Electrified Thermal Solutions

Converting Cheap Electricity to Stored Heat (1800˚C) in Firebrick That Provides Hot Air to Customers

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20 MWh Firebrick Heat Storage Pilot Plant at Southwest Research Institute

Electricity In; Store Heat As Hot Firebrick; Deliver Hot Air Up to 1600˚C

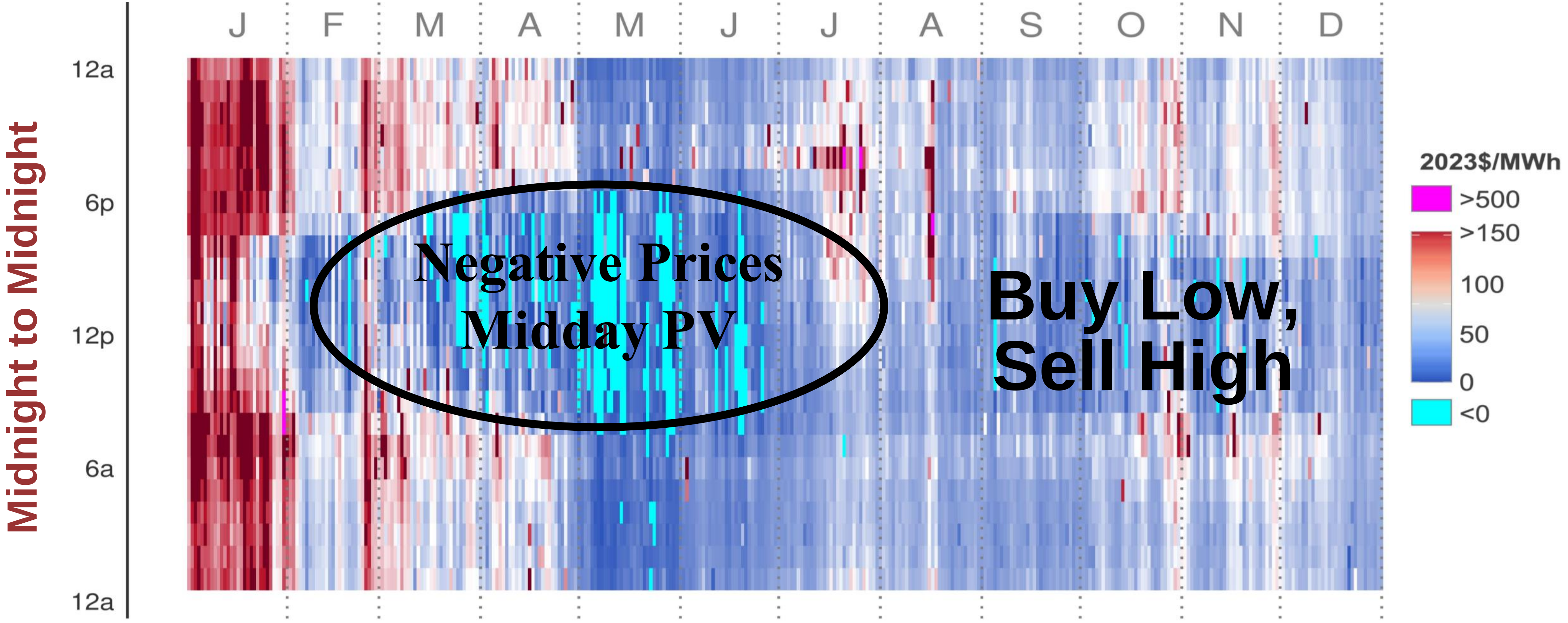
Technology Co-Inventors: Charles Forsberg and Daniel Stack

C. Forsberg and D. C. Stack, Electrically Conductive Firebrick System, U.S. Patent: 11,877,376 B2. January 16, 2024. https://image-ppubs.uspto.gov/dirsearch-public/print/downloadPdf/11877376

Dan Stack: CEO of Electrified Thermal Solutions (MIT spin out company)

Charles Forsberg: MIT
Not an Employee of Electrified Thermal Solutions
Vested Interest (Royalties) but *Not Spokesman for Electrified Thermal Solutions*

Very Low-Price Electricity Creates Incentives for Energy Storage and Deliver as Heat: 2023 Hourly California Electricity Prices



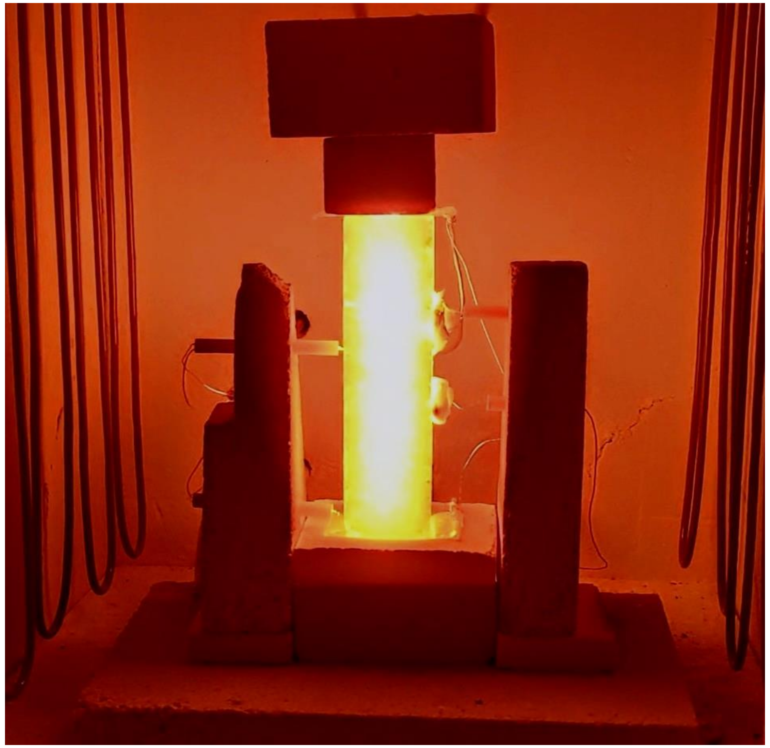
365 Days per Year (January to December)

D. Millstein, E. O'Shaughnessy and R. Wiser, Exploring Wholesale Energy Price Trends, Lawrence Livermore National Laboratory, 2024. https://eta-publications.lbl.gov/sites/default/files/rewep-2024update_tech-brief_20240429.pdf

We Invented Electrically Conductive Firebrick

Firebrick Doped with Materials Such as Nickel Oxide (1 to 2%)

- Enables converting electricity into very high-temperature firebrick (1800˚C)
- **Firebrick is the only low-cost material that can operate at these temperatures in an oxygen environment (Air, etc.)**
- Can use as direct-air heater or embed electrically-conductive firebrick electric heating elements in massive conventional firebrick heat storage systems
- Blow cold air through hot firebrick to produce hot air for customer



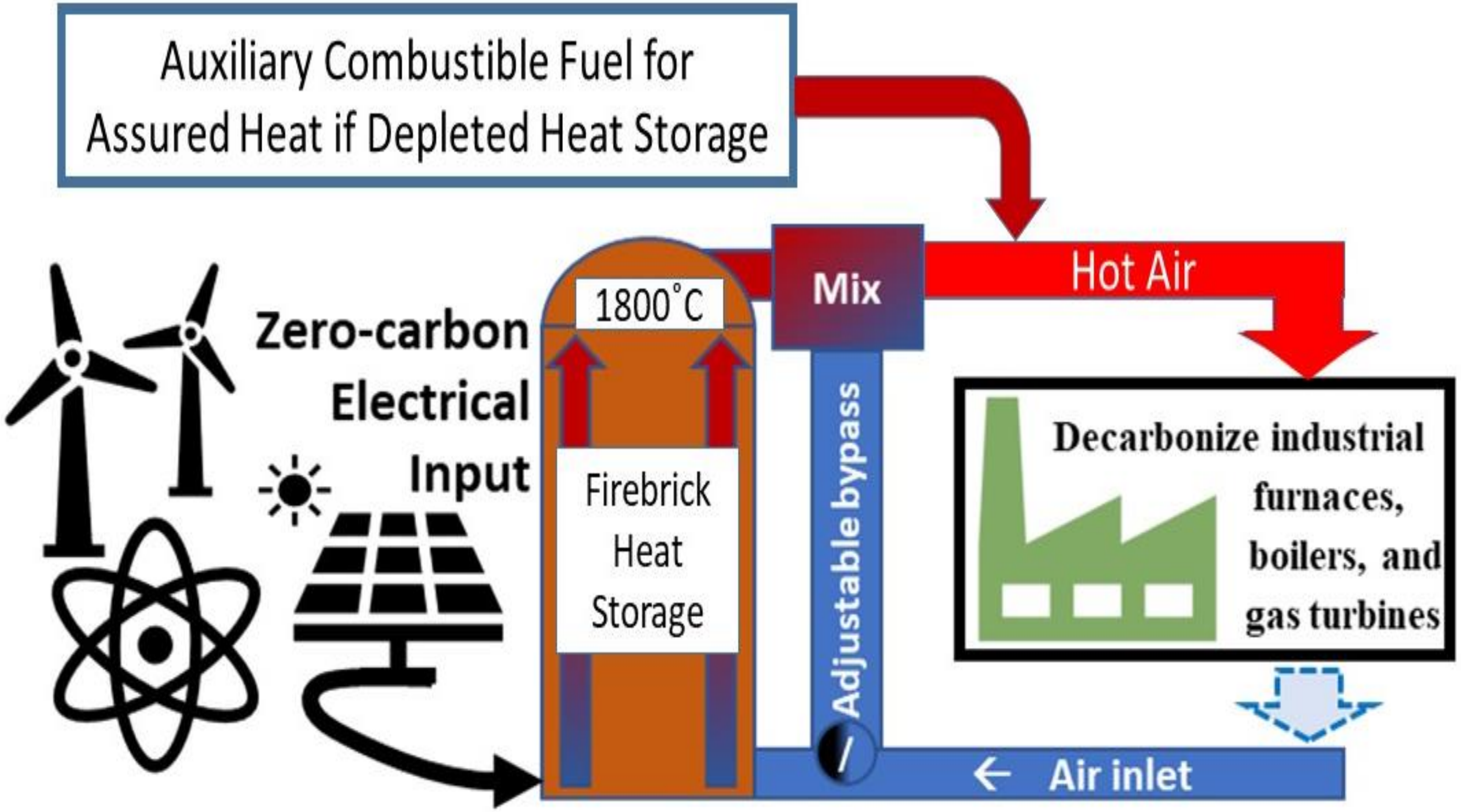
Electrically Conductive Resistance Heater to 1800°C, 13 Kev

Enable High Power Levels

C. Forsberg and D. C. Stack, Electrically Conductive Firebrick System, U.S. Patent: 11,877,376 B2. January 16, 2024. https://image-ppubs.uspto.gov/dirsearch-public/print/downloadPdf/11877376

Electrically-Conductive Firebrick Enables Converting Electricity into High-Temperature Stored Heat at Natural Gas Flame Temperatures Up to Hundreds of MWh Scale

- Consume all electricity less than the price of *delivered* natural gas
- Deliver heat as hot air—replacement of hot air from burning fossil fuels.
- If heat storage empty, burn combustible fuel



Recycle of Warm Air (No Stack) Improves Efficiency Relative to Burning Fossil Fuels

Electrified Thermal Solutions* Pilot Plant Demonstrating (1) Conversion of Electricity to Very High-Temperature Firebrick and (2) Heat Recovery as Hot Air

- Started operations February 2026
- About 5 meters high
- System Design
  - 20 MWh heat storage
  - Peak firebrick temperature 1800°C
  - Peak hot air exit temperature 1600°C
  - 1 MWe input

https://www.youtube.com/watch?v=2XXCBT3VTg0

At Southwest Research Institute, San Antonio, Texas

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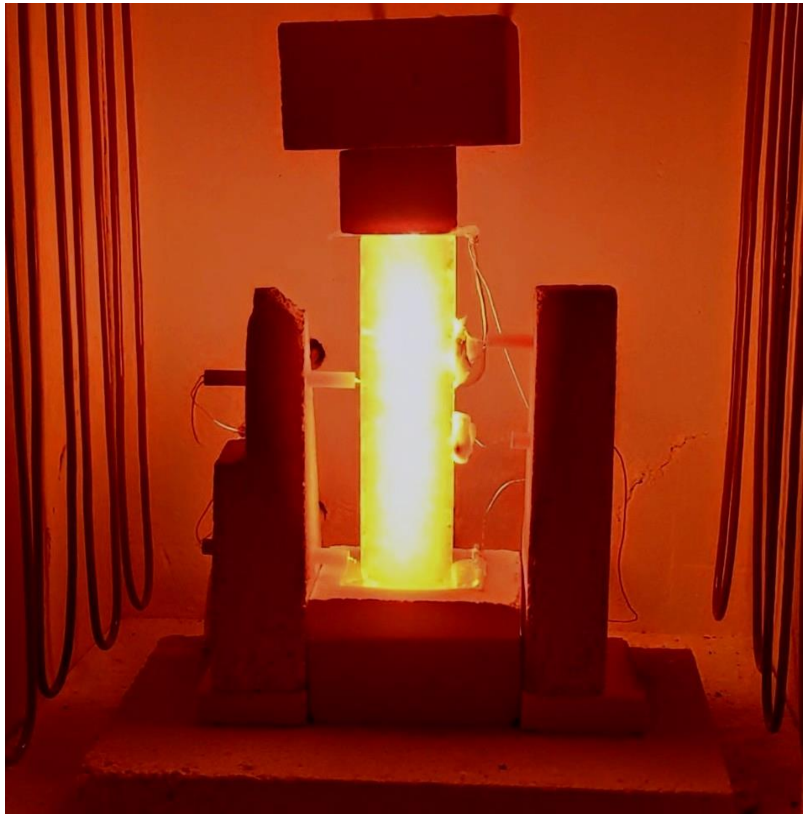
*https://electrifiedthermal.com/

Three Economic Competitive Advantages

- Very high temperature (1800˚C) that meets requirements of gas turbines, glass, cement and steel industries (no competing technologies)—as well as low-temperature applications
- Most heat stored in conventional low-cost firebrick with large hot-cold temperature swing that minimizes costs
- High-voltage power supplies (13 Kev) to minimize power conditioning equipment costs

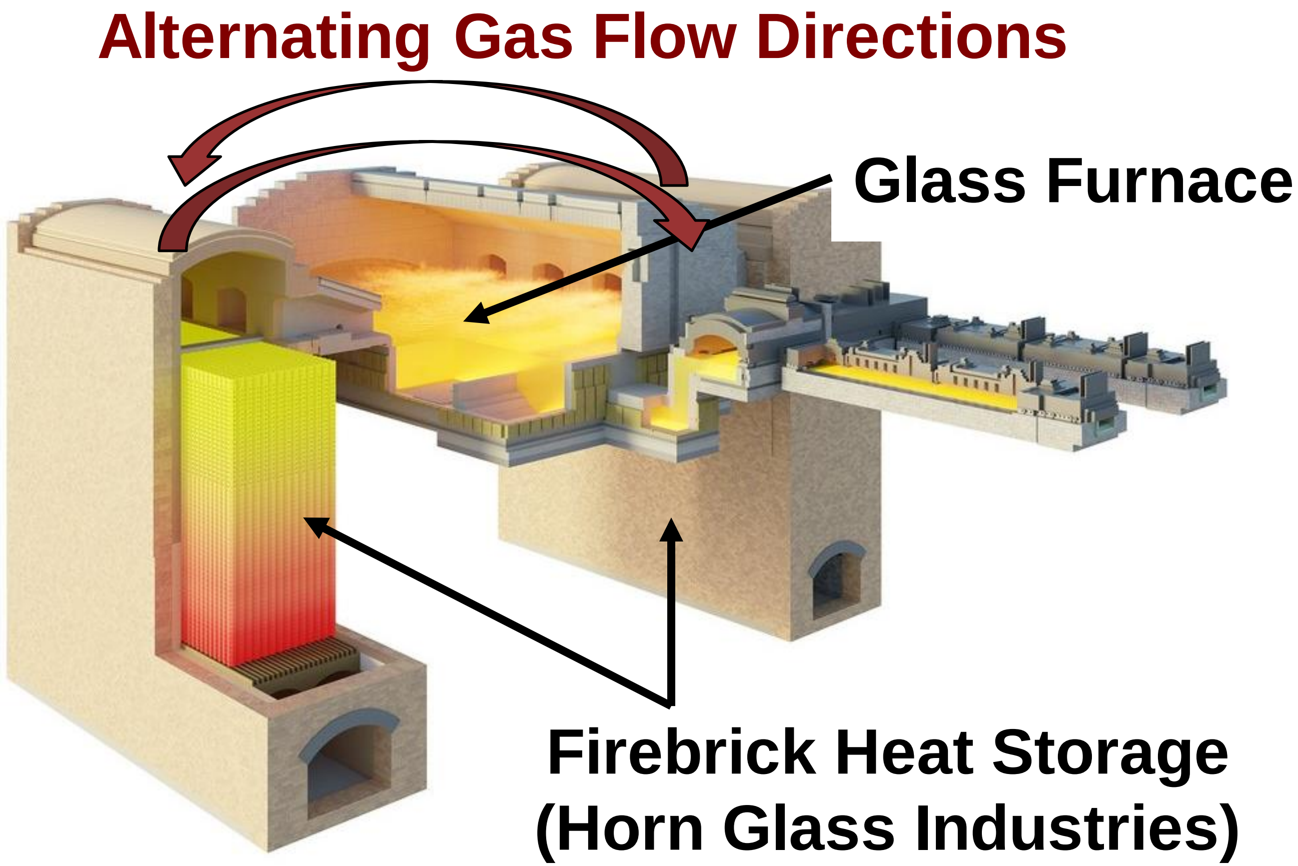


Electrically Conductive Resistance Heater to 1800˚C, 13 Kev

Enable High Power Levels

Firebrick Heat Storage is Proven: Exists at the 100s of MWh Scale in the Glass, Steel and Other Industries

- Glass furnace
  - Recover heat from warm gas (up to 1500˚C) exiting glass furnace by heating firebrick before send off-gas to stack
  - Store heat in firebrick
  - Reverse flow ever 30 minutes
  - Heat incoming air, then boost temperature with natural gas
- 1000˚C firebrick temperature swing (minimize firebrick)



https://www.hornglass.com/products/melting-furnaces-and-equipment/cross-fired-furnaces

- M. Zier et al., A Review of Decarbonization Options for the Glass Industry, *Energy Conservation and Management: X*, 2021. https://doi.org/10.1016/j.ecmx.2021.100083

Conclusions

- Electrically conductive firebrick is the enabling technology for economic high-temperature firebrick heat storage (1800°C) providing hot air to customers
- Technology may consume all electricity less than the delivered price of natural gas to the customer
- Electrified Thermal Solutions has successfully operated a pilot plant and is commercializing the technology

Electrified Thermal Solution's Manufacturing Facility

- C. Forsberg and D. C. Stack, Electrically Conductive Firebrick System, U.S. Patent: 11,877,376 B2. January 16, 2024. https://image-ppubs.uspto.gov/dirsearch-public/print/downloadPdf/11877376

Biography: Charles Forsberg

Dr. Charles Forsberg is a principal research scientist at MIT. His research areas include Fluoride-salt-cooled High-Temperature Reactors (FHRs) and utility-scale heat storage including Firebrick Resistance-Heated Energy Storage (FIRES), 100-GWh Crushed Rock Ultra-large Stored Heat (CRUSH) systems and nuclear-assisted biofuels production. He teaches the fuel cycle and nuclear chemical engineering classes. Before joining MIT, he was a Corporate Fellow at Oak Ridge National Laboratory. Dr. Forsberg and Dr. Daniel Stack are co-inventors of electrically-conductive firebrick

Dr. Forsberg is a Fellow of the American Nuclear Society (ANS), a Fellow of the American Association for the Advancement of Science, and recipient of the 2005 Robert E. Wilson Award from the American Institute of Chemical Engineers for outstanding chemical engineering contributions to nuclear energy, including his work in waste management, hydrogen production and nuclear-renewable energy futures. He received the American Nuclear Society special award for innovative nuclear reactor design. Dr. Forsberg earned his bachelor's degree in chemical engineering from the University of Minnesota and his doctorate in Nuclear Engineering from MIT. .

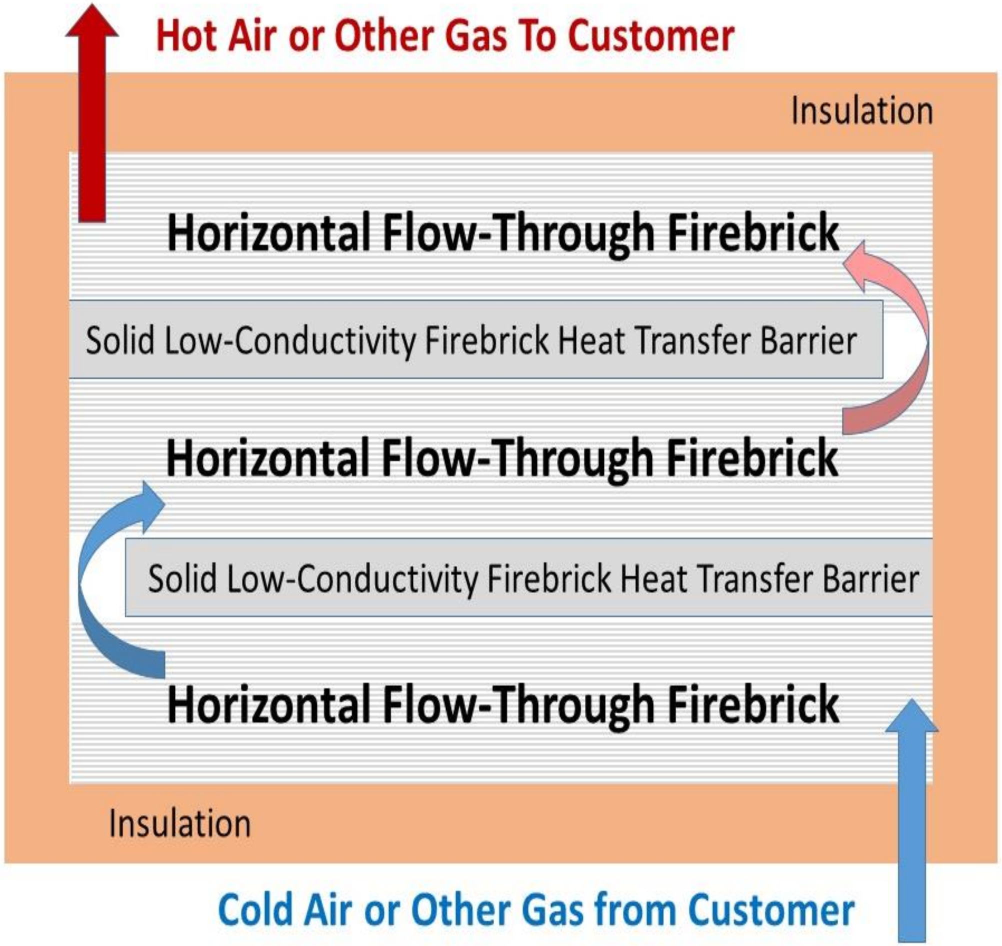
We Are A Hot-Air Society: Produce Hot Air by Burning Fuels

If Excess Electricity, Most Useful If Store and Deliver as Hot Air

We Can Slow Heat Transfer from Hot to Cold Zone During Storage by Increasing Length of Heat Conduction and Radiation Pathways

Current vertical gas flow for heat in and out over short times

- **Industrial recuperators designed to store heat for hours, not days or weeks. Fast heat transfer from hot to cold. Need fix.**
- Create longer heat transfer path from hot zones to cold zones with S shaped flow paths (right)
- Insulator brick layers prevent fast heat transfer



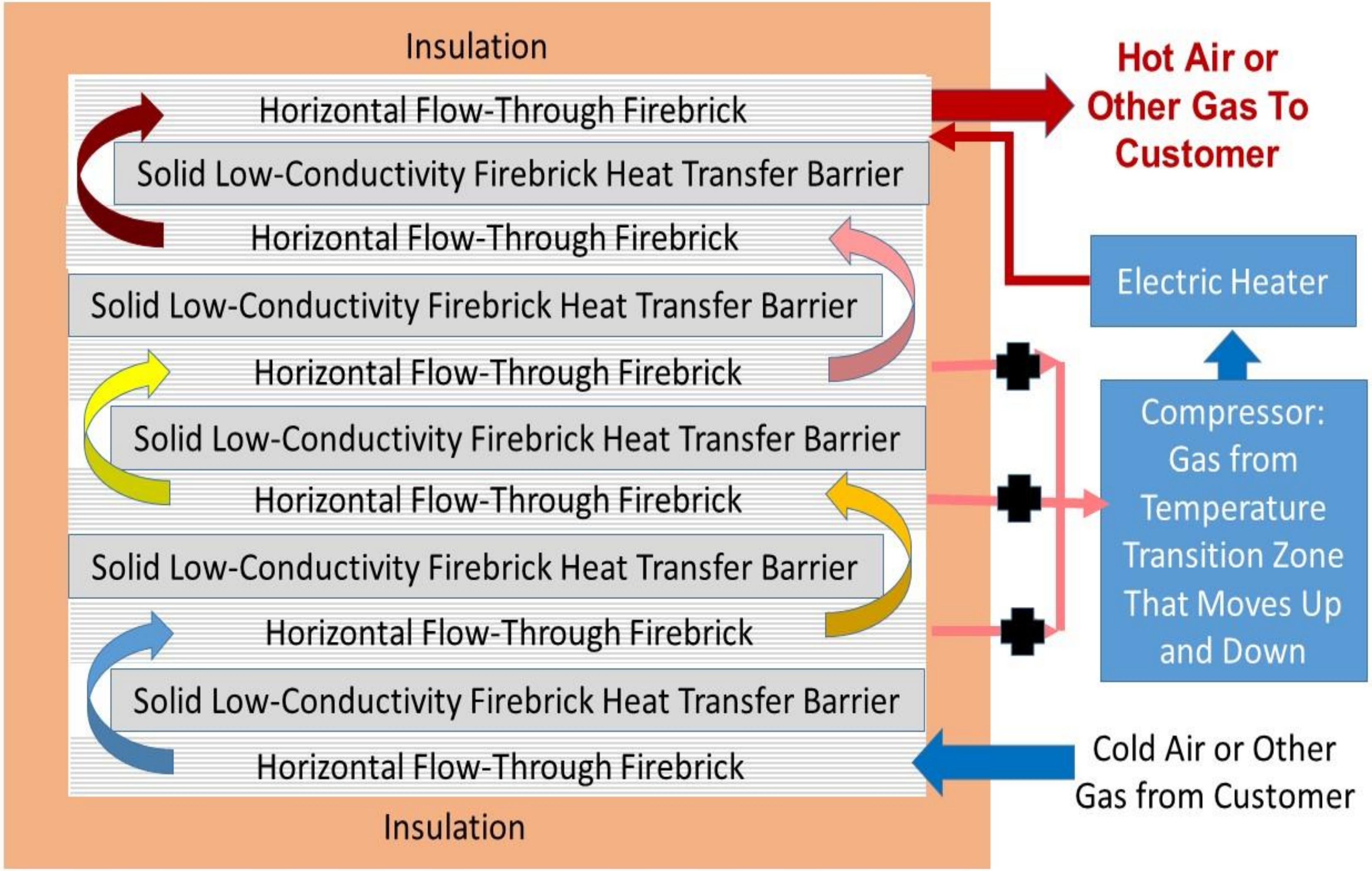
Patent Pending (Forsberg)

C. Forsberg, Base-Load Nuclear Reactors for Fully Dispatchable Electricity: Nuclear Air-Brayton Combined Cycles, Firebrick Heat Storage, Hydrogen Storage and Hydrocarbon Bio-Fuels, *Energies*, 18(4) 821, 2025. https://doi.org/10.3390/en18040821

*C. Forsberg, Large-Scale Long-Term High-Temperature Heat Storage, U.S. Patent Application PCT/US25/55250, November 13, 2025

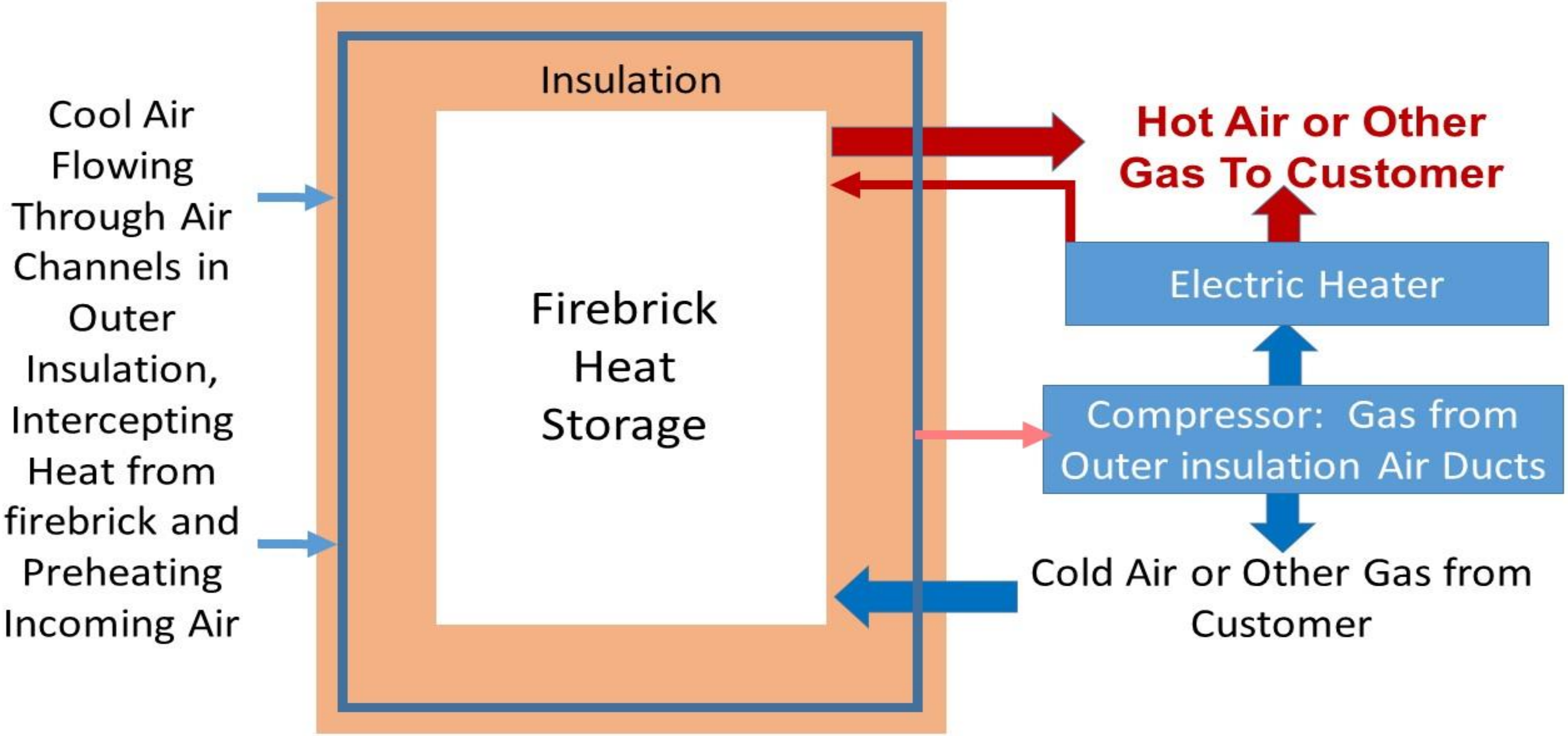
We Developed a Strategy to Minimize Size of the Growing Intermediate Temperature Zone Between Hot and Cold Firebrick

- **Extract gas from intermediate temperature zone to reduce zone size**
- Compress gas and heat to peak temperature
- Inject hot gas into storage system or send to customer (top right)
- Minimizes hot-cold interface zone
- Enabled by heat transfer barriers



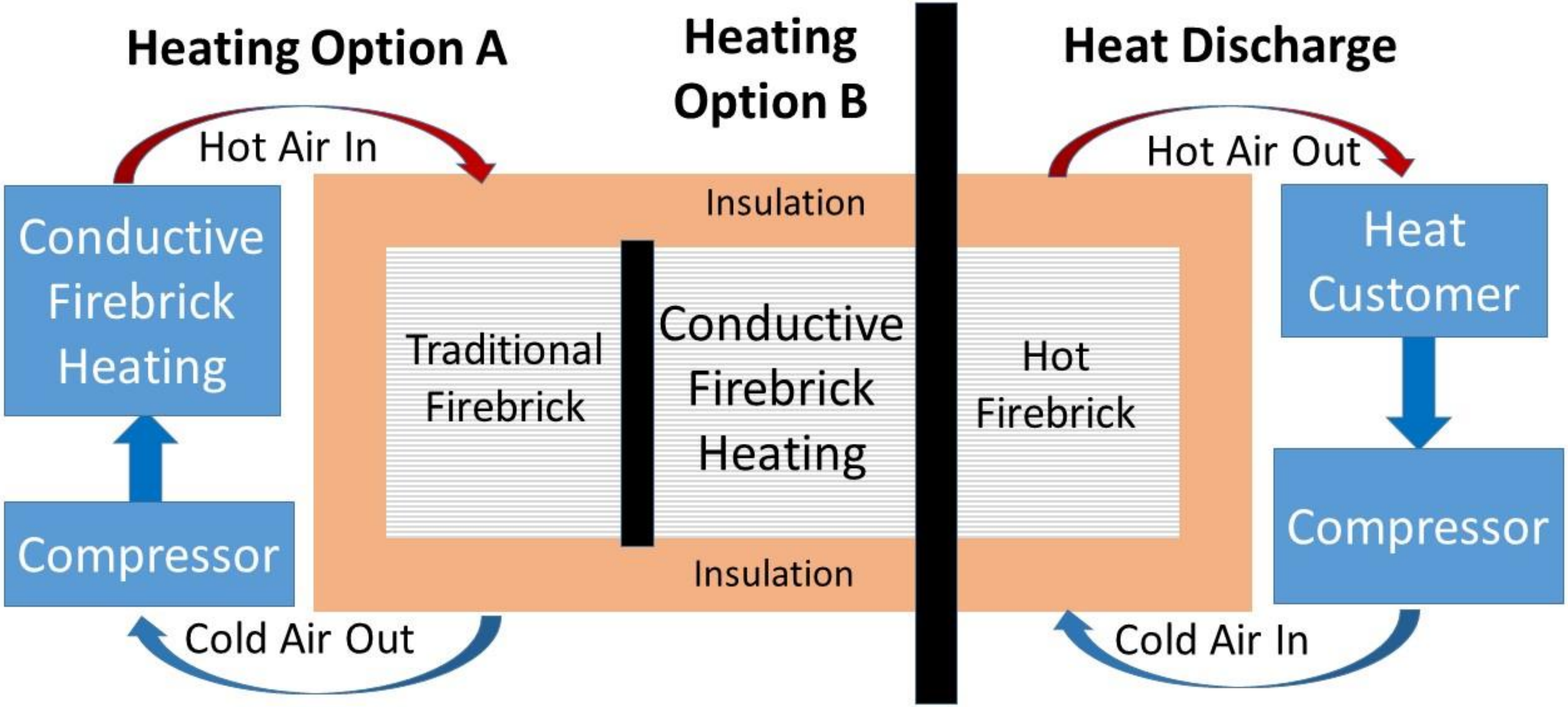
*C. Forsberg, Large-Scale Long-Term High-Temperature Heat Storage, U.S. Patent Application PCT/US25/55250, Nov. 13, 2025

Heat Loses Through Insulation Can Be Made Very Low with Air Ducts Intercepting Heat in the Outer Insulation that Pre-Warms Incoming Air

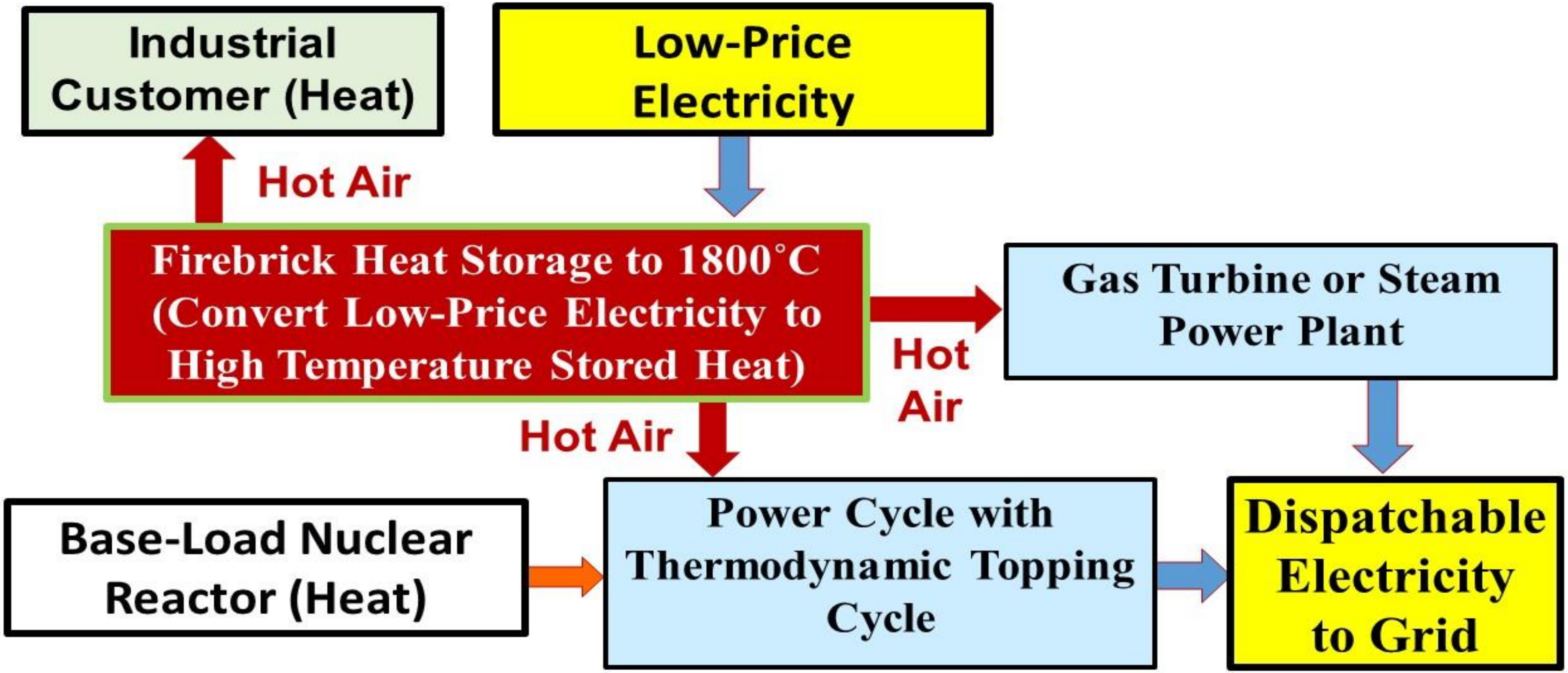


*C. Forsberg, Large-Scale Long-Term High-Temperature Heat Storage, U.S. Patent Application PCT/US25/55250, Nov. 13, 2025

There Are Two Heating Modes (Out of Pile /In Pile)



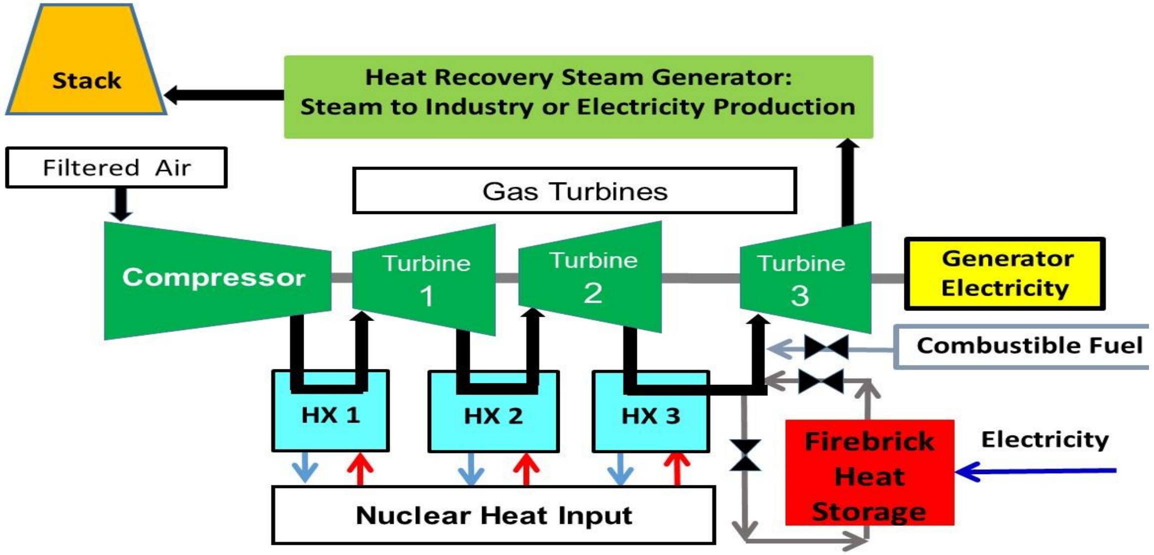
System Design to Efficiently Use All Low-Price Electricity

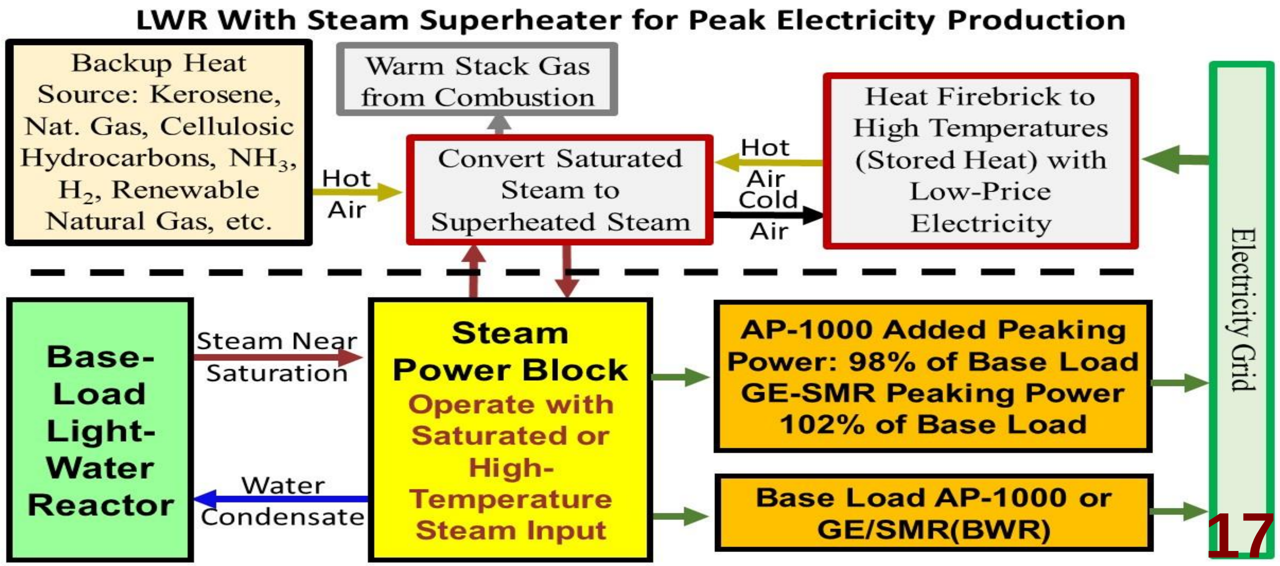


Round-Trip Nuclear Reactors with Thermodynamic Topping Cycle Efficiency: Electricity to Storage to Electricity Greater that 70%

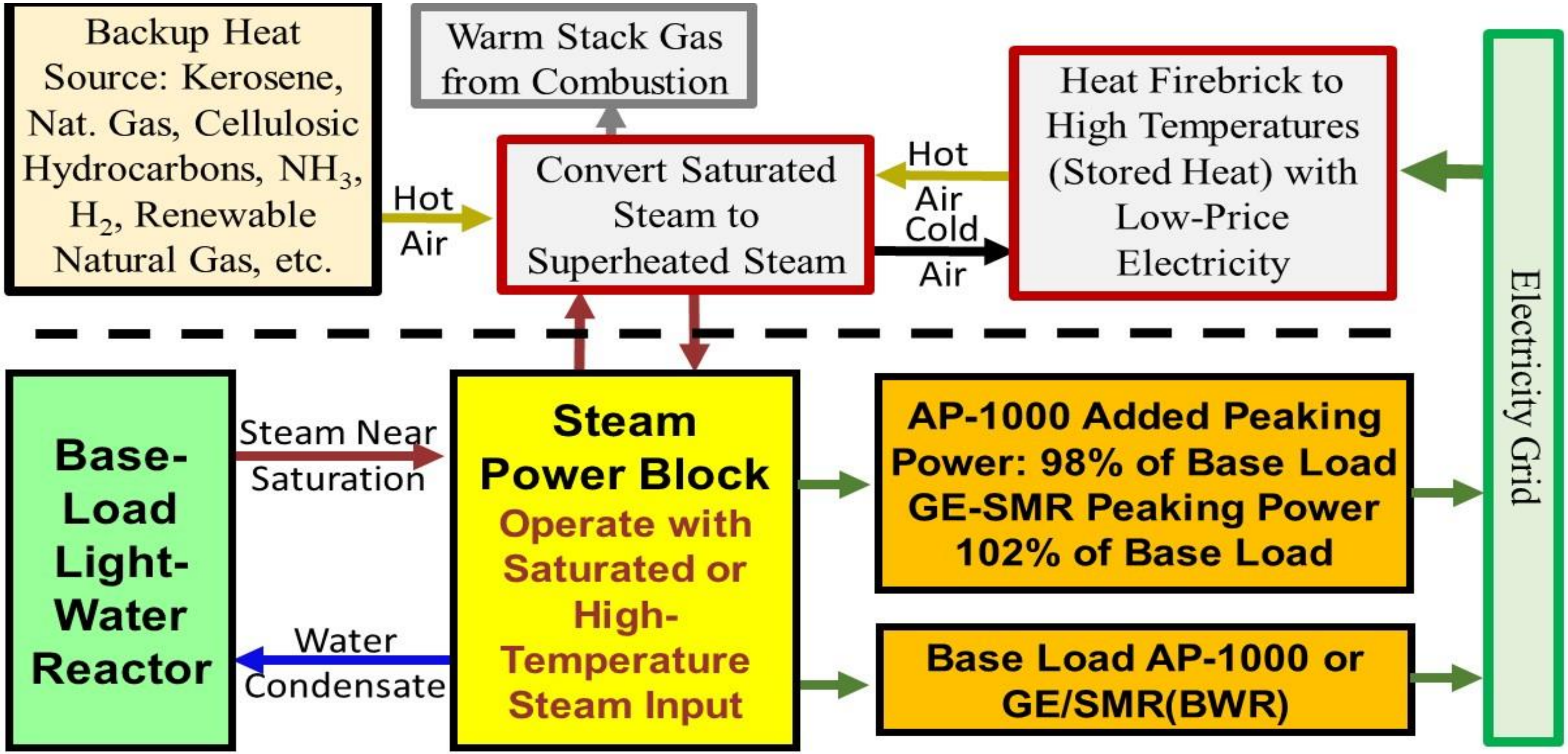
Multiple Electricity to Stored Heat to Electricity Options

- Conventional combined cycle >60% round-trip electricity to heat to electricity efficiency: EPRI / GE / Siemens study underway
- Topping cycle for light water reactors that doubles electricity output
- Nuclear Air Combined Cycle with electricity to heat to electricity efficiency >70%





LWR with Steam Superheater for Peak Electricity Production



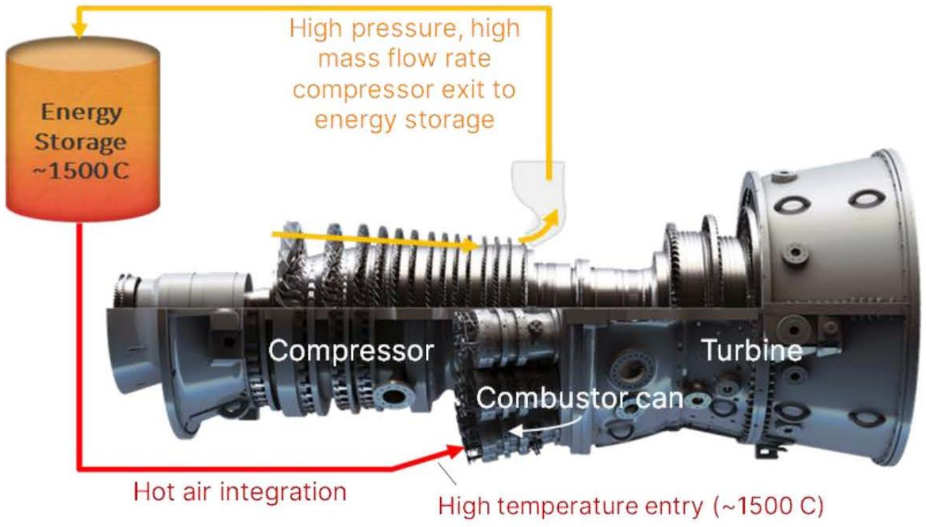
Updated Version of 1970s Indian Point I PWR with Oil-Fired Superheater

Option to Use Stored Heat for Combined-cycle Gas Turbine (GE)

How does it work?

GE VERNOVA

Compressor air is extracted from the GT, sent to the TES where it is heated to combustor temperatures and returned to the turbine section to be expanded and produce power.



- Large Installed base of older technology turbines
  - 6B >1000 units, low risk demonstration
  - 7E ~1000 units, prime application
  - 7F ~1000 units, more intrusive integration

- >60% of LDES cost is contributed by heat-to-electricity conversion system (new unit)
- New turbines also enable pathway to cost target through materials & manufacturing optimization
- Strong utility support
  - ~ 12 expressed interest
- Engagement with multiple LDES vendors
  - Mostly TES agnostic
  - Does require a high-pressure capable TES

J. Mortzheim, Air Brayton Compete Gas Turbine Decarbonization Through TES, Proceedings of the 2025 Thermal-Mechanical-Chemical Energy Storage (TMCES) Workshop, 30-31 July 2025. https://www.swri.org/events/proceedings-of-the-2025-thermal-mechanical-chemical-energy-storage-tmces-workshop

Heat Storage May Become a Feature of Data Centers

- Some data centers have highly variable electricity demand. If excess electricity, can quickly dump excess electricity to heat storage system. Power transients not seen beyond the data center.
- Option to produce or buy wind and solar electricity behind the meter at very low prices and partly match data center demand
- Data centers have massive electricity and air conditioning loads
  - Can provide electricity using high-temperature heat with gas turbines or steam cycles
  - Can provide heat to adsorption air conditioning systems that require heat rather than electricity inputs

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11. C. W. Forsberg, P. J. McDaniel, and B. Zohuri, Nuclear Air-Brayton Power Cycles with Thermodynamic Topping Cycles, Assured Peaking Capacity and Heat Storage for Variable Electricity and Heat, Nuclear Technology, 207 (4), 543-557, April 2021. https://doi.org/10.1080/00295450.2020.1785793
12. D. Stack, Development of High-Temperature Firebrick Resistance-Heated Energy Storage (FIRES) Using Doped Ceramic Heating System (PhD Thesis), Massachusetts Institute of Technology, February 2021