2023 IRP CANDIDATE RESOURCES

MAY 4, 2023

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POSSIBLE FUTURE RESOURCE OPTIONS

Near/mid-term (technology could be deployed today or in the next 5-10 years)

Longer term (technology deployment >10 years)

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- Wind
- Geothermal power

Thermal energy resources:

- Aeroderivative combustion turbine
- Linear generator

Energy storage resources:

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- Iron-air storage
- Pumped-hydro storage
- Compressed/liquified air energy storage
- Thermal energy storage
- Green hydrogen

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- Post combustion carbon-capture from flue gas using chemical absorption
- NET power plant

Distributed energy resources:

- BTM PV & storage
- Energy efficiency
- Demand response

RENEWABLE ENERGY RESOURCES

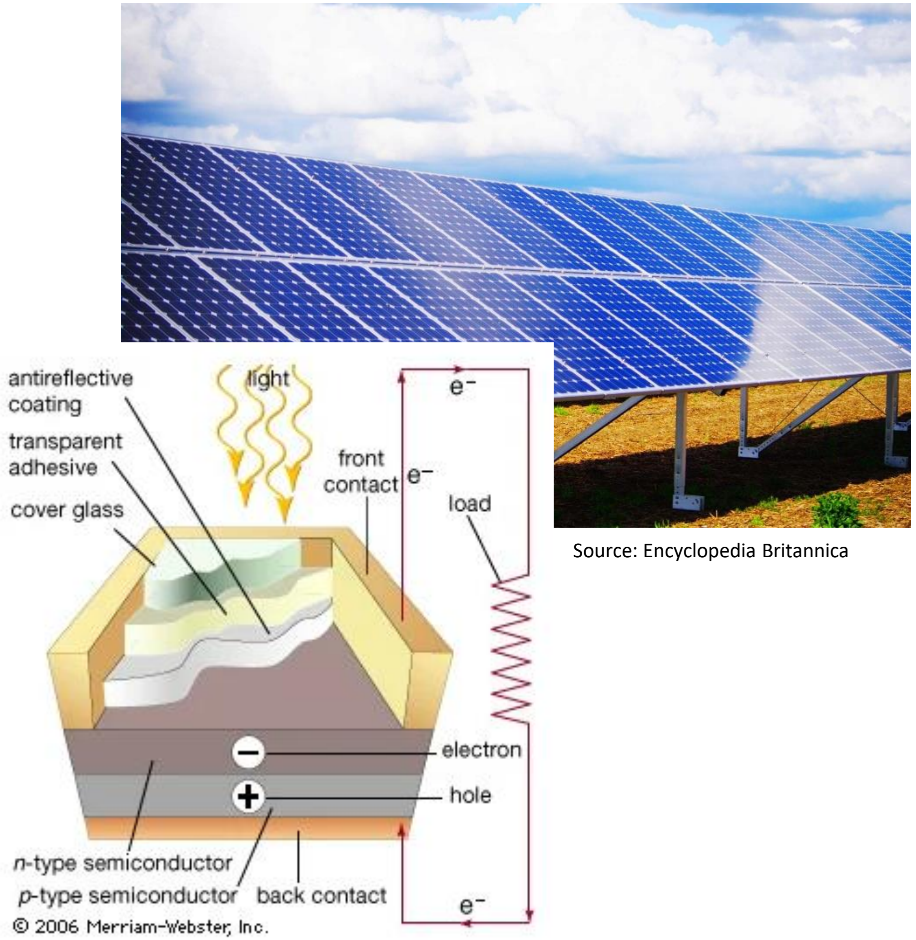
SOLAR PV

Operation:

- Conversion of sunlight into electricity through semiconducting materials
- Semiconductor material absorbs light and transfers energy to electrons within the material
- Charged electrons flow through the material as an electrical current, which is extracted though conductive metal contacts within the solar cells
- Semiconductors create DC electricity, which is converted to AC power output using an inverter
- PV modules consist of multiple cells; PV systems include mounting structures, modules, and power electronics devices

Considerations:

- Renewable, carbon-free power
- New Mexico solar resource is excellent
- ITC/PTC eligibility
- Variable energy resource with production occurring only during daylight hours; storage needed for solar to contribute to decarbonization of offpeak/nighttime hours
- Potential risks around high concentration of inverter-based resources
- Technology is commercially available and widely deployed today; development time is typically less than 2 years
- 2025 cost of $1,259/kW (Siemens estimate for tacking system, 2022 $, assumes ITC)*



Source: Encyclopedia Britannica

* Siemens cost estimates reported in 2021 $, assumes 8.0% inflation in 2022

Source: Energy.gov “*Solar Photovoltaic Cell Basics*”

WIND

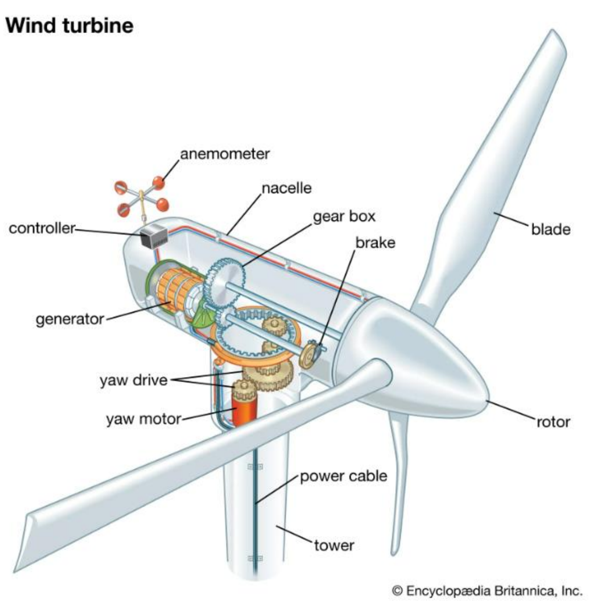
Operation:

- Electricity is produced from the aerodynamic force of the rotor blades of the turbine; the translation of aerodynamic force to rotation creates electricity
- As wind moves across the blade, air pressure on one side of the blade decreases, causing a pressure differential between the two sides of the blade
- The pressure differential creates lift on one side of the blade, and drag on the other – this causes the rotor to spin
- The rotor connects to a generator, either directly or through a gearbox

Considerations:

- Renewable, carbon-free electricity
- New Mexico wind has a high average capacity factor (>40%)
- ITC/PTC eligibility
- Wind can contribute to decarbonization of offpeak/non-solar hours
- Variable energy resource that must be balanced
- Transmission constraints would require transmission build to access significant amounts of new wind
- Technology is commercially available and widely deployed today; development time is typically less than 2 years
- 2025 cost of $1,883/kW (Siemens estimate for onshore wind, 2022 $, assumes PTC)*

Source: Microsoft stock images



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* Siemens cost estimates reported in 2021 $, assumes 8.0% inflation in 2022
Source: Energy.gov *"How Do Wind Turbines Work?"*

GEOTHERMAL POWER

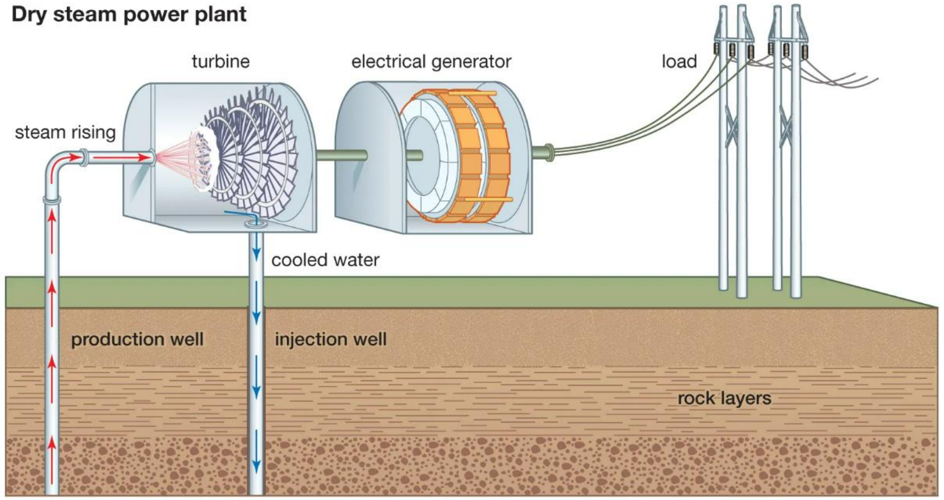
Operation:

- Geothermal power plants generally use steam to produce electricity – the steam is created using geothermal energy
- There are three types of geothermal power plants: dry steam (draws on geysers, and is very rare), flash steam (most common, see below), and binary cycle (in which water heats a secondary working fluid)
- Flash steam plants draw on geothermal reservoirs of water (where water temperatures can be greater than 360°F); high pressure water flows upward through a well, and as it rises and the pressure decreases, it begins to boil and evaporate – the separated steam is used to power a turbine generator, and leftover water is injected back into the reservoir
- Enhanced geothermal systems access heat deeper underground – these wells are up to ~7 km deep – and utilize oil drilling techniques to fracture heated rock for easier pumping of water

Considerations:

- Carbon-free, dispatchable renewable energy source
- ITC/PTC eligibility
- New Mexico has favorable Geothermal resource in western parts of the state – though economics are locationally dependent
- Longer development lead-time (5+ years)
- Commercially viable and deployed technology
- Capital cost of standard geothermal plant ~$7,800-9,800/kW (2030 cost in 2022 $, E3 analysis, does not include IRA impacts)
- Capital cost of enhanced geothermal plant ~$9,000-52,000/kW (E3 analysis; 2030 cost in 2022 $, does not include IRA impacts)

Sources: NREL.gov *“Geothermal Electricity Production Basics”;* E3 *CPUC IRP Zero-Carbon Technology Assessment*



© 2012 Encyclopaedia Britannica, Inc.

Source: https://theconstructor.org/building/geothermal-energy-working-buildings/562287/

THERMAL ENERGY RESOURCES

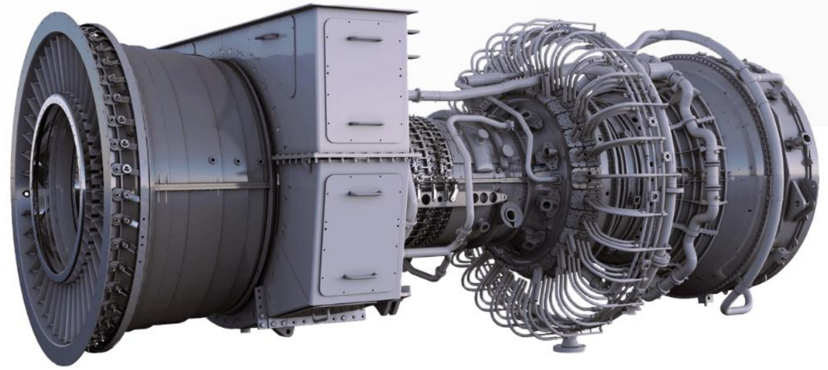
AERODERIVATIVE GAS COMBUSTION TURBINE

Operation:

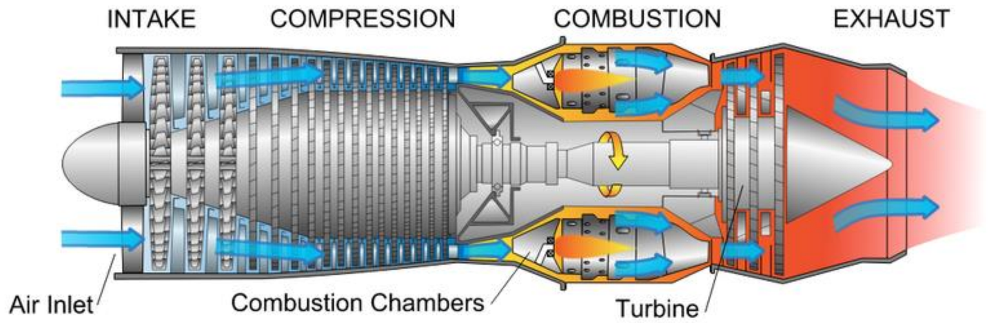
- Often used in a peaking capacity, combustion turbines are designed to ramp quickly
- Air is drawn into the front of the unit, compressed, and sent to the combustion chamber, where it is mixed with fuel
- This mixing results in immediate combustion to produce a high temperature, high pressure gas steam that is expanded through the turbine section
- The turbine section is comprised of alternating stationary and rotating blades; as hot gas expands through the turbine, the rotating blades spin
- The spinning blades drive a generator to produce electricity, and the compressor to draw more pressurized air into the combustion chamber

Considerations:

- Fully dispatchable, fast start time (<5 minutes), with fast ramp capability
- Use of natural gas in near-term; fuel flexibility would allow for use of a natural gas/hydrogen blend with potential conversion to burn 100% hydrogen in the future (though some uncertainties around this remain given the specifications and configuration necessary for 100% H2 combustion)
- Commercially available and proven at utility scale; development and construction period up to ~5 years
- 2025 capital cost of $1,469/kW (Siemens estimate for conventional Aeroderivative turbine, 2022 $)*



GE LM6000; source: GE



Source: https://energyeducation.ca/encyclopedia/Gas_turbine

* Siemens cost estimates reported in 2021 $, assumes 8.0% inflation in 2022

Source: Energy.gov *"How Gas Turbine Power Plants Work"*

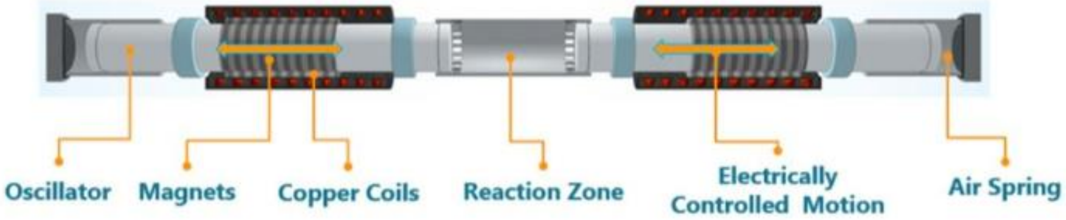
LINEAR GENERATOR UNITS

Operation:

- A linear generator is comprised of two oscillators that move linearly between a center reaction zone and two outer air springs
- Magnets on the oscillators interact with surrounding copper coils for electricity production as the oscillators move back and forth
- Air and fuel are compressed in the center reaction zone, causing a low-temperature flameless reaction, which pushes the oscillators out, through the copper coils, generating electricity and compressing the outer air springs
- The compression of the outer air springs is then used to send the oscillators back towards the center zone, compressing air and fuel and causing a reaction, beginning a new cycle

Considerations:

- Near zero NOx emissions
- Fully dispatchable thermal resource
- Fuel flexibility: allows seamless witch between natural gas, biogas, hydrogen & other fuels
- Modular
- ITC eligible
- Deployed at small scale today; relatively short development and construction period (<2 years)
- Majority of equipment can be repurposed at end of life
- Similar to battery storage, can be used to firm renewable energy and provide ancillary services
- Suitable to local applications reducing the need for transmission
- Capital cost of $2,068/kW (Siemens estimate, 2022 $; Mainspring reports most projects have PPA structure)*



* Siemens cost estimates reported in 2021 $, assumes 8.0% inflation in 2022

Source: Mainspring Energy

Source: www.mainspringenergy.com; Greentech Media

ENERGY STORAGE RESOURCES

LITHIUM-ION BATTERY

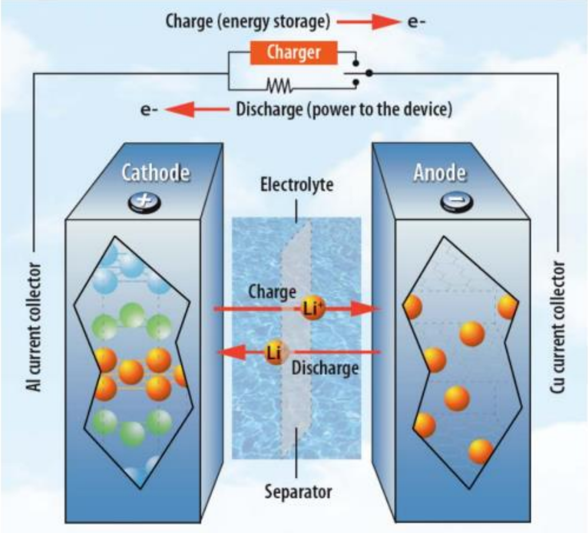
Operation:

- A battery is comprised of an anode, a cathode, a separator, an electrolyte, and both positive and negative current collectors (the positive and negative terminals)
- The cathode and anode store lithium, and release lithium ions when the battery is charging and discharging, respectively
- The separator allows charged lithium ions to flow within the battery, but blocks the flow of electrons inside the battery; electrons must instead flow through the external circuit to maintain charge neutrality at each electrode
- When charging, electrons from the external circuit travel from the positive current collector to the negative current collector, and positively charged lithium ions move through the electrolyte from the cathode to the anode (crossing the separator)
- When discharging, the process works in reverse; the lithium ions travel through the electrolyte from the anode to the cathode, and electrons travel through the external circuit from the negative current collector to the positive current collector

Considerations:

- Widely deployed grid-scale storage technology with relatively short development and construction lead-time (<3 years)
- ITC eligible
- Modular, can be deployed at transmission and distribution levels
- High Round-trip-efficiency (RTE) of ~85%
- Fast-ramping, can balance renewable output and provide grid reliability services
- Ability to optimize energy density vs. power density (capacity vs. duration)
- Best for shorter-duration solutions (30 minutes to four hours), may not be most cost-effective long-duration solution since inventory has little scale economies
- Operational uncertainties over long term
- 2025 capital cost of $1,402/kW (Siemens estimate for 4-hour storage in 2022 $)*

Source: GE (https://www.ge.com/news/reports/leading-charge-battery-storage-sweeps-world-ge-finding-place-sun)



Source: EPA webinar, Argonne National Laboratory (https://www.epa.gov/sites/default/files/2018-03/documents/spanenberger_epa_webinar_-_3-22-18_-_argonne.pdf)

* Siemens cost estimates reported in 2021 $, assumes 8.0% inflation in 2022

Source: Energy.gov *"How Lithium-ion Batteries Work"*

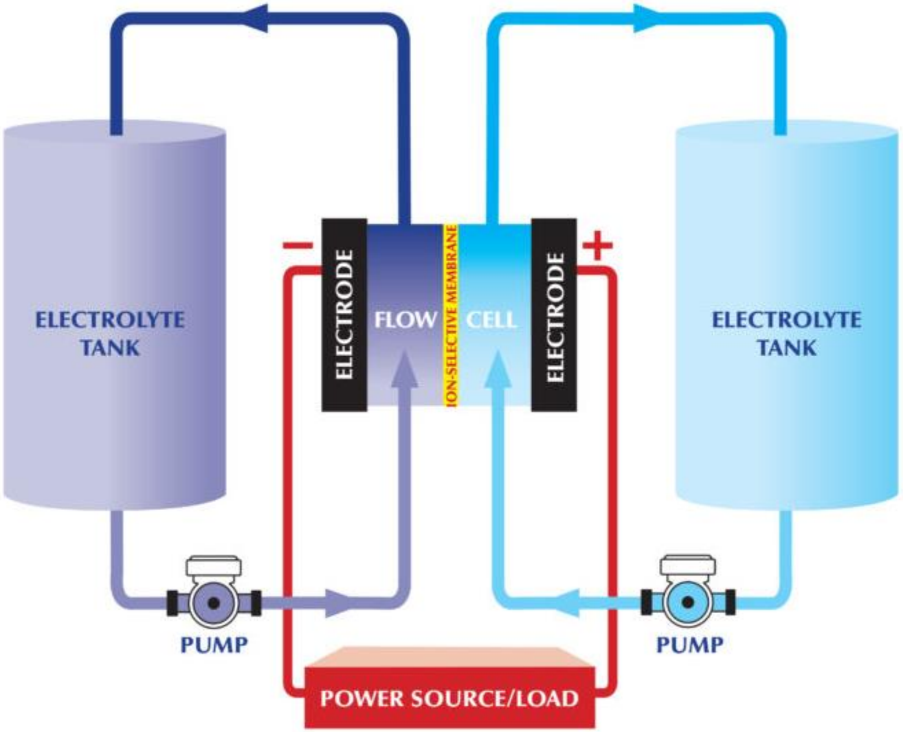
REDOX-FLOW BATTERY

Operation:

- Flow batteries use a chemical reduction-oxidation (redox) process to generate electricity – potential energy is stored (dissolved) in electrolyte solutions
- An anolyte and catholyte (chemical electrolyte solutions) are held in tanks separated by a stack of electrochemical cells
- Flow batteries are differentiated from lithium-ion batteries in that the power and energy components are separate and can be scaled independently; energy density is a product of the volume of the electrolyte, while power capacity is a function of the cell stack size
- When the electrolyte solutions are pumped through the cell stack (each flowing in their own respective loops and separated by a membrane within the cell stack), the resulting ion transfer at the membrane induces an electric current to flow through the external circuit
- During charging, electrons are released in the positive electrolyte (oxidation) and travel though the positive electrode to the negative electrode, where electrons are absorbed into the negative electrolyte (reduction)
- When discharging, the movement of ions from the anolyte to the catholyte induces electrons to flow through an external circuit

Considerations:

- Generally used for longer-duration applications due to economics (4+ hours)
- ITC eligible
- Long cycle life, can be fully discharged with little to no degradation
- Fast-ramping
- Decoupled power and energy
- Most components can be recycled
- Lower efficiency than lithium-ion (~70% vs. ~85%)
- 2025 capital cost of $4,254/kW (Siemens estimate for 10-hour system in 2022 $)*



Source: Flow battery forum (https://flowbatteryforum.com/what-is-a-flow-battery/)

* Siemens cost estimates reported in 2021 $, assumes 8.0% inflation in 2022

Sources: Energy Storage Association *“Redox Flow Batteries”;* Clean Energy Institute University of Washington *“Flow Batteries”;* CleanTechnica *“Vanadium Flow Battery Benefits for Our Future”;* Powermag.com *“Flow Batteries: Energy Storage Option for a Variety of Uses”*

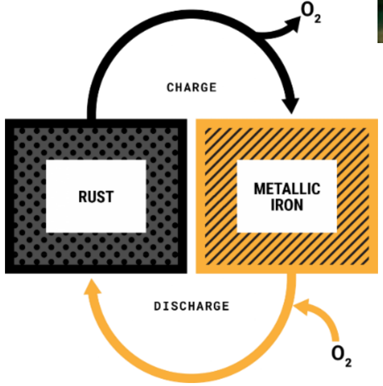
IRON-AIR STORAGE

Operation:

- When discharging, battery “breathes” in oxygen from the air, converting iron to rust
- When charging, the process is reserved when an electrical current converts the rust back to iron
- Modular: each battery module is the size of a side-by-side washer/dryer and contains ~50 cells; each cell contains the iron and air electrodes and is filled with a water-based electrolyte
- Scalable: modules are grouped together in enclosures, many enclosures grouped together to create MW-scale power blocks; 1 MW requires ~0.5 acres of land (lowest density)

Considerations:

- Modular and scalable without specific siting requirements other than adequate space
- ITC eligible
- Three pilot projects underway, utility scale applications yet unproven; earliest large-scale deployment likely in the late 2020’s
- Can reduce renewable generation curtailment and firm variable renewable generation over days (100 hours of storage capability)
- Slower start time and ramp than li-ion; lower efficiency than li-ion (~50%)
- Cannot optimize between capacity and energy – all capacity has fixed storage duration
- Peaker replacement use case
- Siemens estimates 2025 capital cost of $2,228/kW (2022 $)*



Source: www.formenergy.com

* Siemens cost estimates reported in 2021 $, assumes 8.0% inflation in 2022

Sources: Form Energy; Energy Storage News, “*Renewables as baseload energy: Form Energy’s multi-day storage seeks to replace gas and coal*”

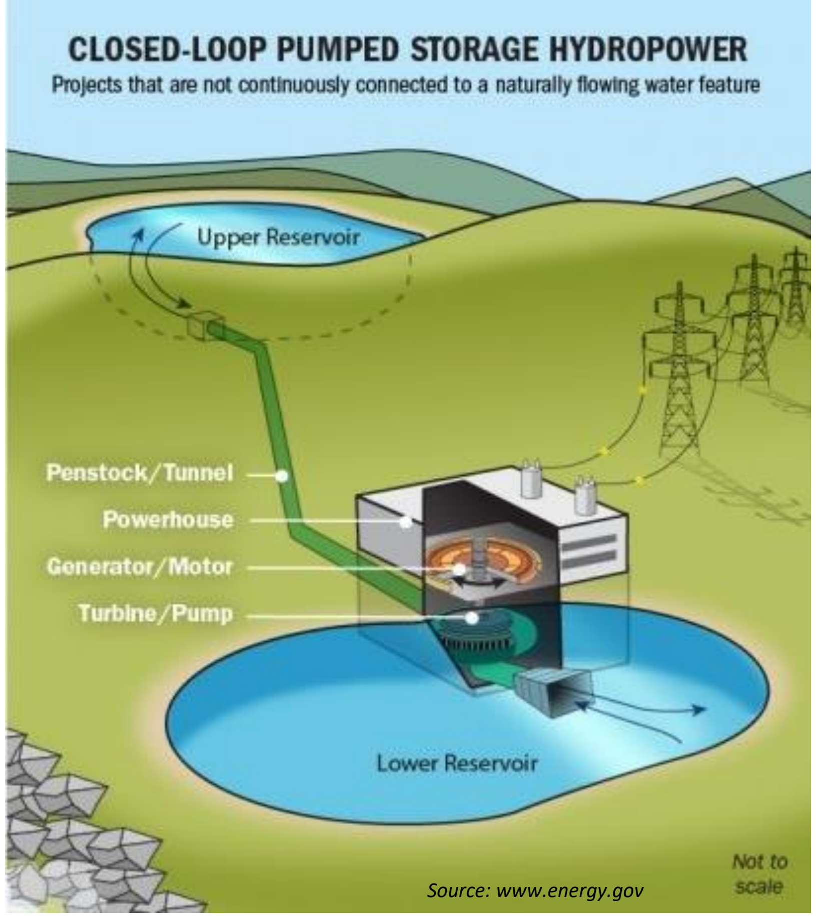
PUMPED-HYDRO STORAGE

Operation:

- Pumped-hydro storage can be a closed-loop or open-loop system; closed-loop consists of two independent reservoirs, while an open-loop system is connected to a naturally flowing water feature
- Charging process consists of pumping water (using electricity) from a lower reservoir to the upper reservoir
- Discharging consists of power generation from water moving through a turbine as it flows from the upper reservoir to the lower reservoir
- Beyond initial fill, water usage mainly consists of evaporative losses – pumped hydro RFI responses generally indicate evaporate losses are ~5% of initial fill per year

Considerations:

- A form of long-duration storage, pumped-hydro can have 70+ hours of duration (depending on size of reservoir)
- ITC eligible
- Pumped-hydro storage has a technology readiness level of 9 and is at full commercial application today; longer development and construction timeframe of 5+ years, earliest deployment late 2020's
- RTE >80%
- This type of plant has specific siting requirements (elevation differential), and there is some uncertainty around the feasibility of a hydro facility in the desert (though reservoirs can be covered)
- Siemens 2025 capital cost estimate of $3,577/kW for 10-hr system (2022 $)*



Source: www.energy.gov

* Siemens cost estimates reported in 2021 $, assumes 8.0% inflation in 2022

Source: Energy.gov "*Pumped Storage Hydropower*"

COMPRESSED AIR/LIQUIFIED AIR ENERGY STORAGE

Operation of compressed air energy storage (CAES) system:

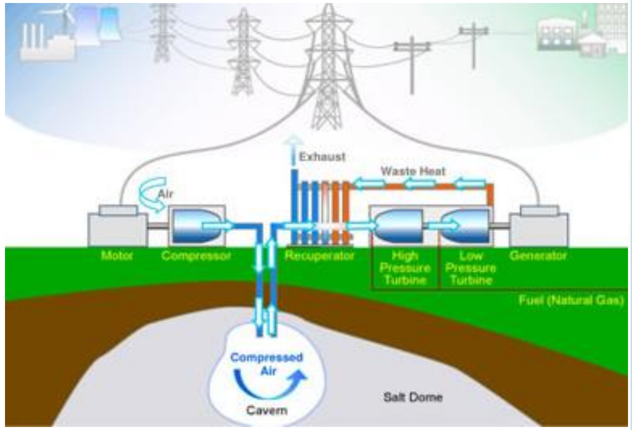
- When charging, power from the grid is used to run a multi-state motor-compressor to compress ambient air – heat generation in the compression process can be captured for later use in the expansion process (adiabatic CAES)
- Compressed air is stored under high pressure – usually in underground caverns (salt, rock)
- To deploy energy, the pressurized air is released from the cavern and expanded in multiple stages – the air cools as it expands, and so heat must be added as the pressure falls; the heating and expansion process drives a turbine generator
- In an adiabatic process, expansion uses recovered heat from compression; in a diabatic process, natural gas or other fuel is added for heat during expansion

Operation of liquified air energy storage (LAES) system:

- Charging process consists of chilling and liquefying ambient air using an electric air liquefier – this creates heat, which can be stored for later use in the generation process
- Liquid air is stored in tanks at low pressure (similar to liquid nitrogen or LNG storage)
- To generate electricity, liquified air is drawn from tanks, pumped to high pressure, evaporated and superheated to ambient temperature – this high-pressure gas is used to drive a turbine generator
- Waste cold from the expansion stage can be captured for use in liquefaction process

Considerations:

- CAES requires large storage volume and specific siting; LAES has no geographical constrains on location
- Both CAES and LAES use technologies that are mature and rely on established power-generation processes and off-the-shelf equipment; both can be modular and scalable
- Both ITC eligible
- Only diabatic CAES proven at large scale
- Longer development and construction period of 5+ years
- RTE of ~50-70% depending on design
- Waste heat/cold can from industrial processes can be utilized
- Siemens estimates a 2025 CAES capital cost of $1,472/kW for a 100-200 MW, 30-hr system (2022 $)*
- Siemens estimates a 2025 LAES capital cost of $3,147/kW for a 100-200 MW, 8-hr system (2022 $)*



Source: https://phys.org/news/2010-03-compressed-air-energy-storage-renewable.html

Source: https://highviewpower.com/technology/

* Siemens cost estimates reported in 2021 $, assumes 8.0% inflation in 2022

Sources: Energy Storage Association *"Compressed Air Energy Storage (CAES)"*; Highview Power

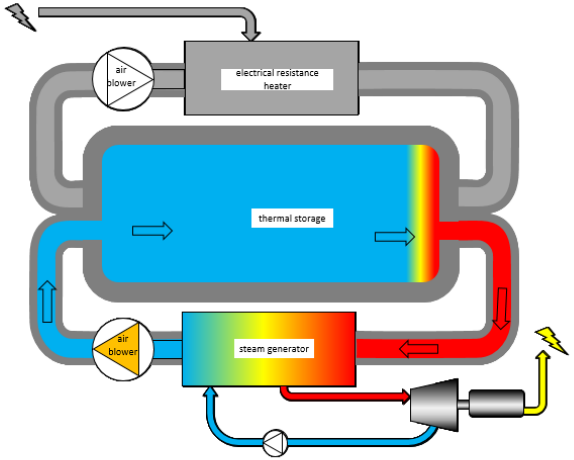
THERMAL ENERGY STORAGE

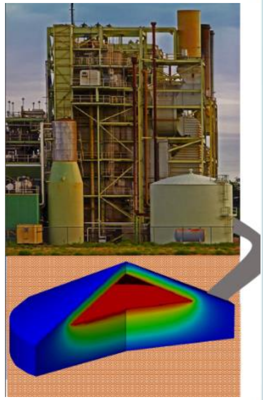
Operation:

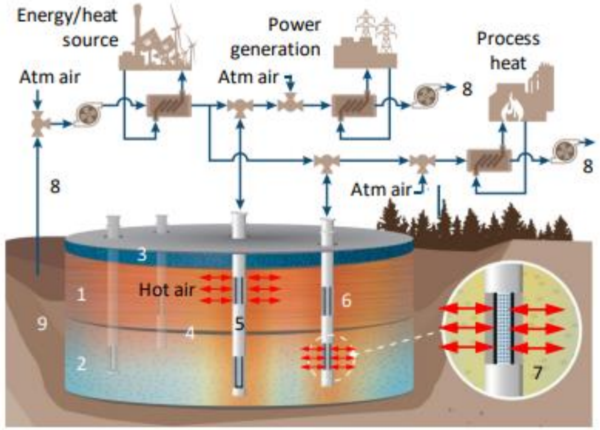
- There are many types of thermal storage utilizing a wide array of technologies
- Generally, thermal storage systems utilize inexpensive and safe materials; storage medium can be contained in tanks, or underground
- The following describes operation of a packed-bed project submitted as a response to PNMs 2022 future resource RFI
- A granular storage medium surrounds a primary well used for the heat transfer fluid – this particular design uses air as the working fluid
- The charging process consists of heating geomaterials (basalt, quartzite) with blown hot air – air is heated using an electrical resistance heater powered by the grid
- Discharging consists of moving the working fluid through the repository to move heat from the storage medium to a steam generator – this steam can then be used to power an existing turbine generator unit for electrical power production

Considerations:

- Thermal energy storage has been implemented with concentrated solar power projects at a utility scale, though other large-scale grid storage applications have not been proven
- ITC eligible
- Storage capacity is limited by the heat capacity of the storage medium
- Development and construction timeframe not entirely clear given technology deployment/readiness level, but estimated to be greater than 5 years
- Thermal storage process can be implemented at existing generation sites
- Siemens has provided a capital cost estimate of $809/kW for the thermal storage component of a 104 MW CSP plant with 10 hours of storage (2022 $)*







* Siemens cost estimates reported in 2021 $, assumes 8.0% inflation in 2022

Sources: www.csolpower.com; Clifford Ho and Walter Gerstle *"Terrestrial Heat Repository For Months of Storage (Therms): A Novel Radial Thermocline System" (https://www.csolpower.com/wp-content/uploads/2021/07/ES2021_THERMS_Ho_v8.pdf)*

Sources: www.csolpower.com, https://www.csolpower.com/wp-content/uploads/2021/07/ES2021_THERMS_Ho_v8.pdf

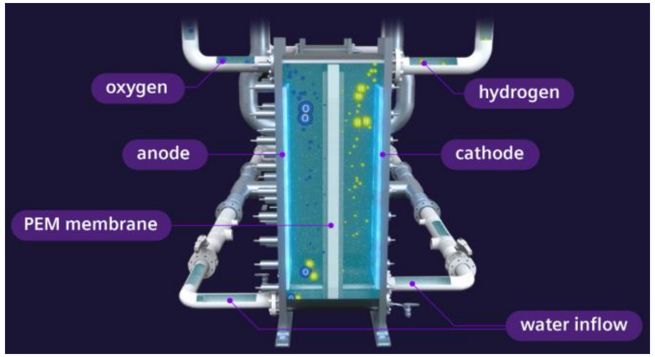
GREEN HYDROGEN

Operation:

- Green hydrogen is produced using power from renewable resources (as opposed to blue or gray hydrogen, which is created using power from fossil-fuels)
- To make hydrogen, an electrolysis process is used to split water molecules into their hydrogen and oxygen components – the following describes a process that utilizes a Polymer Electrolyte Membrane Electrolyzer
  - Each electrolyzer has two electrodes – the cathode is negatively charged, and provides electrons, while the anode is positively charged, and extracts electrons
  - The electrodes are immersed in water, which must contain salts and minerals (and thus positively and negatively charged ions) to conduct electricity
  - The negatively-charged electron-producing cathode attracts ions with a positive charge, while the positively-charged electron-releasing anode attracts ions with a negative charge
  - Water reacts at the anode to form oxygen and positively charged hydrogen ions, which flow across the PEM membrane to the cathode
  - At the cathode, hydrogen ions combine with electrons from the external circuit to form hydrogen gas
    - The hydrogen is captured and either stored or combusted in a turbine generator
- Green hydrogen is a form of energy storage – renewable power is stored as hydrogen, and later converted back to electricity

Considerations:

- ITC/PTC available for hydrogen and renewable production (potential for stacking of credits)
- Uncertain feasibility of 100% hydrogen combustion by 2040 – technology readiness, safety issues, transportation and storage of hydrogen
- Potential for green H2 production and use in another non-power application
- Low RTE of a green hydrogen to power system, ~30%
- While PEM electrolyzers are preferable, they are expensive and use precious metals
- Siemens 2025 capital cost estimate of $1,100/kW for electrolysis equipment, and $337/kW for CT conversion (2022 $)*



Source: Siemens

* Siemens cost estimates reported in 2021 $, assumes 8.0% inflation in 2022

Sources: Green Power "*Hydrogen Production by Electrolysis*"; Energy.gov "*Hydrogen Production: Electrolysis*"; Encyclopedia Britannica "Electrolysis"

CARBON CAPTURE TECHNOLOGIES

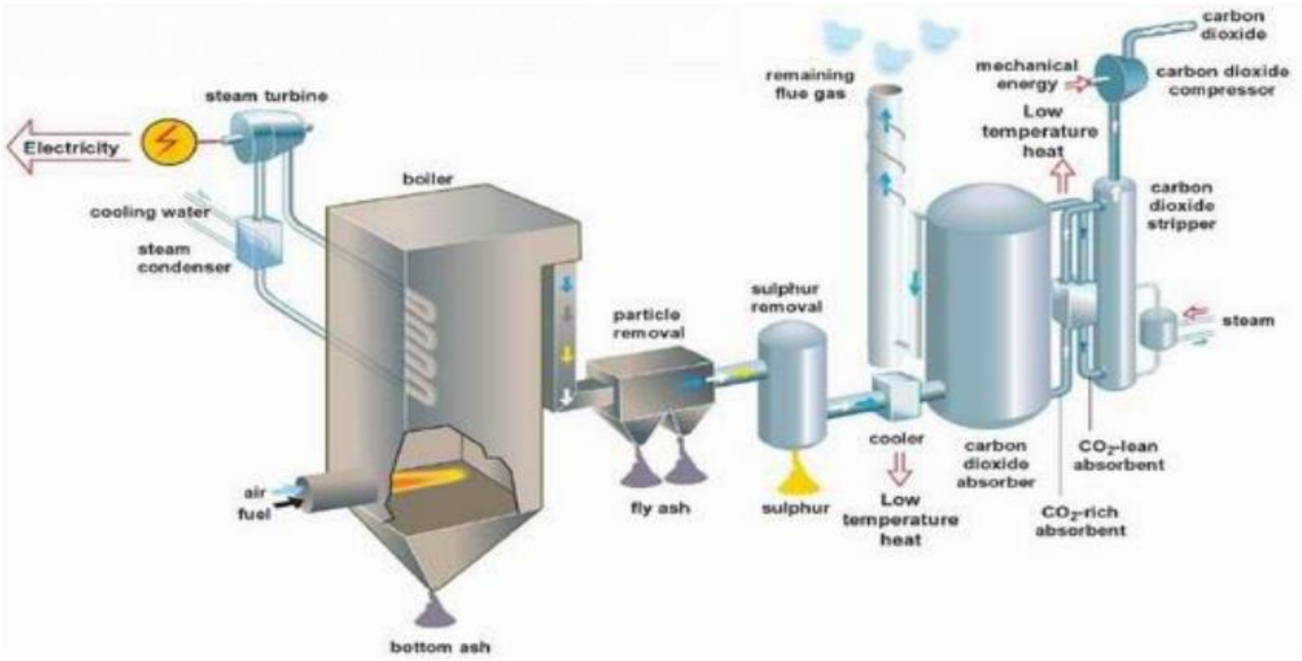
POST COMBUSTION CARBON-CAPTURE FROM FLUE GAS USING CHEMICAL ABSORPTION

Operation:

- Exhaust gasses from combustion are put into contact with a liquid amine solution, which binds with and separates the CO2
- The CO2 is then stripped out of the liquid amine solvent using steam
- The concentrated CO2 is compressed for transport and/or storage

Considerations:

- Can be utilized with existing infrastructure
- Transportation and/or storage costs for CO2 must be considered
- Carbon capture credit/ITC/PTC eligible
- Due the concentration of carbon stream in flue gas, this method is less energy intensive and cheaper than direct air capture
- Designed to capture 85-95% of CO2 produced; may not be able to capture 100% of CO2 without additional cost for CO2 absorption reactor (~10% cost increase)
- Does not reduce SOx or NOx emissions – flue gas must be treated prior to chemical absorption (though these criteria pollutant emissions would still be non-zero)
- Capital cost of natural gas combined cycle with >99% CCS ~$2,500-3,200/kW (E3 analysis; 2030 cost in 2022 $, does not include IRA impacts)



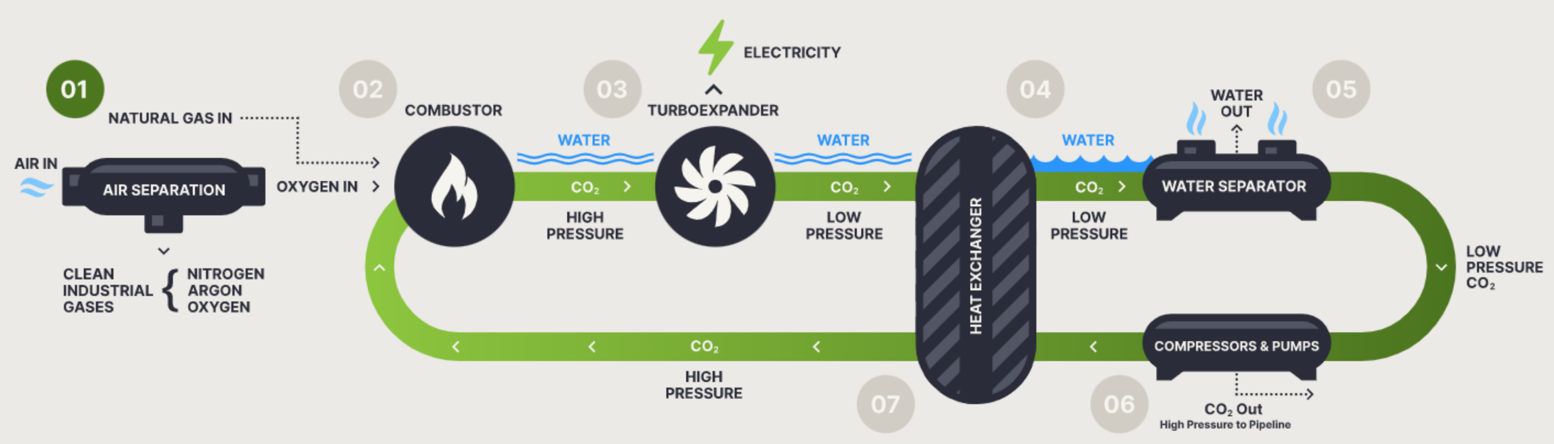
Source: E3 CPUS Zero Carbon Technology Review (https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan-irp-ltpp/2022-irp-cycle-events-and-materials/cpuc-irp-zero-carbon-technology-assessment.pdf)

Sources: E3 *CPUC IRP Zero-Carbon Technology Assessment;* National Energy Technology Laboratory *"Carbon Dioxide Capture Approaches"*

NET POWER PLANT

Operation:

- Allam power cycle uses supercritical CO2 to produce power, instead of steam (it has no emissions)
- CO2 remains in closed-loop system and never enters atmosphere, though carbon byproduct is generated
- Natural gas is combusted with oxygen (primary oxidant) and recuperated CO2
- Resulting working fluid consists of high-pressure CO2 and water; this is then expanded through a turbine for power production
- Expansion process results in low-pressure CO2 and water, which are then cooled in a heat exchanger before the water is removed, and the remaining pure CO2 stream is compressed
- At this point, excess high-pressure CO2 can be exported as a stream of pipeline-quality CO2 (could be sequestered, or sold for use in other applications), while the rest is returned to the combustor



Source: www.netpower.com

Considerations:

- Provides firm, dispatchable capacity and energy
- Uses proprietary Allam-Fetvedt process that recycles CO2 as a working fluid and captures excess as pipeline-quality CO2
- No NOx, SOx, VOC or particulate emissions
- Water-neutral; eliminates water consumption
- Proven at small scale (25 MW), but commercial viability at utility scale remains unproven; 280 MW Coyote Clean Power plant utilizing NET technology expected online in 2026
- PNM carbon emissions targets would likely necessitate requirement for 100% carbon capture and sequestration
- Siemens estimates capital cost of $2,649/kW in 2025 (2022 $, includes IRA assumptions)*

* Siemens cost estimates reported in 2021 $, assumes 8.0% inflation in 2022

Sources: NETpower, NET Power, LLC Allam Cycle Overview: https://www.youtube.com/watch?v=vFcbev1TkoU

DISTRIBUTED ENERGY RESOURCES, ENERGY EFFICIENCY, AND DEMAND RESPONSE

BEHIND-THE-METER SOLAR AND STORAGE

Operation:

- Solar/storage sited at customer location, connected to the distribution system
- BTM resources are on the customer side of the meter; PNM sees load net of BTM resource production (or load, in the case of storage)
- Residential solar is generally fixed-tilt, installed on rooftops
- Residential storage systems are generally lithium-ion or lead-acid batteries

Considerations:

- Increasing adoption of BTM PV can be expected given tax incentives, net metering, and general customer trends towards green energy
- Customer usage patterns and may shift as we implement time-of-use rates and AMI; customers may begin to install BTM storage at their homes and businesses
- Widespread adoption of BTM solar, storage, and EVs combined with AMI could enable aggregated customer-sited resources to become a system resource when needed (Virtual Power Plants)
- In current framework, distributed energy resources are load modifiers
- Eventually DERs will be evaluated independent of load in the resource adequacy and capacity expansion/production cost modeling framework
- These resources have their own associated risk profile, and will impact the system-level risk

Source: Microsoft stock images

ENERGY EFFICIENCY

Operation:

- Residential and commercial customers reduce energy usage by implementing efficiency measures
- Residential examples include more efficient household appliances, replacement of incandescent lighting with LEDs, better insulation and weatherization measures
- Commercial and industrial examples include high-performance buildings and efficient design, retrofits, installation of high-efficiency equipment

Source: PNM Energy Efficiency

Considerations:

- Available potential less than technical potential
- Estimates of potential for modeling involve rigorous studies
- Incremental efficiency incentives become increasingly costly; savings from “low-hanging fruit” captured early on
- Energy efficiency modeled as load modifier
- Energy efficiency generally reduces energy needs with little impact on capacity needs

Sources: PNMenergyefficiency.com; energystar.gov; Microsoft stock images

DEMAND RESPONSE

Operation:

- Energy users participate in a program that provides compensation for reduced consumption when the grid is particularly stressed – such as peak summer demand periods
- During periods of high demand, users are asked to reduce energy consumption
- Demand reductions effectively act like increased generation, helping to reduce stress on the system

PNM Power Saver:

- For residential customers
- $25/year incentive to participate
- Air conditioners and heat pumps put into activation during hot summer days when electric demand is particularly high
- Home temperatures generally rise a few degrees

PNM Peak Saver:

- For commercial and industrial customers
- Annual incentive based on amount of electricity managed during participation in program
- Response called upon by system operators when needed during peak hours
- Performance measured and verified

Considerations:

- Reductions in demand – particularly during peak periods – have outsized impact on system costs as they can reduce the amount of capacity needed on the system
- As the system decarbonizes, shifting peak demands will help to enable a smoother transition
- Demand response modeled as a system resource
- Has little impact on energy needs
- AMI expected to enhance efficacy of demand response
- Customers will have varying levels of willingness to participate – achievable level of DR uncertain
- Pairs best with variable electricity rates
- New programs and incentives will need to be designed/structured

Source: https://www.pnm.com/peaksaver; https://www.pnmpowersaver.com/business/

APPENDIX: SUPPLEMENTAL INFORMATION

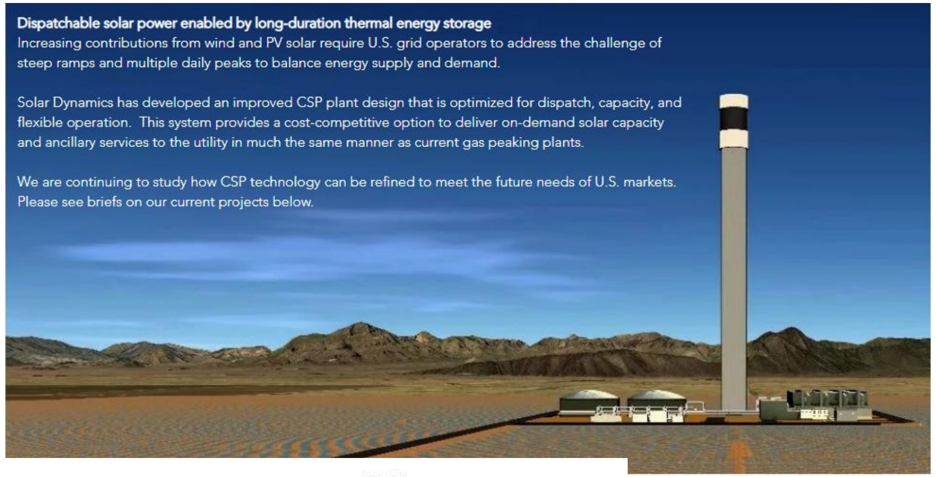
CONCENTRATED SOLAR WITH THERMAL ENERGY STORAGE

Operation:

- Concentrated solar molten-salt tower with thermal energy storage is a central receiver system
- Central receiver power plants use a field of large mirrors to track the sun; these mirrors reflect energy to heat the working fluid in the tower – working fluid examples are water/steam, molten salt
- A heat exchanger transfers heat from the working fluid to water, creating steam for use in a conventional steam turbine
- The working fluid can be stored to produce power when most needed – storage size depends on the desired operating parameters

Considerations:

- 12-16 hours of energy storage possible
- No cycling limits
- Commercially available and proven at grid-scale (though not widely deployed, <10 tower projects exist)
- ITC/PTC eligible
- Longer development and construction lead-time of ~5+ years, earliest deployment late 2020's
- Siemens estimates a 2025 capital cost of $6,579/kW for a 10-hr system (2022 $)*

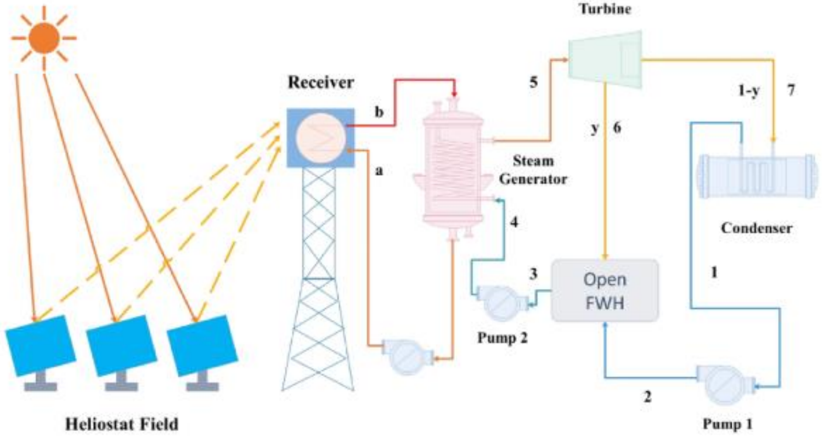


Dispatchable solar power enabled by long-duration thermal energy storage
Increasing contributions from wind and PV solar require U.S. grid operators to address the challenge of steep ramps and multiple daily peaks to balance energy supply and demand.

Solar Dynamics has developed an improved CSP plant design that is optimized for dispatch, capacity, and flexible operation. This system provides a cost-competitive option to deliver on-demand solar capacity and ancillary services to the utility in much the same manner as current gas peaking plants.

We are continuing to study how CSP technology can be refined to meet the future needs of U.S. markets. Please see briefs on our current projects below.

Source: Solar Dynamics, LLC



Source: https://onlinelibrary.wiley.com/doi/full/10.1002/ese3.802

* Siemens cost estimates reported in 2021 $, assumes 8.0% inflation in 2022

Sources: Energy.gov "*Concentrating Solar-Thermal Power Basics*"; Energy.gov "Power-Tower System *Concentrating Solar-Thermal Power Basics*"

SMALL MODULAR NUCLEAR REACTOR

Operation:

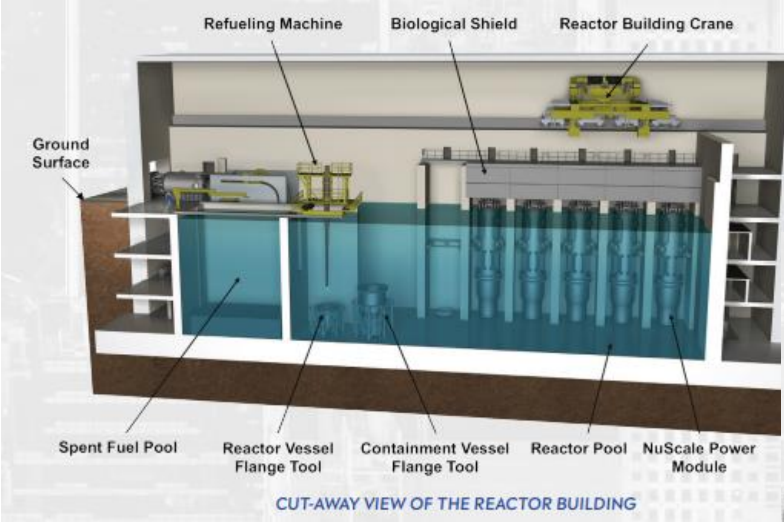
- SMRs are small (<300 MW) nuclear fission reactors that can be built in one location and shipped to operate at a separate site
- Nuclear fission is the process by which a neutron splits a uranium atom, generating additional neutrons that in turn split other uranium atoms
- Fission produces heat, which is used to make steam for use in a steam turbine generator
- SMRs employ passive safety features, which is expected to improve safety performance and require less staffing relative to conventional nuclear

Considerations:

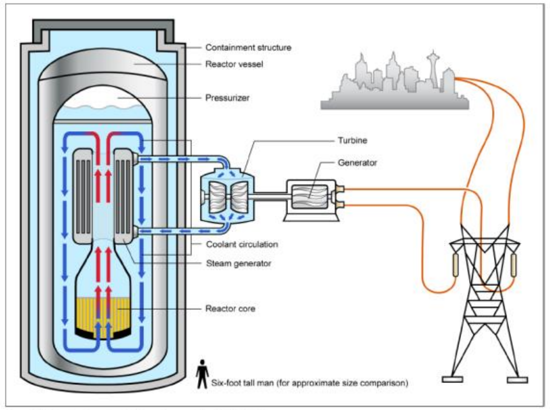
- Carbon-free dispatchable power
- Relatively small physical footprint, modular
- Reduced fuel requirements relative to conventional nuclear
- Small reactors may produce more waste than traditional light water reactors, particularly those cooled by water, sodium, or molten salt (Stanford study published May 31, 2022)
- Could be paired with renewables to firm variations in renewable output; or provide carbon-free charging energy to batteries
- Nuclear PTC
- Most designs remain in various stages of development; not yet deployed at utility scale
- 2025 capital cost of $9,944/kW (Siemens estimate for single module Small Modular Reactor, 2022 $)*

* Siemens cost estimates reported in 2021 $, assumes 8.0% inflation in 2022

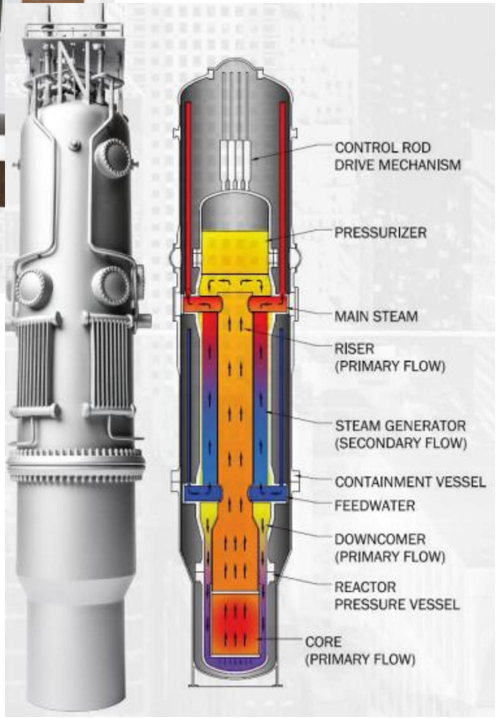
Sources: EIA *"Nuclear Explained"; NuScale*



CUT-AWAY VIEW OF THE REACTOR BUILDING



Source: GAO, based on Department of Energy documentation. | GAO-15-652



Source: NuScale Power, LLC

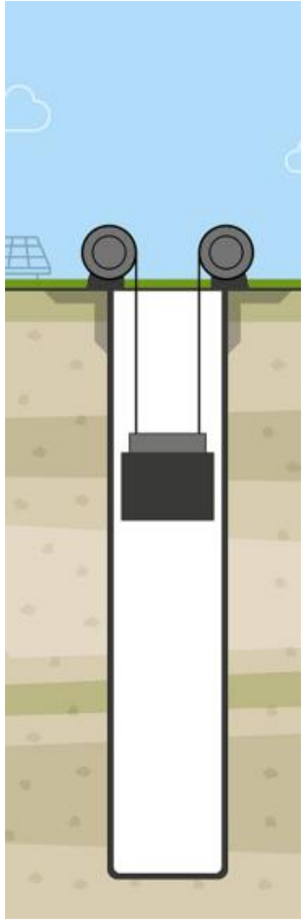
GRAVITY ENERGY STORAGE

Operation:

- Utilizes gravity to generate electricity; potential energy is stored in the elevation gain of the raised mass
    - Pumped hydro storage is a form of gravitational energy storage
- There are several forms of gravitational storage, but all employ the use of electricity to lift a large object when charging
    - Electrical energy can be used to power a crane to lift and stack large bricks or composite blocks
    - Another form utilizes an electric winch to lift a weight up through an underground shaft
- When discharging, the mass is lowered using a controlled gravitational force, releasing kinetic energy which is converted to electricity through a generator

Considerations:

- 2-18 hours of duration
- Efficiency >80%
- ITC eligible
- Lots of moving parts – charging and generating equipment require maintenance
- Can require naturally occurring elevation differential or have specific siting needs
- The crane and block approach has been deployed at grid-scale in Europe, Australia, and China
- Siemens estimates a 2025 capital cost of $5,535/kW for a 100-200 MW, 12 to 16-hr system (Energy Vault (tower construction) or similar, 2022 $)*



Sources: https://gravitricity.com/technology/, Energy Vault

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* Siemens cost estimates reported in 2021 $, assumes 8.0% inflation in 2022

Sources: Gravitricity, Energy Vault