

Operating Cost of Electric Heat



Operating cost of electric heat is cost-competitive with gas-based heat:

- **Hybrid operation –** Maximises benefit of low-cost wholesale prices; redundancy; transition path to 100%
- **Flexible –** Control for a wide range of operating costs and gas displacement
- **Network tariff –** Solar-soaker tariffs with a Dynamic Operating Envelope; Improved network utilisation; No contribution to peak demand
- **Capital costs –** Not considered in these these results

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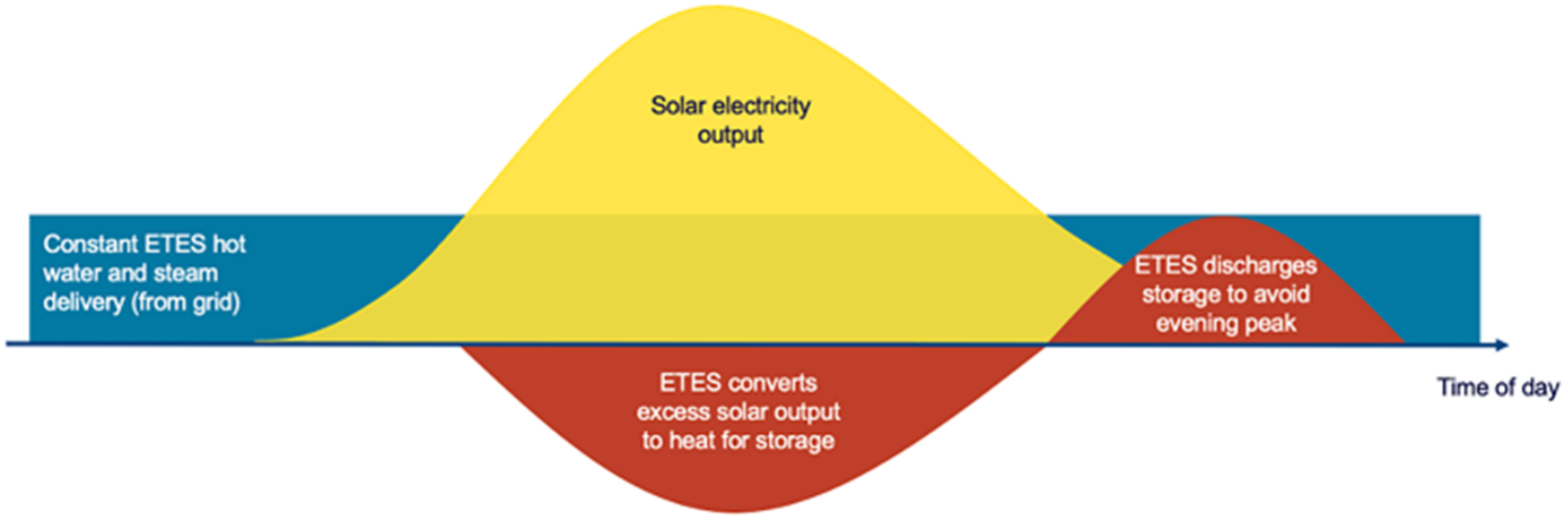
Economics of TES

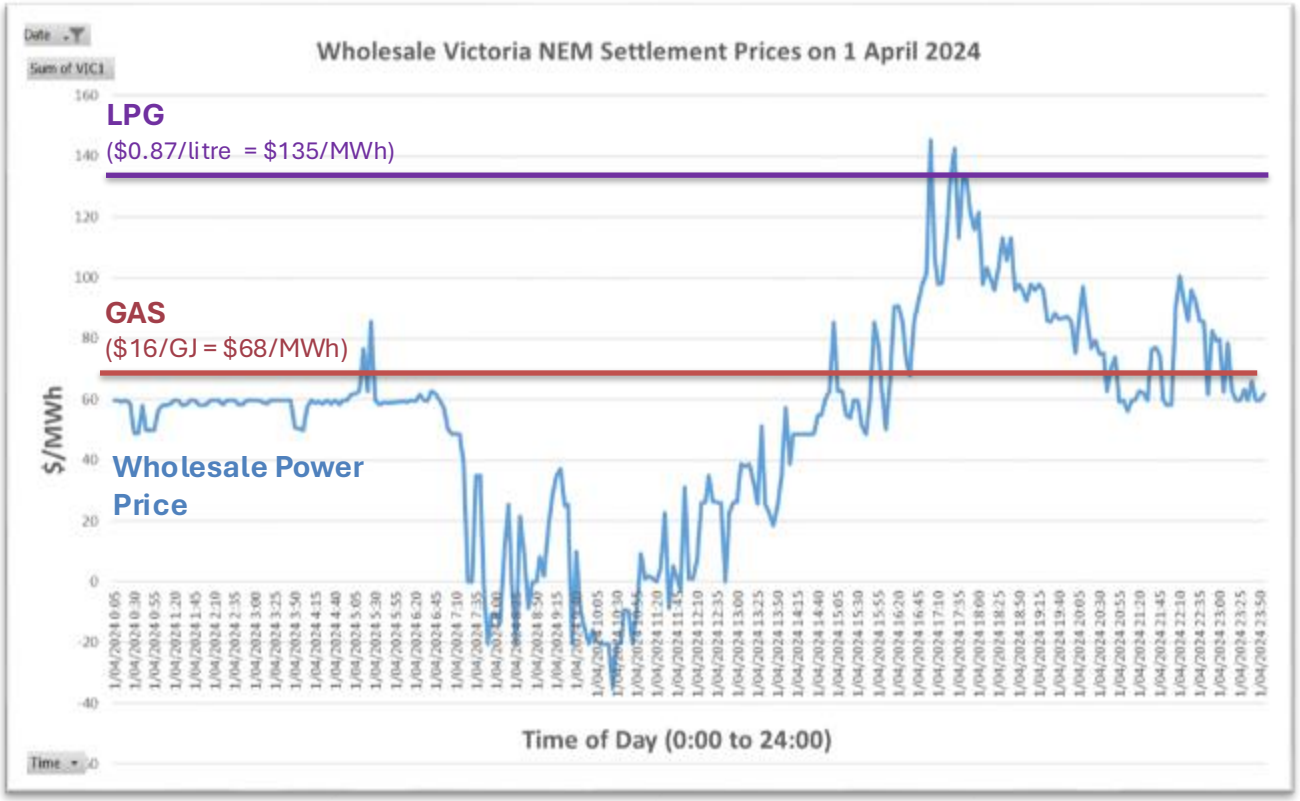
Cost justification depends on exploiting intra-day electricity price spreads. Daytime wholesale electricity fall below $20/MWh ($5.5/GJ) for 4-6+ hours in Summer. With TES, this cheap electricity can replace gas at $12–20/GJ.

Solar deepened price spreads (low midday, high evening), but longer term increased home/business load flexibility/storage may diminish spread.

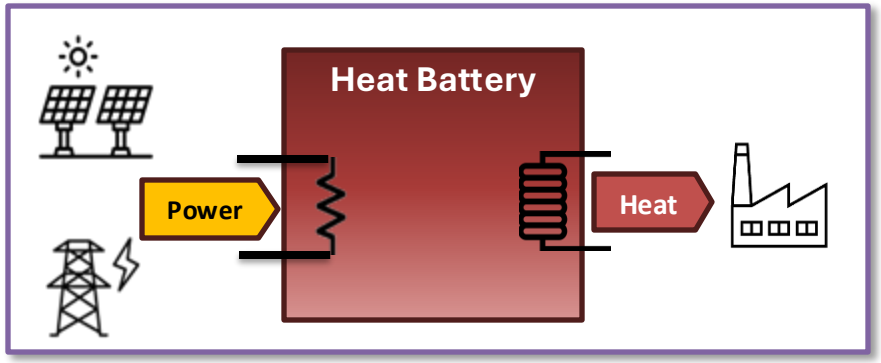
Figure 2. Charging ETES with electricity from onsite solar and the grid (schematic overview)



The Opportunity to Electrify



- From Oct 2021 the NEM moved to 5 min price settlements
- Rising solar rooftop penetration and variable renewable energy generators = significant periods of low to negative pricing.
- This (random) day in Victoria saw ~8 hours below $20/MWh and ~3 hours below $0/MWh



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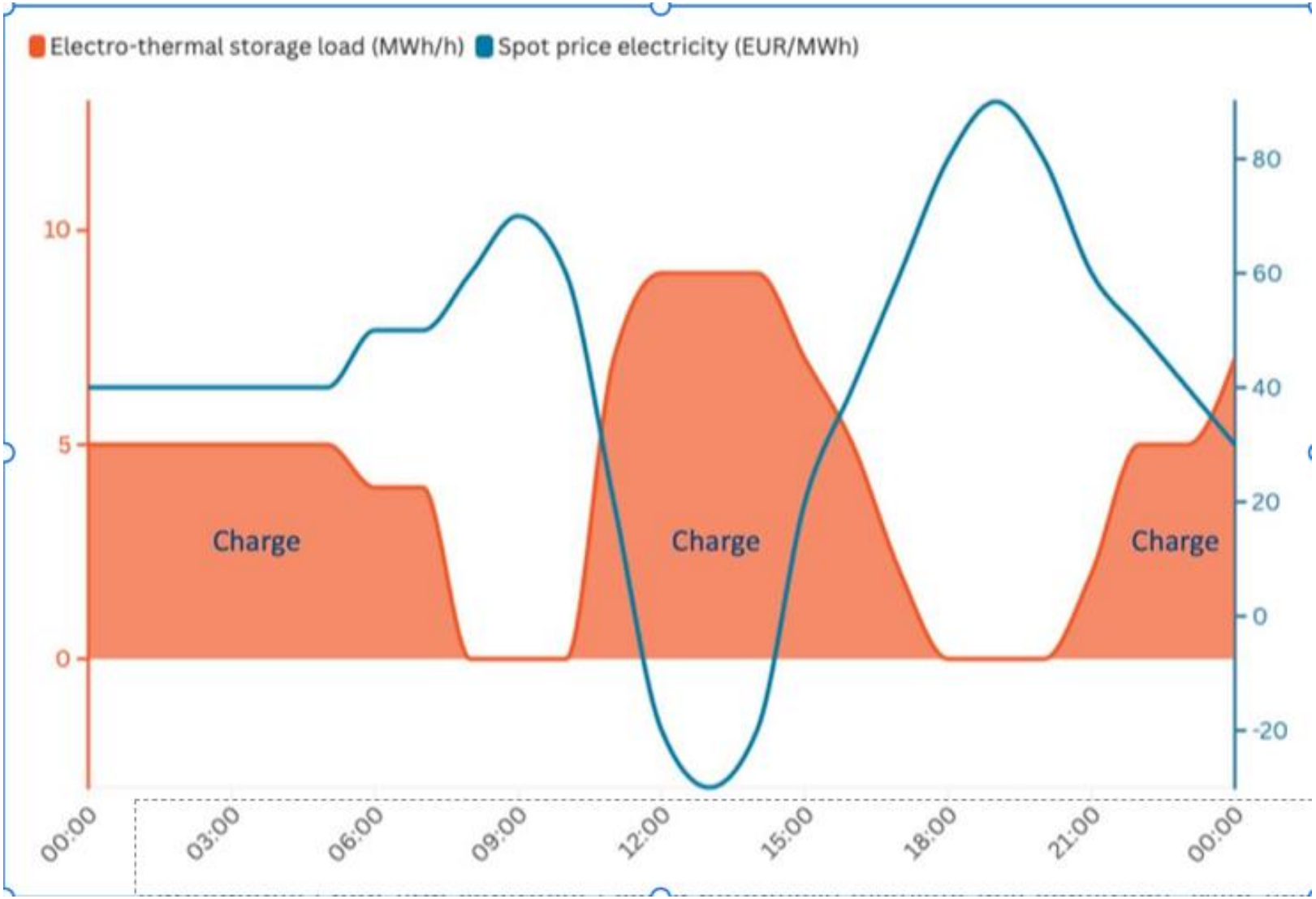
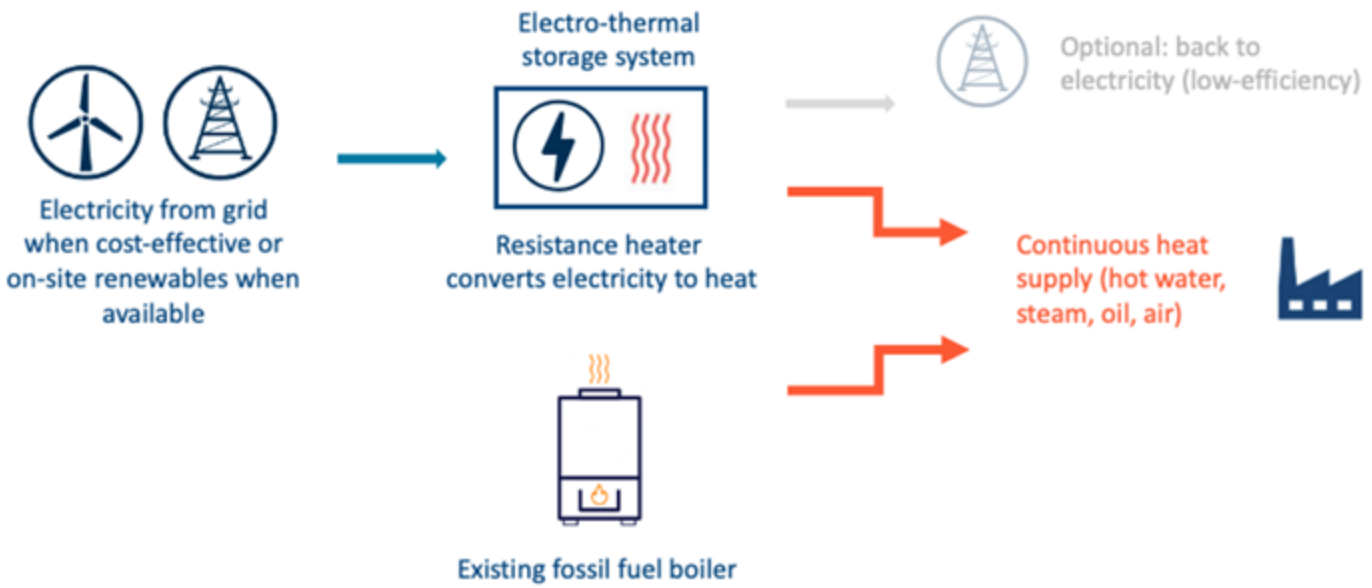
Use of Thermal Storage to Optimise Average Purchased Electricity Price



Hybrid Operation as Transition

Figure 4. Hybrid ETES use (schematic overview)

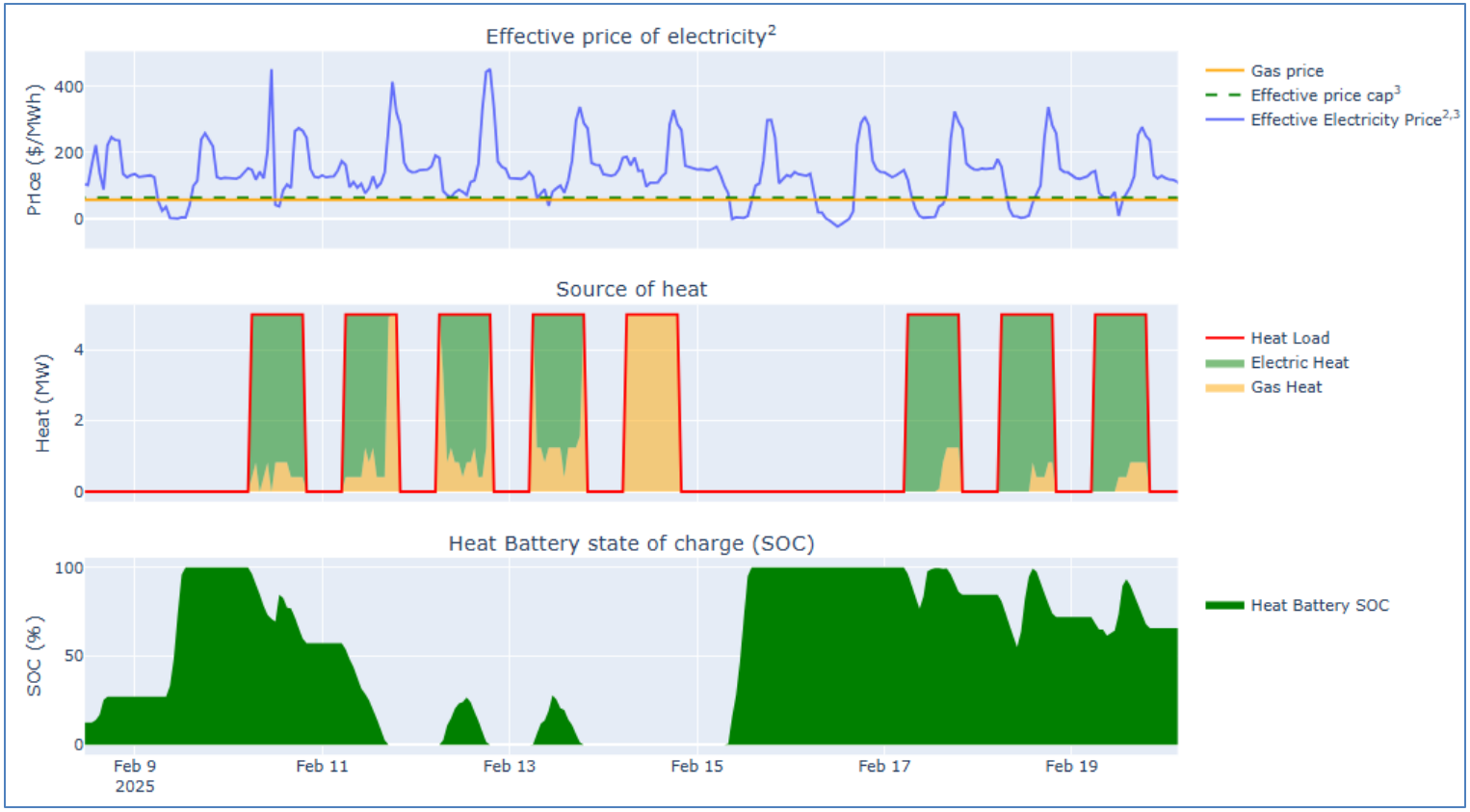


Businesses don't need to replace their whole heating system at once. TES allows **phased retrofits** and this can provide more economical outcomes in short-medium term:

- Install TES alongside an electrode boiler or heat pump.
- Keep gas as a backup for unusual peaks.
- Over time, ramp up the share of heat from electricity.

This reduces disruption and spreads CAPEX. Care not to sub-optimize

Heat Battery Operation



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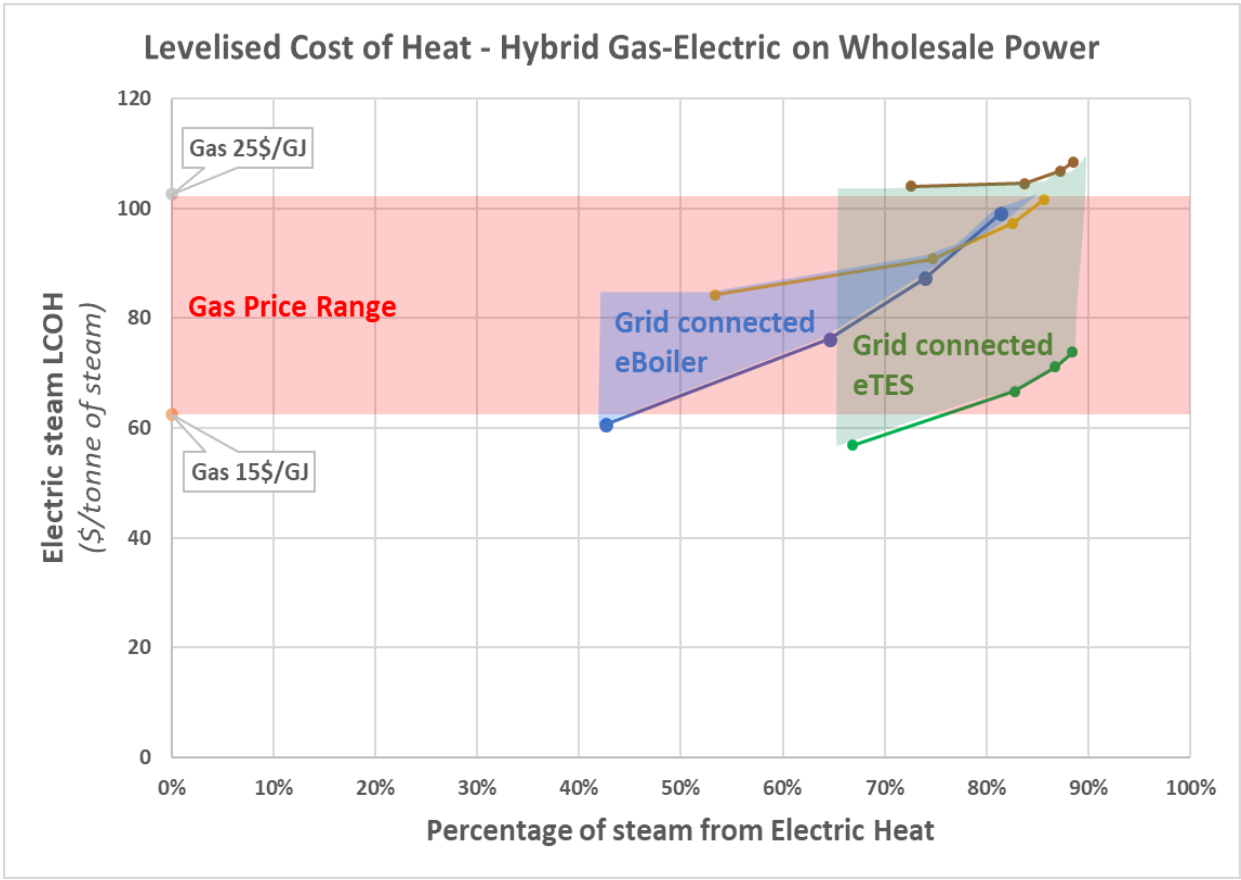
NSW wholesale prices over FY 24/25. Hybrid gas/electric operation:

- **64%** gas displacement at heat operating energy cost of **$7/GJ** or $25/MWh
- **100%** gas displacement at heat operating cost of **$19/GJ** or $68/MWh.

Levelised Cost of Electric Heat



Levelised cost of electric heat is cost-competitive with gas-based heat:

Hybrid operation – Maximises benefit of low-cost wholesale prices and ensures reliability

Network Tariff – Solar-soaker tariffs with a Dynamic Operating Envelope dramatically improve LCOH

Capital subsidies – Improve LCOH, but to a lesser extent

Carbon pricing – Ignored for this analysis

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Thermal vs. Electrical Storage

Aspect	Electrical Storage (Li Batteries)	Thermal Energy Storage (TES)
Cost per kWh	$200–500/kWh	<$50/kWh + integration costs
Round-trip Efficiency	90-95% for Li (- degradation), Flow/lead acid lower.	85–95%
Lifespan	10-15 years+	Lasts decades
Role	Rapid release, short duration	Bulk heat storage
Reliability	High	High
Flexibility of Use	Flexible	Flexible
Applications	Storing power from on-site generation/grid for short term load management	Large scale load shifting

TES Technologies & Target Markets

Temperature Range	Storage Medium	Application	Stage of Development
<200°C	Hot/cold water tanks	Typically to integrate with heat pump systems	Mature, scalable, and cost-effective. Already deployed at multi-MWh scale in industrial and district settings.
<200°C	Phase-change materials (PCM)	Higher energy density with tight temperature control.	Ice storage in use for many years. Other PCMs still being developed/commercialized.
150-400°C+	Electric resistance heating and storage in bricks/ceramic/balls of heat storage materials	Typically integrated with steam systems or hot gas applications	Being commercialized currently. Accelerating activity and use cases.
800-1200°C+	Brick, rock, or sand-based storage	Generally integrated with HT processing.	Being commercialized currently. Accelerating activity and use cases.

Integrating TES into Industrial Processes

Integration costs and efficiency key to cost effective projects.
Heat expelled as HT air/steam and needs to be designed into process

Considerations include:

- Compatibility with existing process heating systems and controls
- Space constraints in existing plants
- Safety & materials handling (molten salts, PCMs)
- Skills & awareness in engineering teams

TES Suppliers

- Global: Rondo Energy, AtmosZero, Brenmiller Energy, HEATEN, Antora Energy, Fourth Power, Electra (backed by Amazon)
- Australian companies include: MGA Thermal, Aratherm,1414 Degrees
- Many of the companies are well funded and scaling up

Australian case study projects

Mars Petcare Albury Wodonga ETES pilot project
MGA proposed Kwinana project – positive pre-feasibility completed for 180 megawatt-hour ETES project capable of delivering 20 tonnes per hour of steam to an industrial site

Heat as a Service

TES can be offered as **Heat-as-a-Service**: third parties design, finance, install, operate and maintain TES, selling heat by the unit.

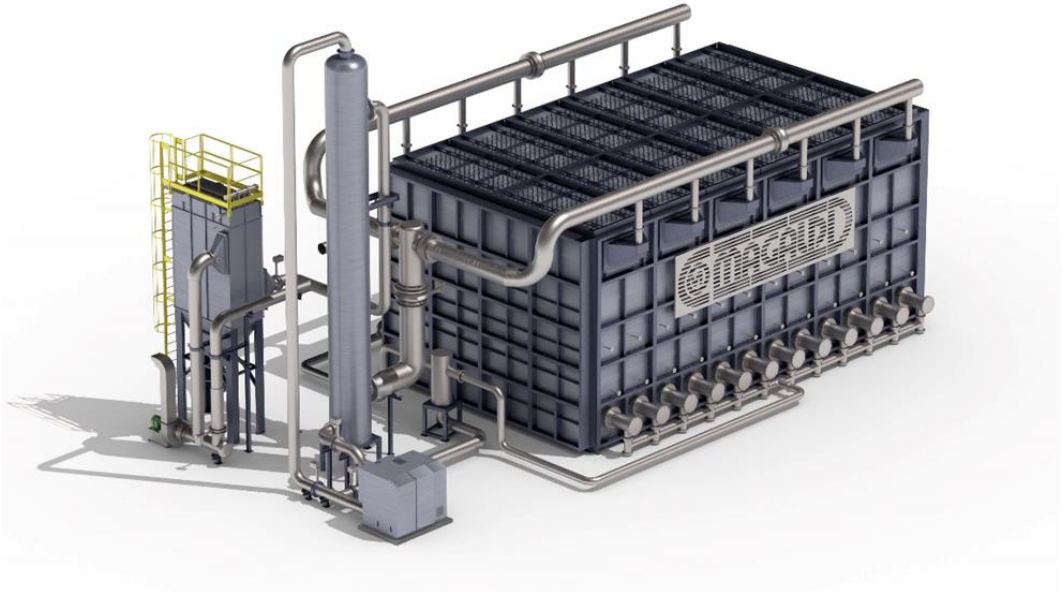
Removes upfront capital barrier. Contracts structured to give predictable long-term heat prices, reducing risk. Ideally allows investment to be off balance sheet of host company and can be treated as operating expense.

Potential to use white certificates (e.g. PDRS in NSW) to improve ROI

Investors may see TES + electrification as “infrastructure-class assets” because they reduce energy risk over 20–30 years. May access cheaper green finance.

Summary of Application of TES in Industry

- Reduce maximum new electrification loads to minimise capital costs for internal and grid electrical upgrades.
- Arbitrage on price spreads to reduce average electricity costs
- Improve plant reliability and backup primary thermal heating systems
- Cost effectively store on-site renewable energy as heat
- Unlock new revenue streams: Demand response and flexibility services markets.



Some Policy Recommendations

- Funding for demonstration projects
- Dynamic electricity pricing – network and wholesale energy prices
- Incentives for TES retrofits and new builds
- Streamlined, fair and cost-effective connection process for electrification

- Design tools for TES and heat network optimisation
- Training and workforce support for TES