Joule Hive

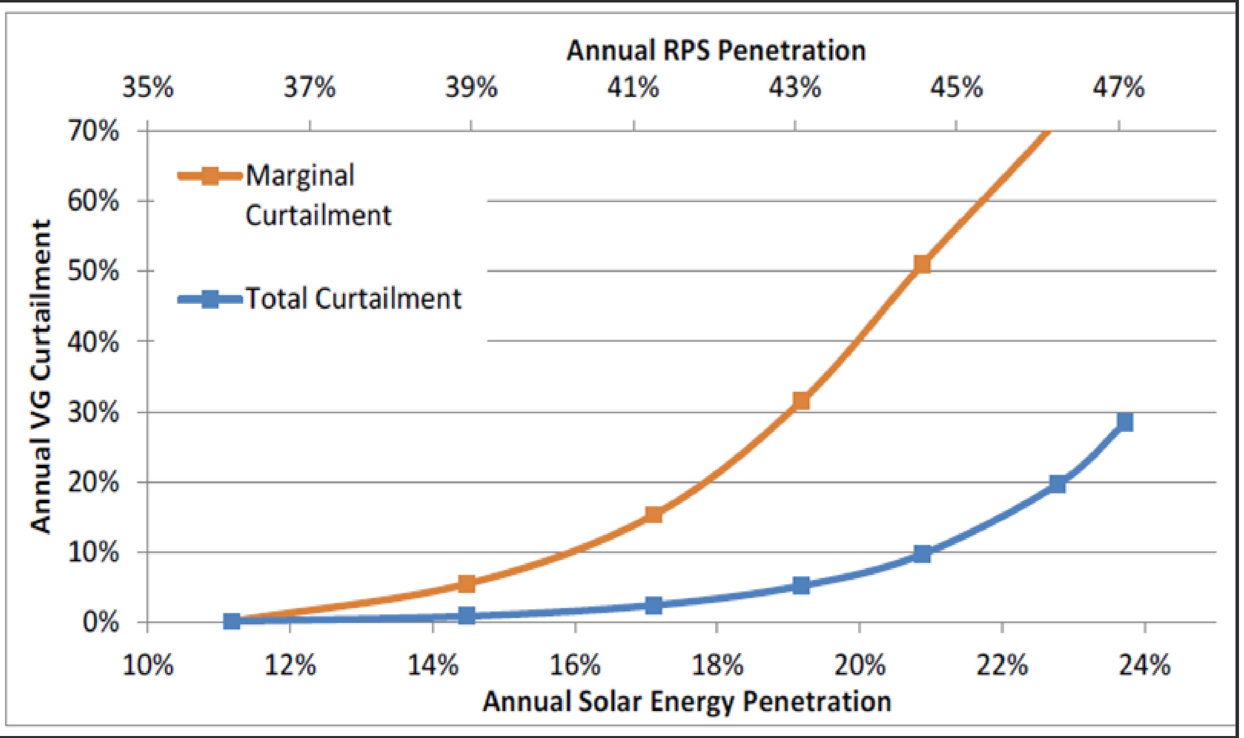
Replacing fire with renewable heat.

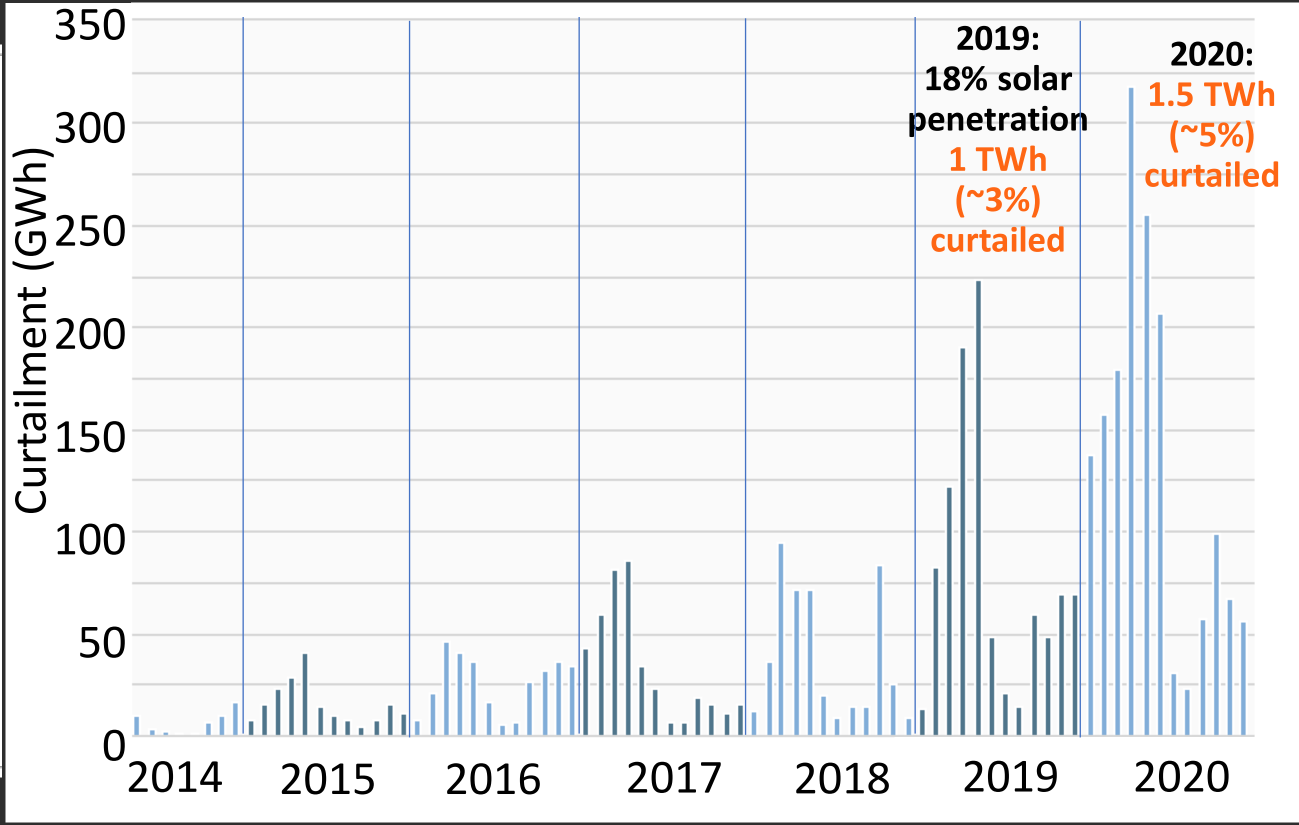
Electrified Thermal Solutions, Inc.

Daniel Stack, PhD. – *CEO*

Joey Kabel, PhD. – *CTO*

Problem: renewable energy is creating many hours of low value electricity, rising curtailment





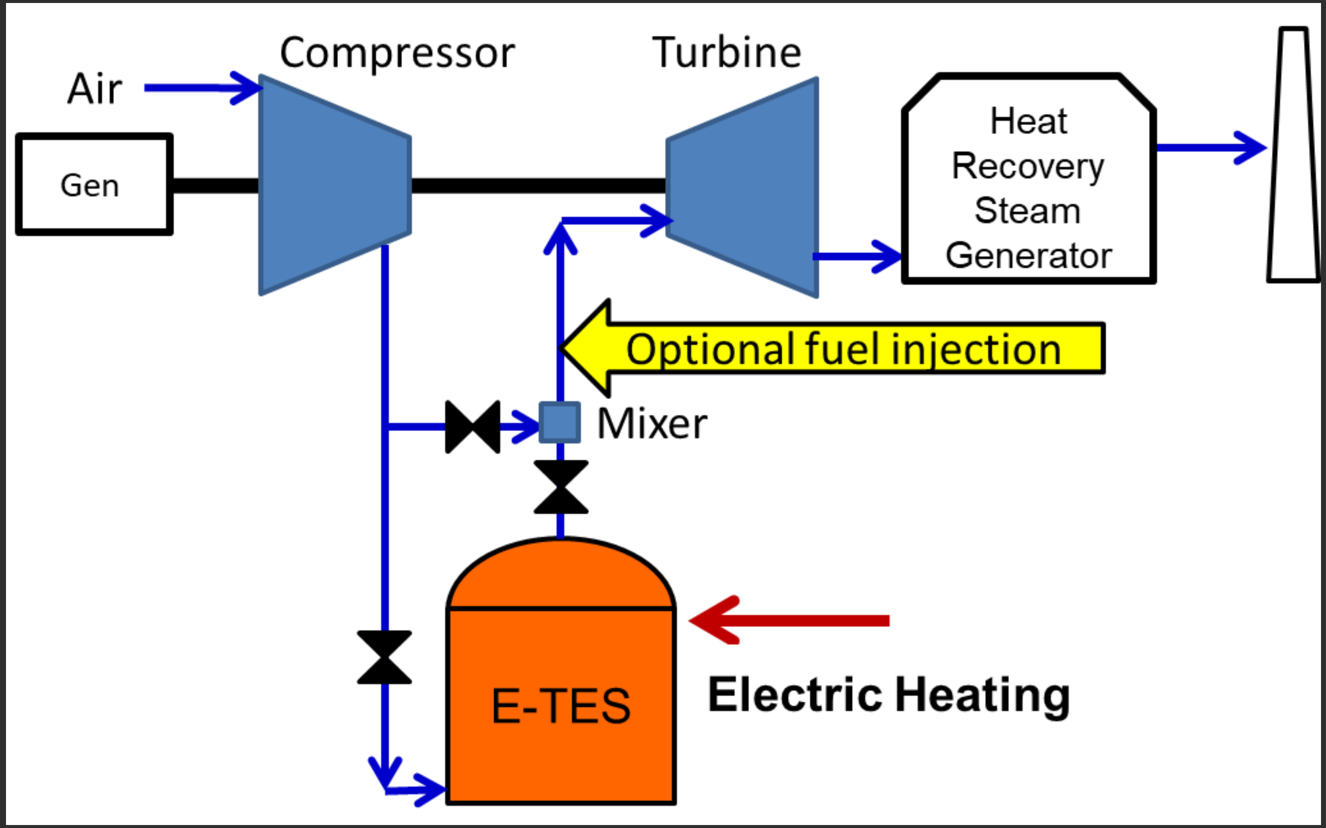
Prediction
Source: NREL

reality
Source: CAISO

Significant zero-carbon energy is wasted today, and will increase without affordable storage technology

Solution: use low-value electricity to run gas turbines, via Electrically-heated Thermal Energy Storage (E-TES)

- E-TES converts low-value electricity into heat, stores for later use.
- Attached to a combined cycle gas turbine (CCGT) where fuel is normally used.
- **When prices are low:** Charge the E-TES.
- **When prices are high:** Produce electricity using heat stored in E-TES.
- If E-TES is empty, use fuel source.



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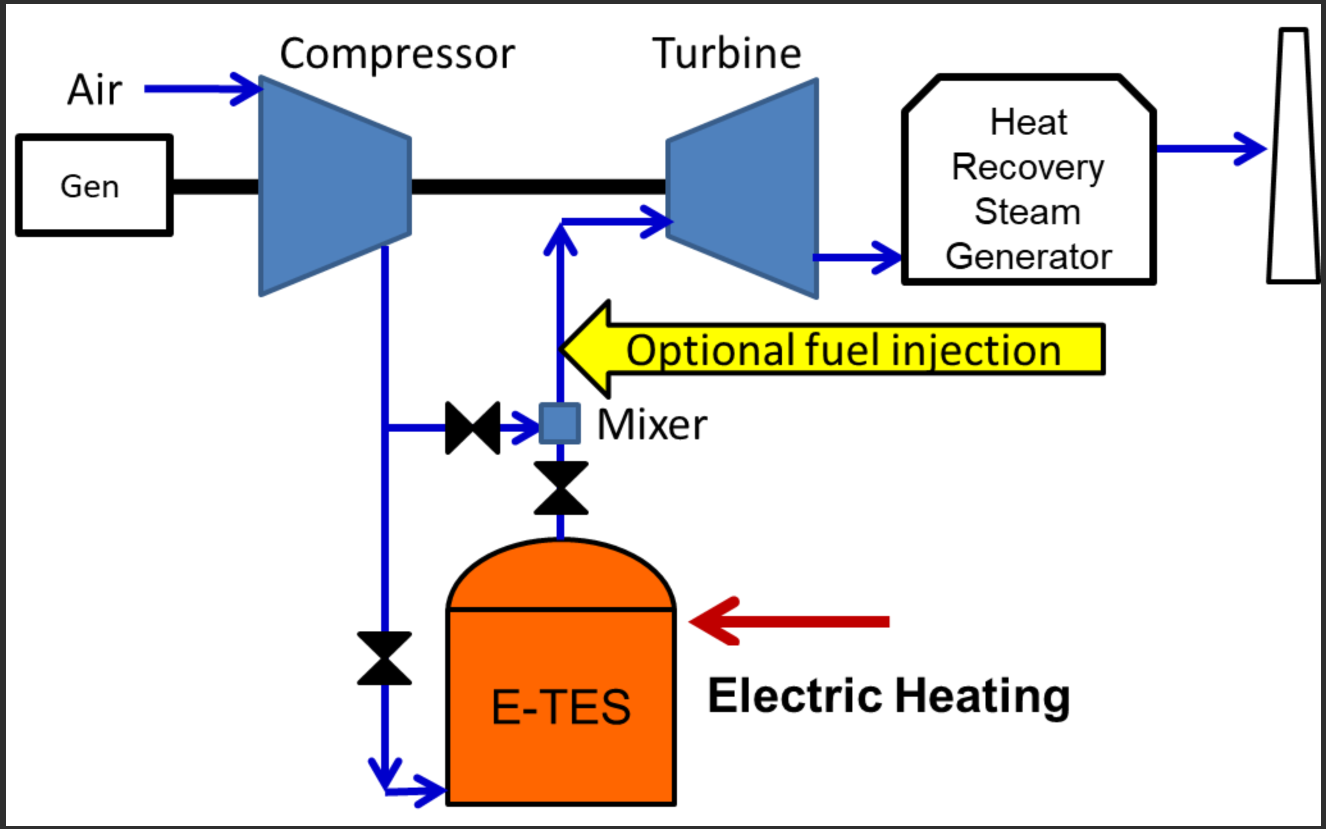
From plant perspective: E-TES is a ***fuel option***

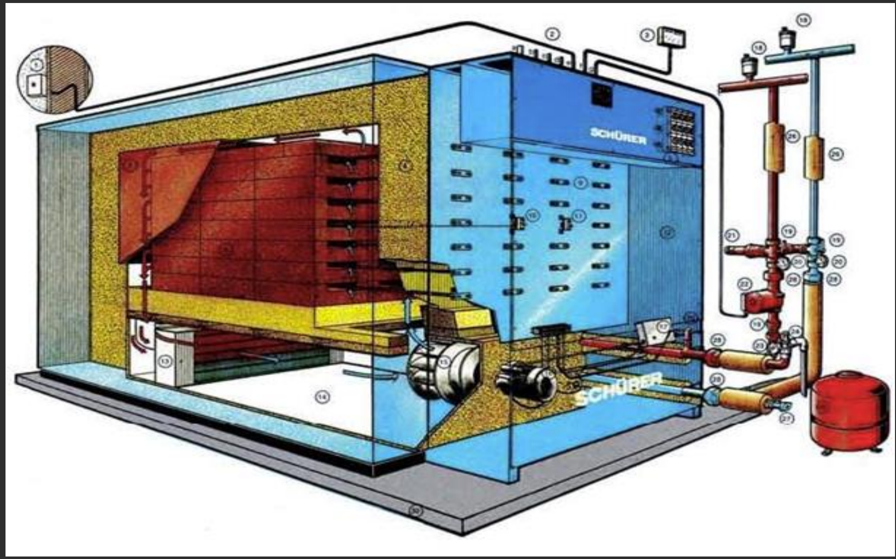
From grid perspective: CCGT + E-TES is a ***battery***



E-TES for gas turbines requires innovation

mature, but too cold (700-800ºC)

Residential heat



Commercial heat

Siemens Gamesa

Industrial steam

Need a heating approach for E-TES that solves the shortcomings of existing heater options

Introducing: the Joule Hive

Innovating on 100 years of ceramic energy storage…

- A stack of **electrically conductive** honeycomb firebricks in a steel vessel

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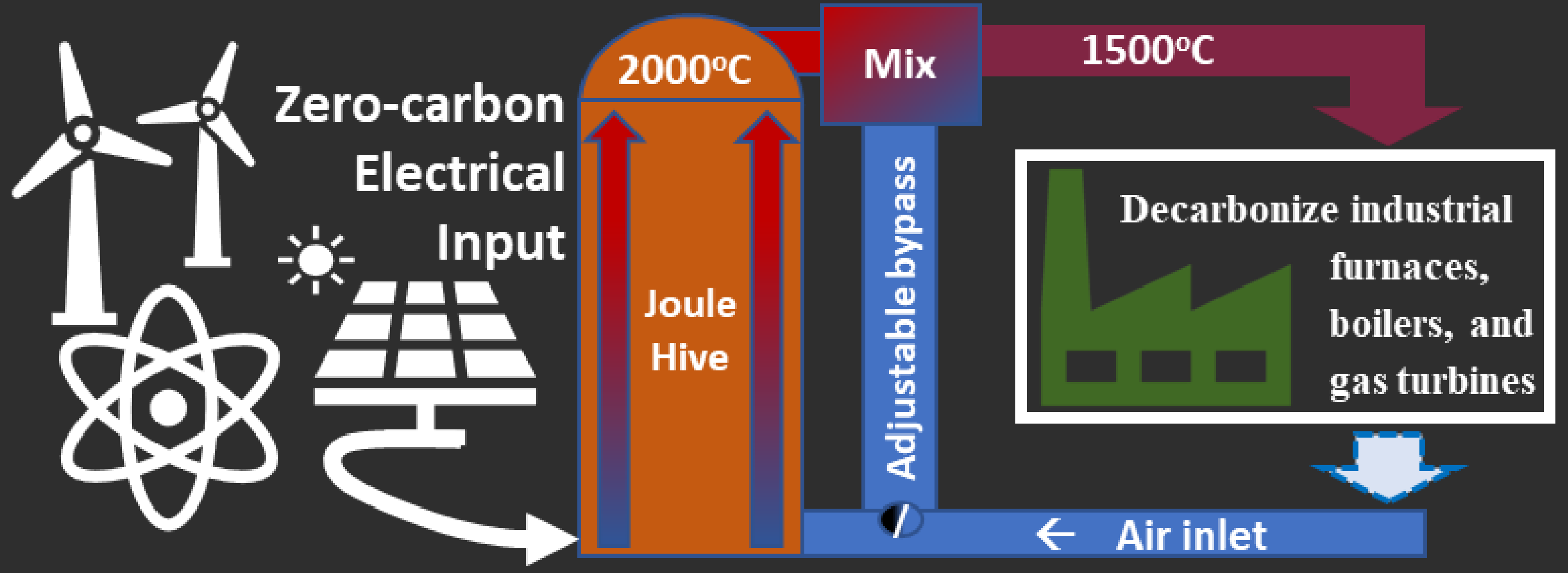
- Charge up to 2000ºC via 100% efficient **joule-heating**
- Discharge via convection with an air/gas stream, creating hot gas
- Solves heater limitations using novel patent materials and brickwork designs

Joule Hive can match temperature of many applications



- 100-1000 MWh storage
- 1 MWh/m^3 density
- Day-night or weekly cycling
- <2%/day Heat leakage
- 1-10 kPa pressure loss
- $10-$30/kWh cost

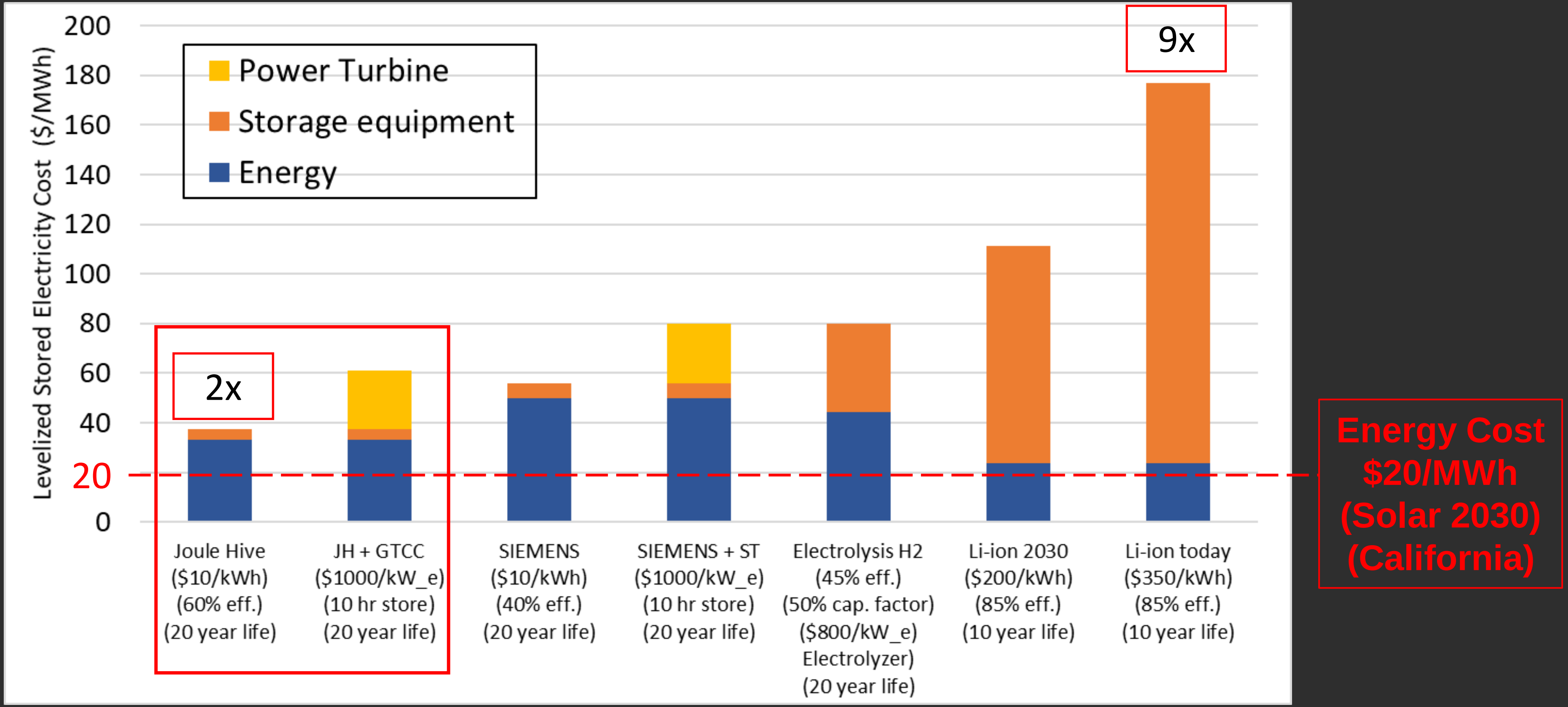
Constant heat

- Steam systems (<500°C): chemicals, pulp, paper, food, others
- **Gas systems (500-1600°C):** glass, ceramics, cement, steel, others

Cheap electrical storage

- Steam power plants (35-45%)
- **Gas turbine combined cycles (55-65%)**
- Advanced solar/nuclear (65-75%)

Joule Hive + CCGT is lowest cost of energy storage: low capital cost, moderate efficiency



- Li-ion storage is **$200-350/kWh** → Batteries **dominate** cost
- Joule Hive **$10/kWh** → **negligible** cost
- Buying a full power plant is a better value than Li-ion batteries

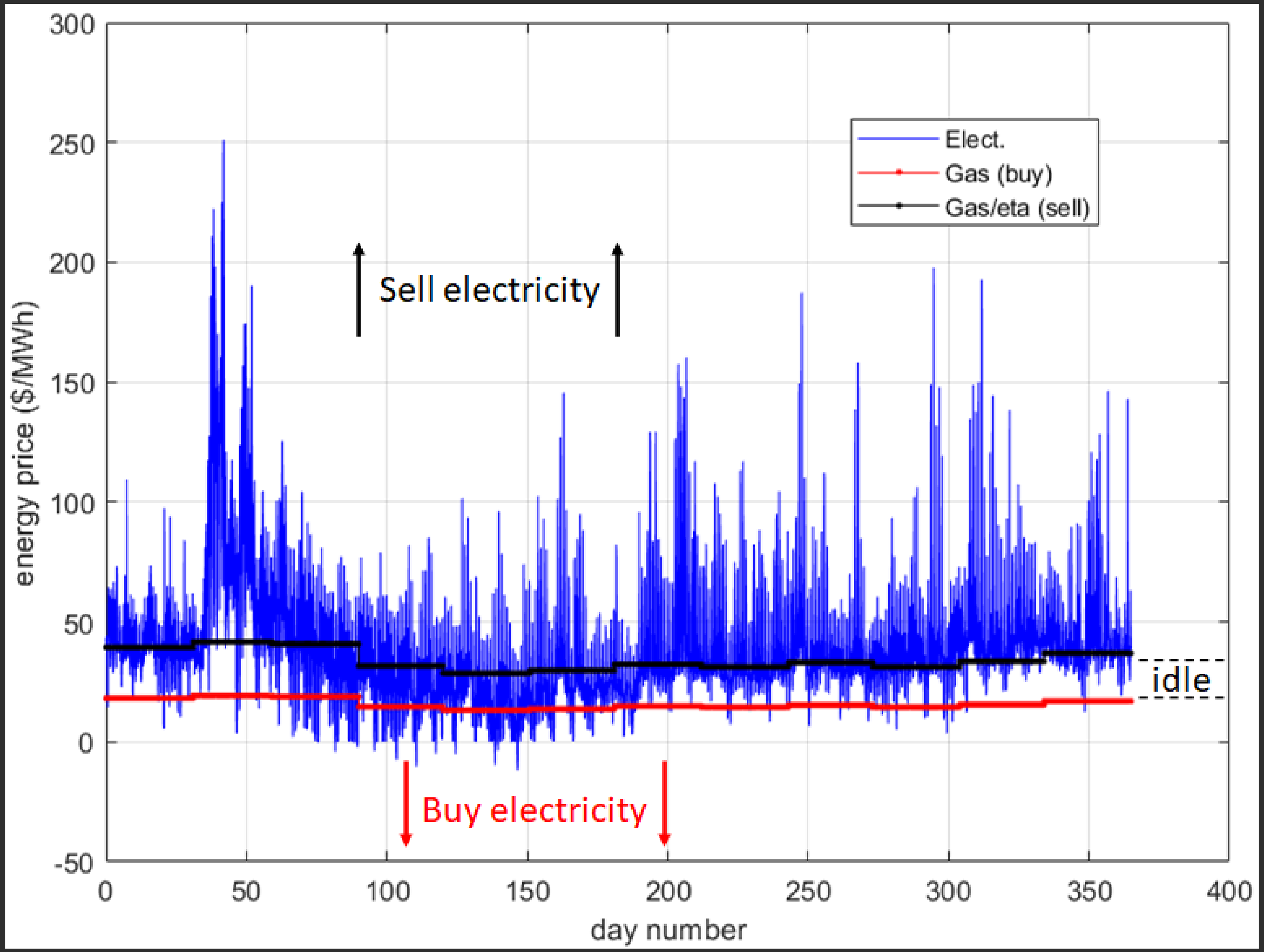
LESSON: Efficiency isn't everything. Cost-effectiveness is.

2019 Case study in Southern California using electricity and natural gas price data

- Operated on “Day-ahead market” data
- Charge E-TES if elec. price < gas price
- Produce electricity if elec. price > gas price/η
- Use E-TES instead of fuel whenever available

Results: 5 hr charge, 5 hr discharge:

- 10% of the time elec. price < gas price
- 12% reduction in fuel usage
- 7 year payback period*



Status and looking forward

Joule Hive is being developed by Electrified Thermal Solutions, Inc. with $1.1M non-dilutive and in-kind funding

- Year 1: Materials refining and production (bottom right)
- Year 2: Lab-scale prototyping and follow-on funding

Joule Hive
Electrified Thermal Solutions

X

arpa·e
CHANGING WHAT'S POSSIBLE

MASSACHUSETTS CLEAN ENERGY CENTER

Activate

WORLD MATERIALS FORUM

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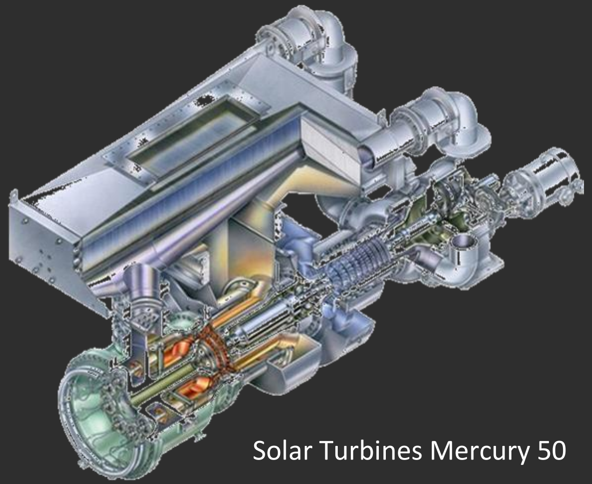
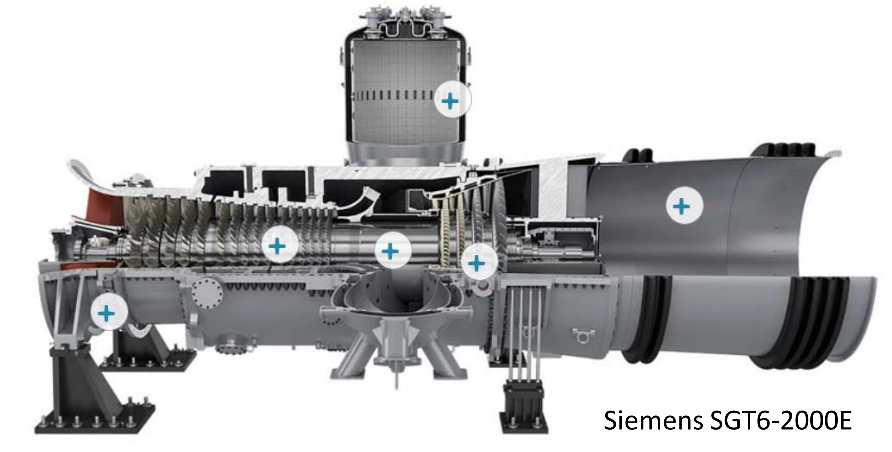
We need help hooking up to gas turbines:

- Easy access: recuperated turbines and silo combustors (bottom)
- Need to design inlets for higher temperatures



Solar Turbines Mercury 50



Siemens SGT6-2000E

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Daniel Stack, PhD
CEO
daniel.stack@joulehive.com
845-741-5708

Joey Kabel, PhD
CTO
joey.kabel@joulehive.com
360-481-0255

www.joulehive.com