Advanced Power Conversion Technologies and Role for Energy Storage

Dr. Andrew Maxson
Electric Power Research Institute, Inc.
amaxson@epri.com; +1 650-862-7640

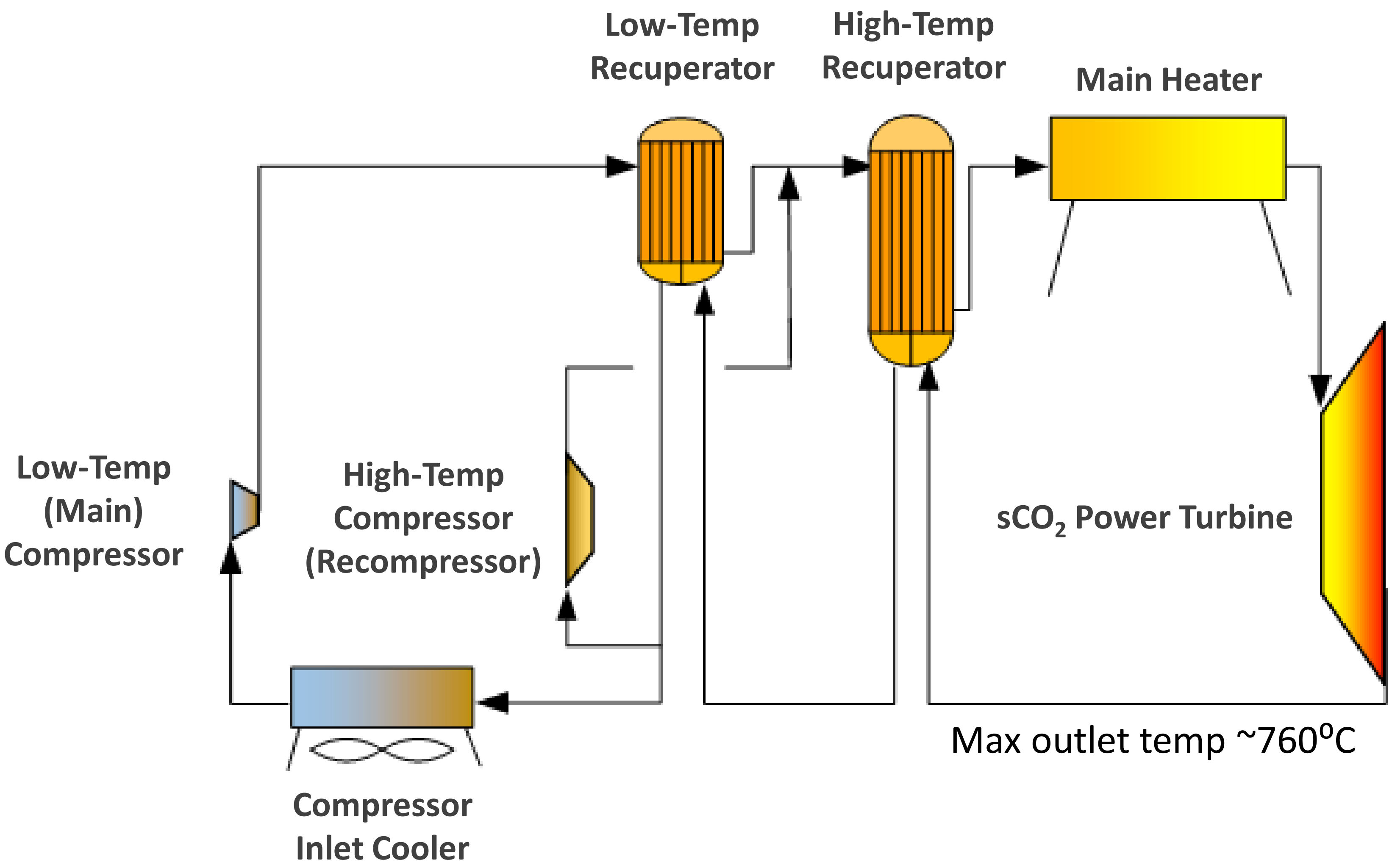
Innovation Network for Fusion Energy Workshop
December 1, 2020

sCO_2 Power Cycles

- Can achieve higher net efficiencies using a sCO_2 power cycle
  - 2–4% points better than a steam-Rankine cycle >300 MWe; 2–8% points <300 MWe
- Cycles are closed and heat is provided indirectly through a heater
- Expansion ratios are low at 4:1
- Turbines are 10 times smaller than a steam turbine with more flexibility
- Heat duty is high in sCO_2 power cycles, 5 times a steam-Rankine cycle
- Use of dry cooling to reduce water use
- Potentially lower costs
- Work on a wide range of temperatures and can be used for fossil, renewable, and nuclear, as well as waste heat recovery – fusion?

Compete directly with steam-Rankine and open air-Brayton cycles

Recompression Closed Brayton sCO_2 Cycle



sCO_2 Power Cycle	Steam-Rankine Cycle	Air-Brayton Cycle
sCO_2 Turbine	Steam Turbine	Combustion Turbine (CT)
Compressor	Feedwater Pump	Air Compressor
Compressor Inlet Cooler	Steam Condenser	No comparable component
Main Heater	Boiler	Combustor
Recuperator	Feedwater Heater	Recuperator (seldom included)

Highest efficiency indirect-fired sCO_2 power cycle design

Echogen

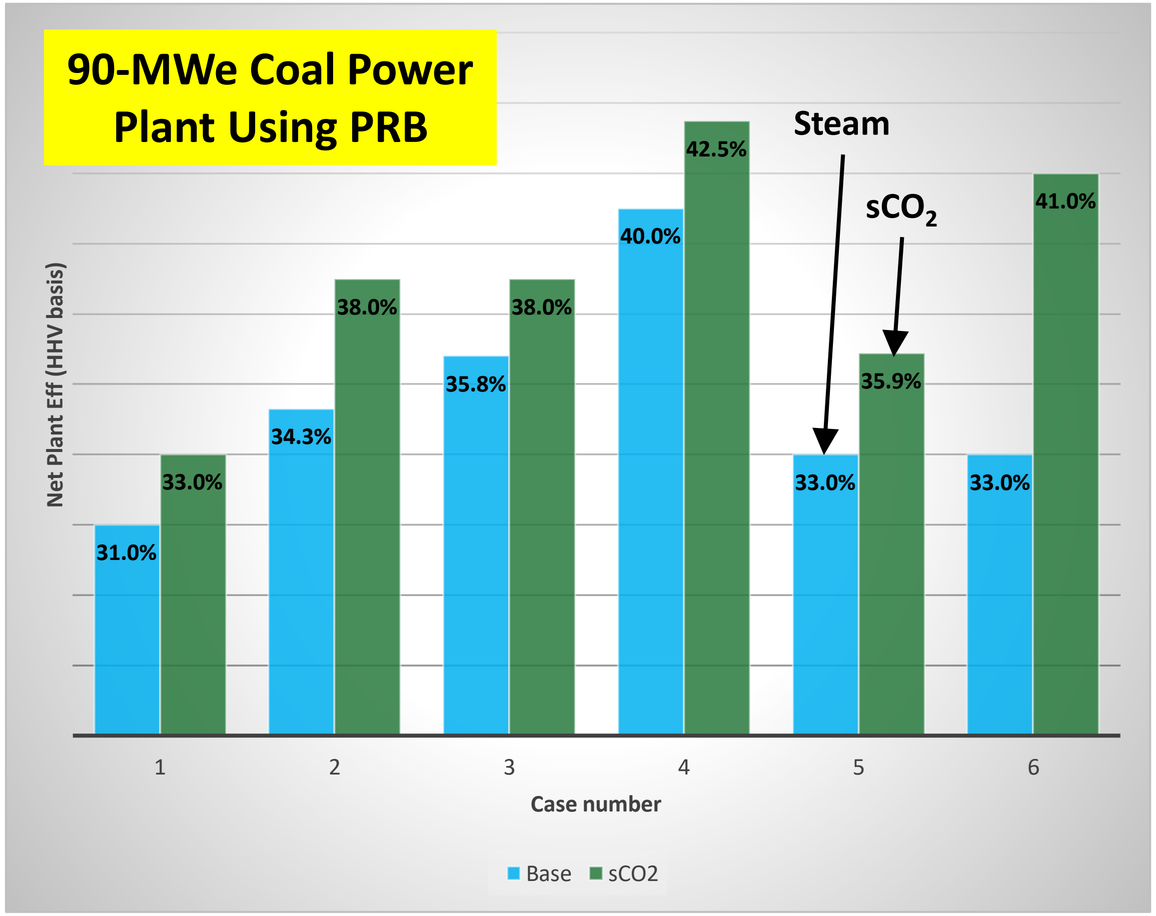
Indirect-Fired sCO_2 Power Cycle

- "EPS 100" (7 MWe) tested for 100s of hours
- First commercial sCO_2 power cycle: CT bottoming cycle using 450°C waste heat
- Developing a 10-MWe demo for solid fuels with ~600–700°C turbine inlet temp
- Gaps include pressure drop in heat exchangers, material concerns at high temps, and cost
- Standalone systems could be commercial at 50–100 MWe scale by 2025–30

Used with permission from Echogen Power Systems LLC

Most mature sCO_2 power cycle; EPRI involved in several projects

Echogen: Techno-Economics



DOE Project DE-FE0025959: "High-Efficiency Thermal Integration of Closed Supercritical CO_2 Brayton Power Cycles with Oxy-Fired Heaters"

Net Power, MWe	Turbine Inlet Conditions		Net Efficiency, % (HHV)		Levelized Cost of Electricity, $/MWh	
	Base	Test	Base	Test	Base	Test
90	538°C / 10.6 MPa	593°C / 24.1 MPa	33.0	36.0	96.5	95.1
90	538°C / 10.6 MPa	730°C / 27.6 MPa	33.0	41.0	96.5	106.4

More efficient than steam-Rankine and potentially less expensive

Need for Energy Storage

Today: 2020

As variable renewable energy (VRE) grows, dispatchable resources are being shut down or operated flexibly

- Primarily batteries provide new storage
- Other storage technologies being developed

100s MWh for 0–4 hours

Tomorrow: 2030

Conventional dispatchable resources further replaced with VRE, diurnal and multi-day energy storage needed

- Higher VRE penetration
- Retrofit stranded assets with thermal energy storage (TES)
- Other non-battery types

10s GWh for 4–48 hours

Target: 2050

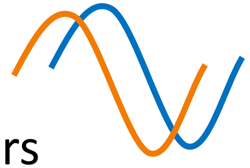
> 80% low-carbon generation, primary energy sources stored in sufficient quantities for year-round power resilience

- Bulk energy storage, e.g., large-scale TES (immediate use)
- Chemical fuel storage (hydrogen, ammonia) for seasonal energy shifting

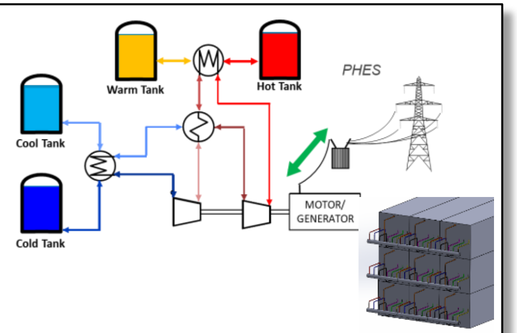
100s TWh Stable and Dispatchable

Wind, solar, and batteries are inverter-based energy supplies – inertia limiting

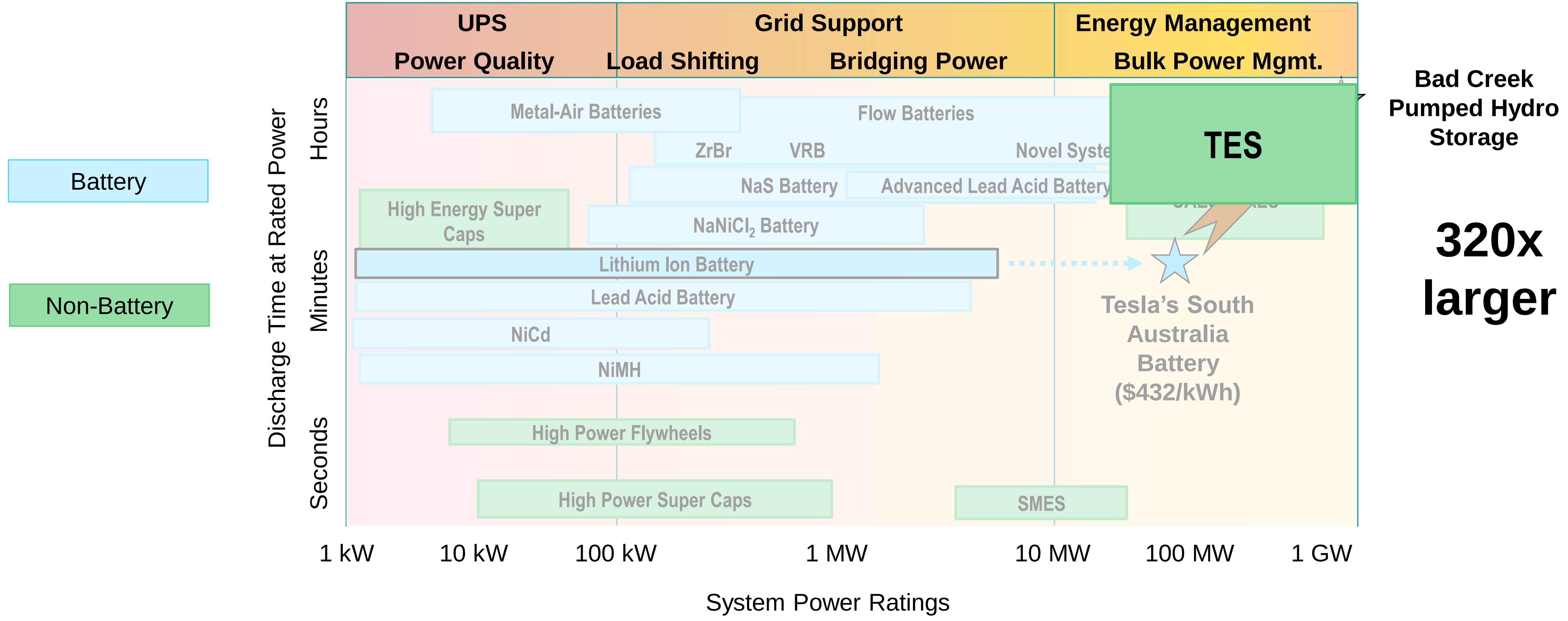
Gas, nuclear, coal, and solar thermal plants provide system inertia by synchronizing generators



Low-cost bulk energy storage, coupled with power cycles, provides synchronous power and system inertia

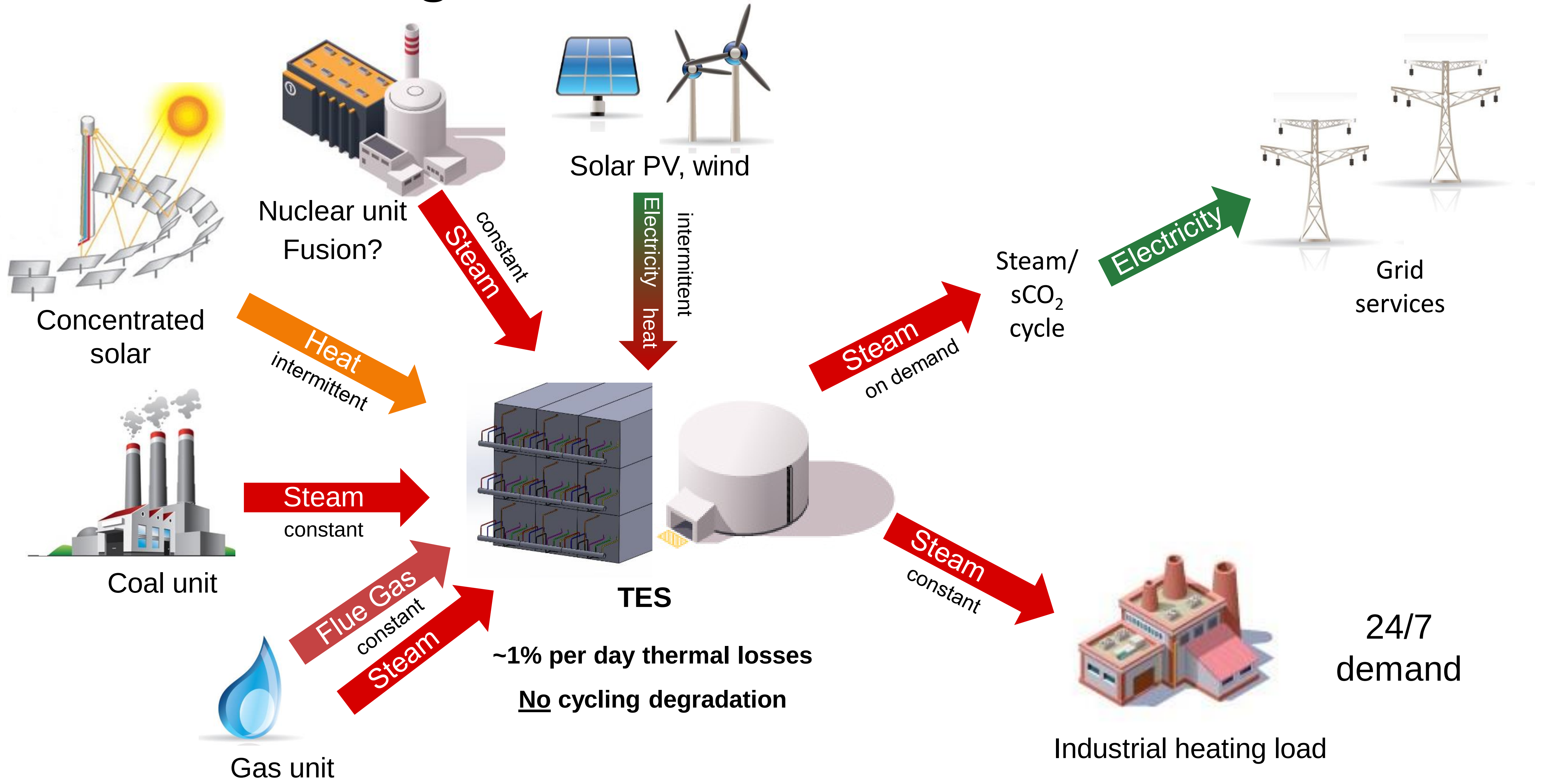


Energy Storage Technology Comparison



TES has potential for more power, longer duration, and lower cost

TES Is Crosscutting

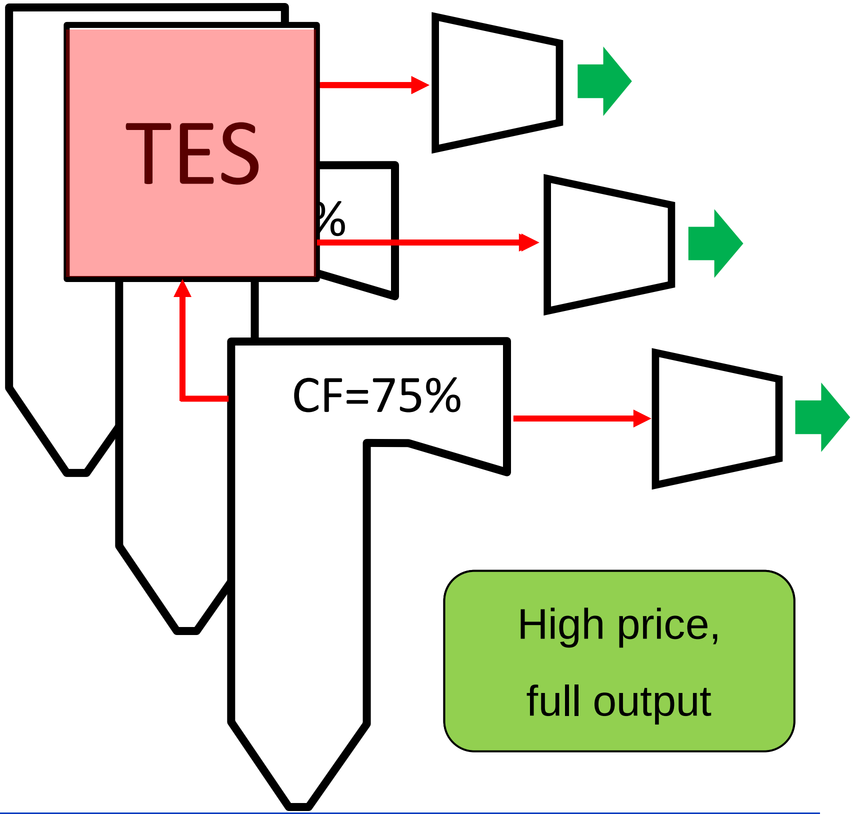


~1% per day thermal losses

No cycling degradation

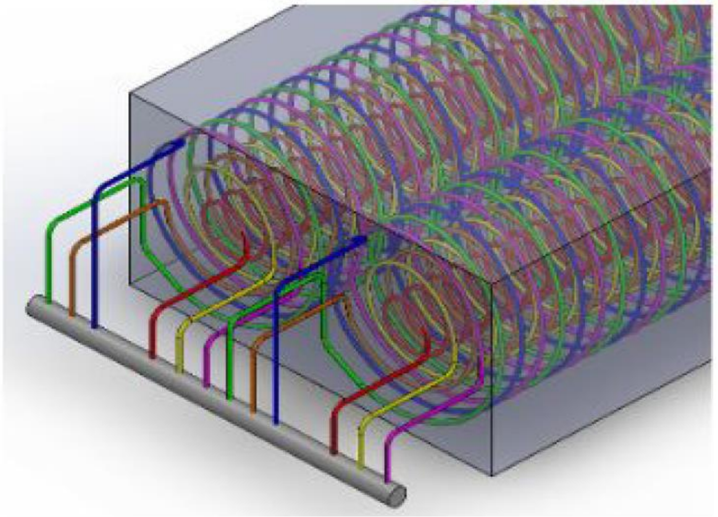
Potential TES Deployment

- By providing steam to TES during periods of low energy prices, the unit remains operational, avoiding cycling or shutdown and restart
- When energy prices increase, steam from the boiler can be diverted to the steam turbine AND the TES units can provide steam to the turbines of the units with retired boilers
- All units generate power when needed



TES can be applied to any thermal plant (including fusion)

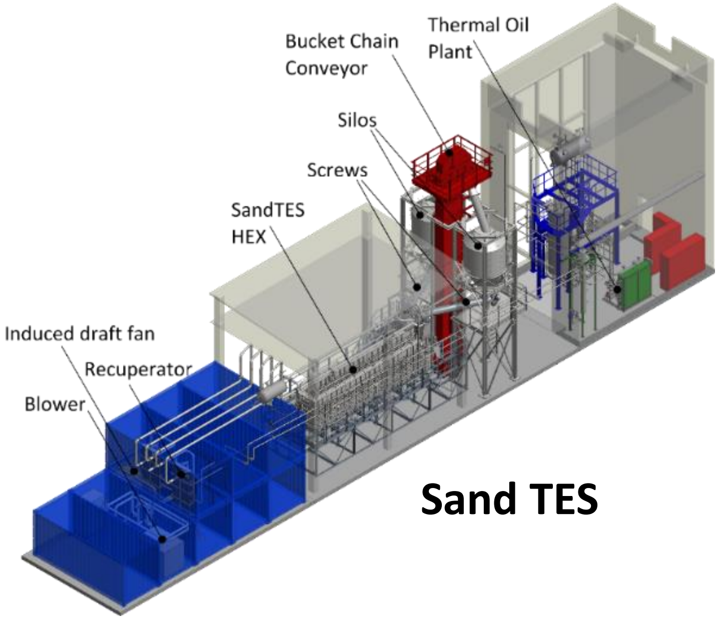
TES Examples



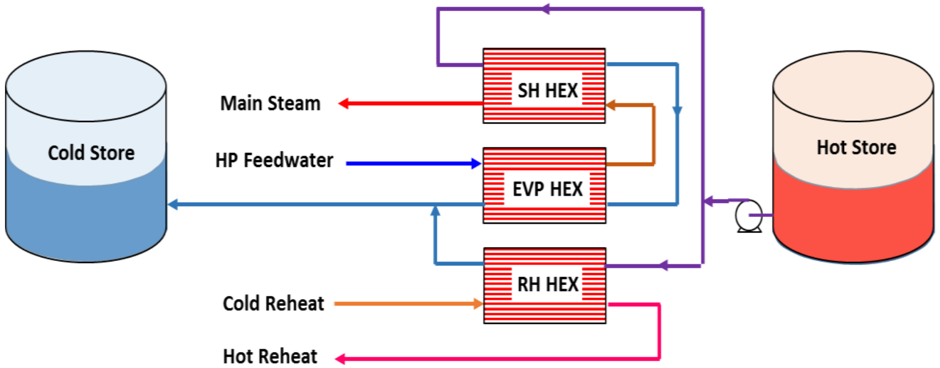
Courtesy of Bright Generation Holdings

Concrete TES

Key: Low-cost thermal media



Sand TES



Molten-Salt TES

Dispatchable, synchronous power over long periods (upto ~48 hours)