Thermochemical Energy Storage Integrated with an sCO_2 Power Cycle

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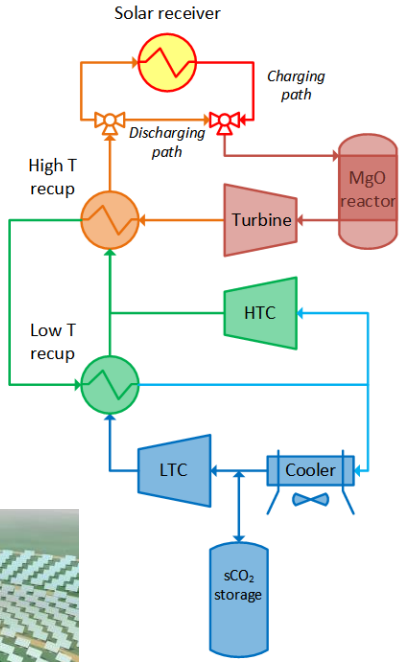
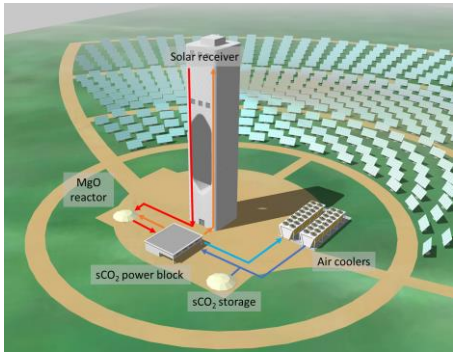
Echogen Power Systems background

- Founded in 2007
- Mission: To develop and commercialize a better exhaust and waste heat recovery power system using CO_2 as the working fluid
- First company to deliver a commercial sCO_2 power cycle
- Developing a CO_2-based PTES/ETES system

Program summary

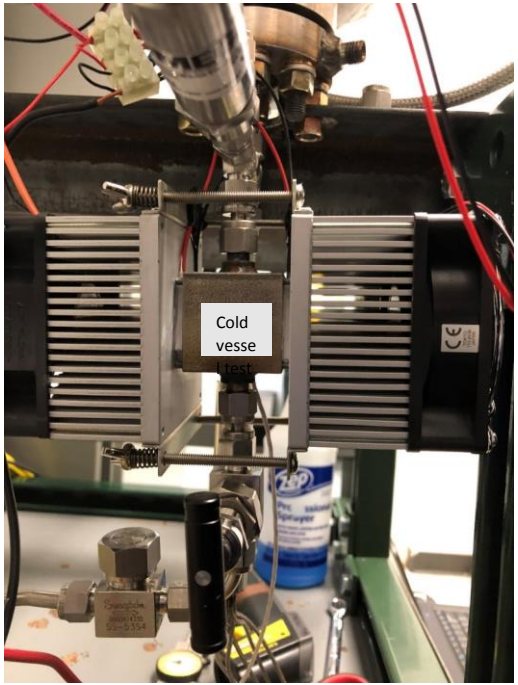
- Thermochemical energy storage using $MgO+CO_2=MgCO_3$ reversible reaction with sCO_2 power cycle
- CO_2 generated/consumed stored by sCO_2 inventory control system (ICS)
- Reactor and ICS storage in underground pressure vessel
- Overall technology requirements:
  - >50% cycle thermodynamic efficiency
  - >95% exergetic storage efficiency
  - Storage system cost < $15/kWth





Southern Research sorbent development program

Samples are individually wrapped in steel mesh and bound with copper wire, after test the mesh is substantially oxidized



Cold side including pressure transducer, two thermocouple probes, RTD, fill valve and cold vessel with thermoelectric modules and heat sinks.

1. The carbonation was performed at 610 ℃ with a pressure of 225 atm and de-carbonation was performed at 660 ℃ with a lower pressure of 75 atm.
2. The cycling process initiation was done at the de-carbonation steps.

SR SOUTHERN RESEARCH

Sorbent screening study summary

sample name	weight gain (≥0.25 g/g)	Energy density (≥500 MJ/m^3)	cost ($/kWh_th) sorbent	containment	total (<9)
E13 pellet 0% promoter	0.125	398	5.89	3.21	9.11
E13 pellet 10% promoter	0.165	581	4.98	2.20	7.18
E13 pellet 20% promoter	0.228	872	3.95	1.47	5.42
E13 pellet 22% promoter	0.188	733	4.85	1.74	6.60
E13 pellet 40% promoter	0.211	941	4.84	1.36	6.19
E19(older) pellet 40% promoter	0.330	1474	1.23	0.87	2.10
SR1.1 powder 0% promoter	0.717	1139	1.02	1.12	2.15
SR1.1 pellet 0% promoter	0.351	761	2.09	1.68	3.77
SR1.1 powder 10% promoter	0.833	1537	0.99	0.83	1.82
SR1.1 pellet 10% promoter	0.574	1424	1.44	0.90	2.33
SR1.1 powder 20% promoter	0.825	1282	1.09	1.00	2.09
SR1.1 pellet 20% promoter	0.615	1204	1.46	1.06	2.52
SR1.1 powder 40% promoter	0.826	865	1.23	1.48	2.71
SR1.1 pellet 40% promoter	0.723	1299	1.41	0.98	2.39
E3 pellet 20% promoter	0.149	500	6.03	2.55	8.59
E4 pellet 20% promoter	0.300	778	3.00	1.64	4.64
E5 pellet 20% promoter	0.069	163	13.04	7.86	20.90
E6 pellet 20% promoter	0.149	293	6.05	4.36	10.41
E19(new) pellet 20% promoter	0.245	420	3.68	3.04	6.72
E26 pellet 20% promoter	0.255	437	3.54	2.92	6.46
SR1.1Pcal_coated_40wt%	0.772	2081	1.32	0.61	1.93
SR1.2 pellet 40% promoter	0.735	1968	1.39	0.65	2.04
Mg-citrateP _coated_ carbon _sintered_40wt%	0.731	1735	1.39	0.74	2.13
Mg-citrateP _coated_ carbon _40wt%	0.789	1699	1.29	0.75	2.04
Mg-citrateP_carbon_sintered _40wt%	0.668	1586	1.52	0.81	2.33
Mg-citrateP_carbon_ _40wt%	0.739	1739	1.38	0.73	2.11

Selected for scale up → SR1.2 pellet 40% promoter

Highlighted text means expectations met

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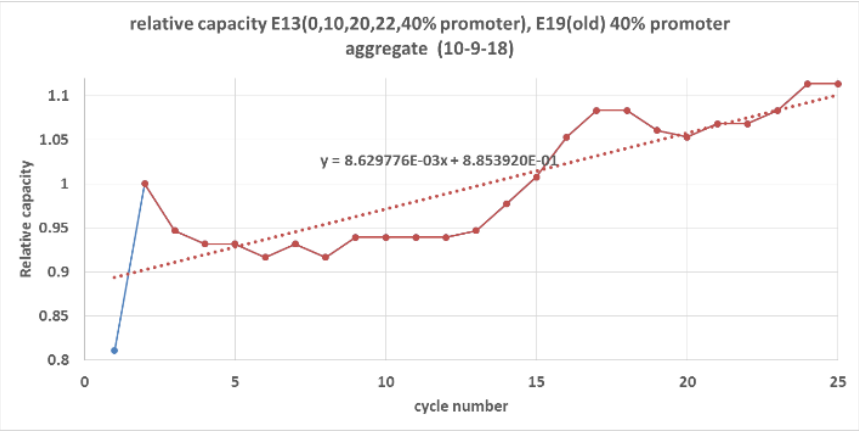
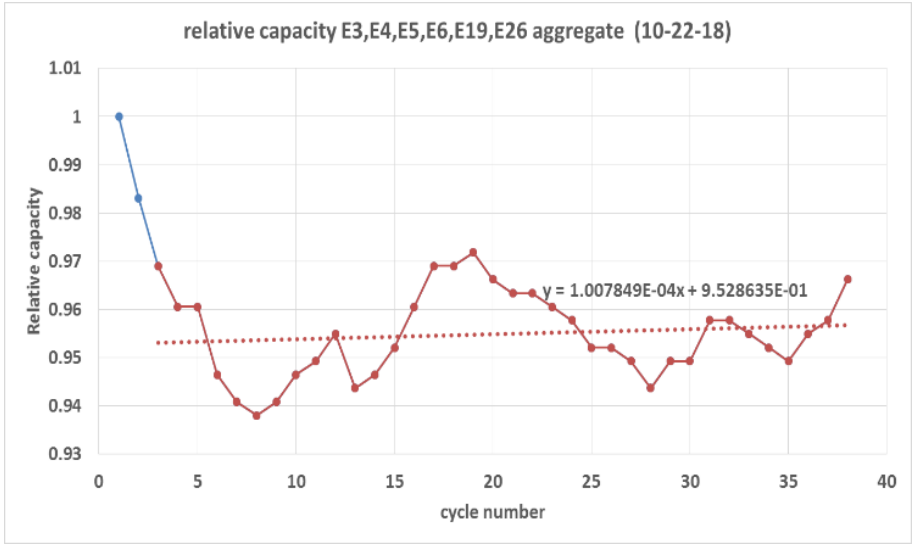
Durability and capacity of sorbent



Durability of aggregate samples E13, E19 (old), meet the milestone metric. 25 cycles plotted, 24 fit to the degradation curve the average capacity change was a positive 21.6 %/25 cycles, which meets the degradation target of <2% degradation/25-cycles



Durability of aggregate samples E3, E4, E5, E6, E19, E26 meet the milestone metric. 38 cycles total, 36 fit to the degradation curve the average capacity change was a positive 0.25 %/25 cycles, which meets the degradation target of <2% degradation/25-cycles

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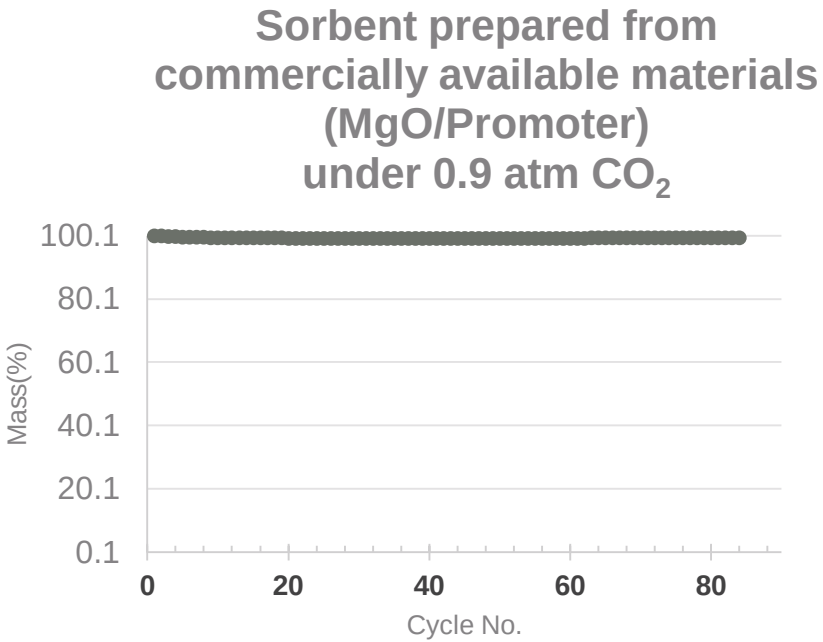
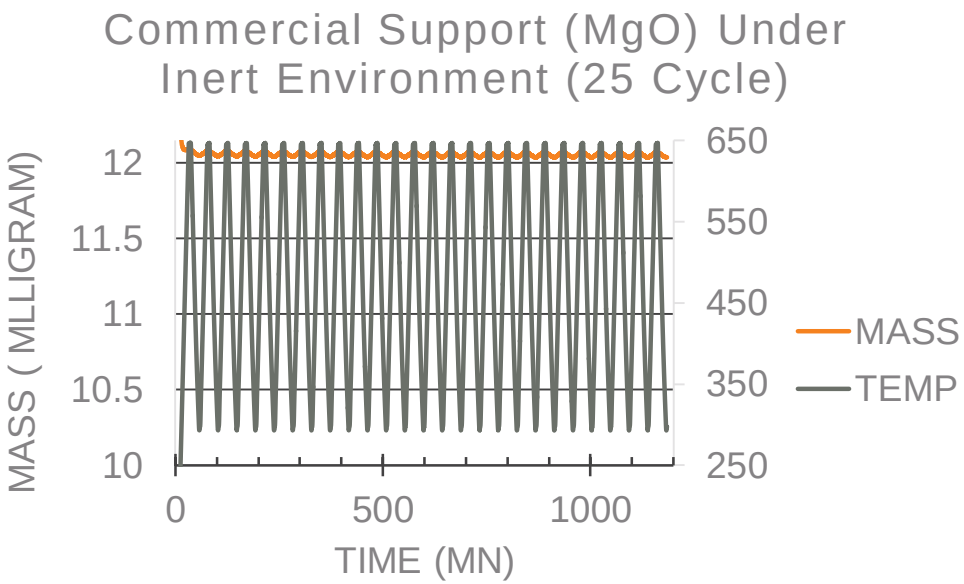
Stability of selected sorbent





Scaled up sorbent was tested using laboratory setup under identical carbonation-decarbonation for 10 cycles. Sorbent was collected after full carbonation cycle and measured for weight gain. 0.418g CO_2/g sorbent capacity was observed, indicating validation of results for BP1. This work is ongoing for higher number of cycles.

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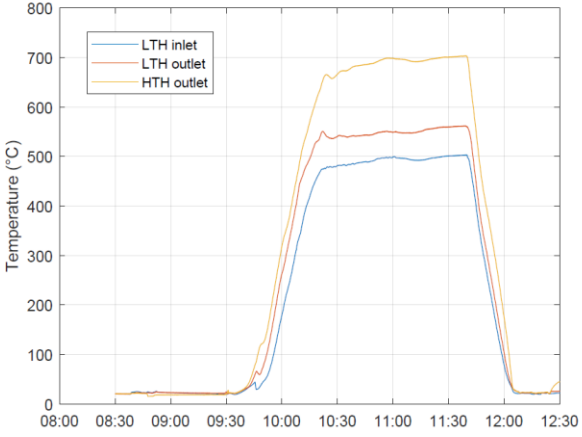
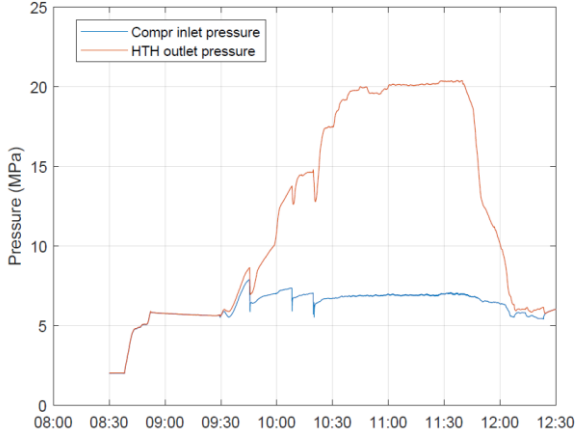
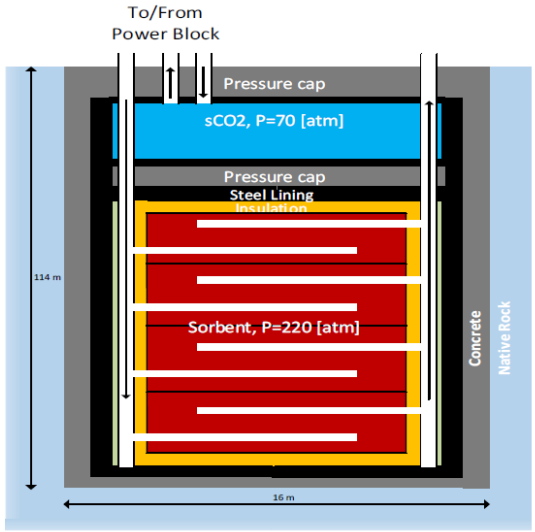
Lab sCO_2 flow loop

- 20 MPa, 700°C, 0.25 kg/s design
- Custom in-house sCO_2 heater
- Met/exceeded all requirements
- Upgrading to 800°C low-pressure side (8 MPa) for ARPA-E HITEMMP program

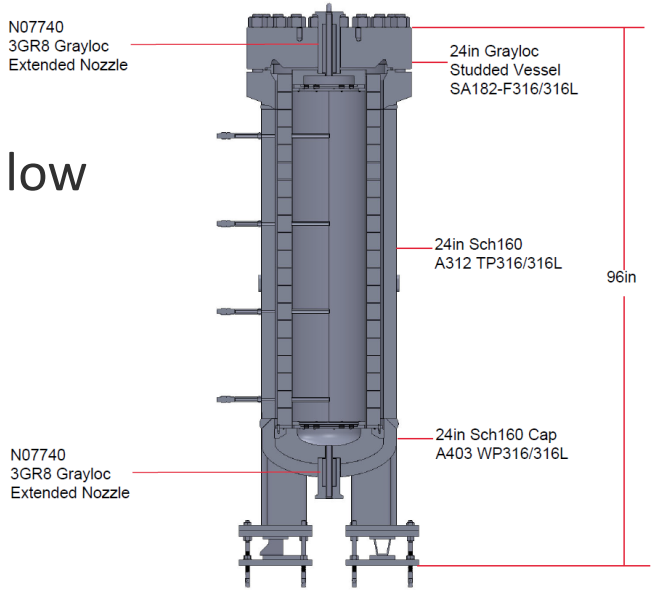




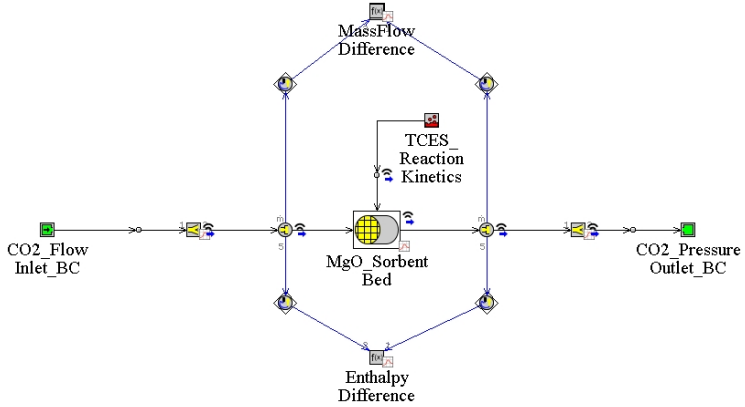
Reactor design concept and lab-scale design



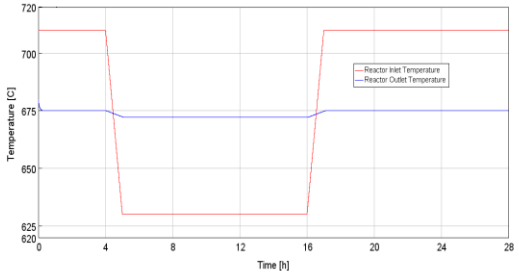
- Full-scale design concept is a hybrid drilled-rock vessel with internal insulation
- Also considering array of smaller-scale surface-mounted vessels
- Lab-scale design internally-insulated, low wall temperature

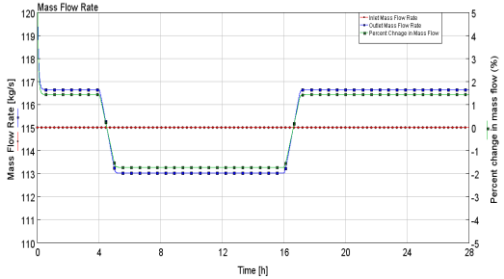


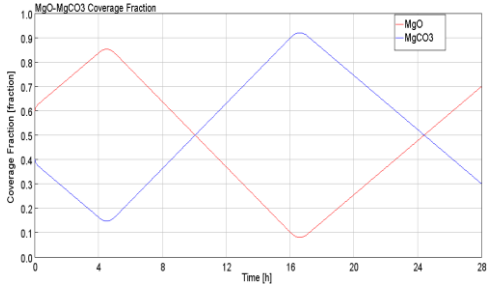
Transient reactor modeling



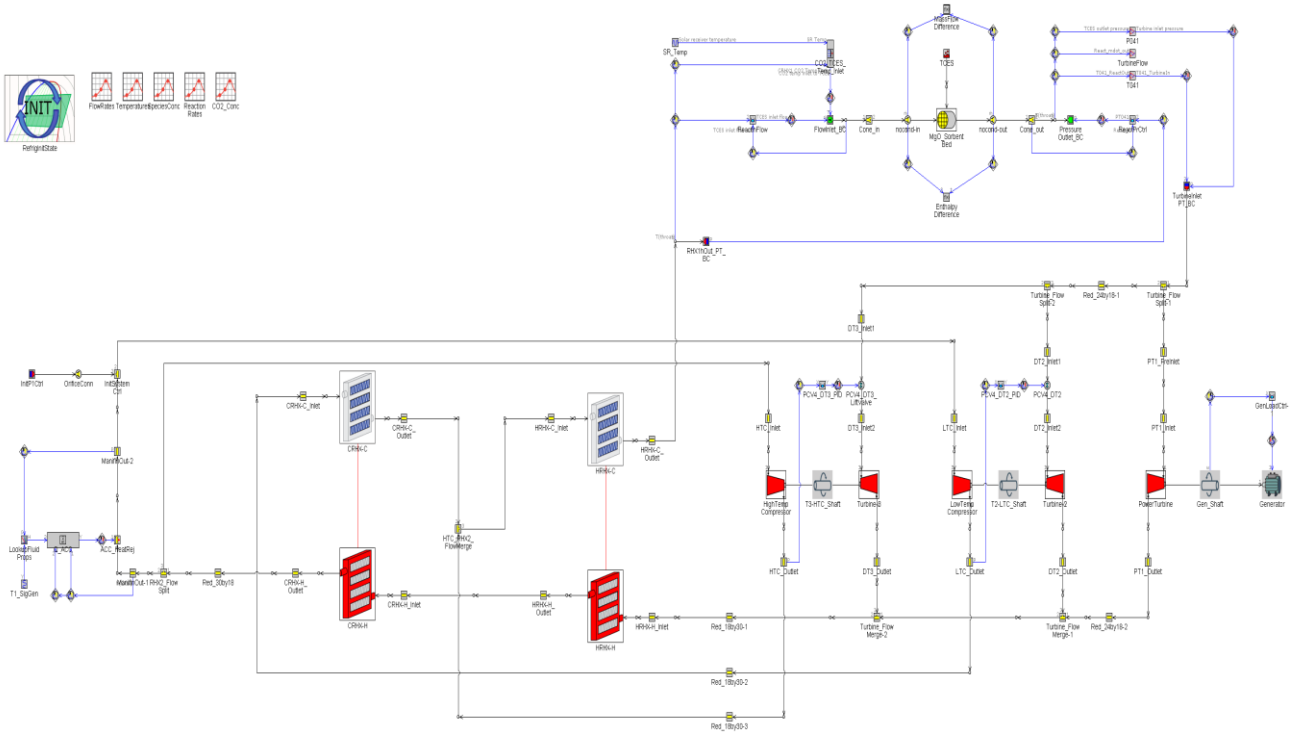
Sorbent particle diameter	3 mm
Sorbent bed void fraction	0.5
Reactor frontal diameter	5 m
Reactor length	20 m
Active sorbent density	6171.3 mol/m^3



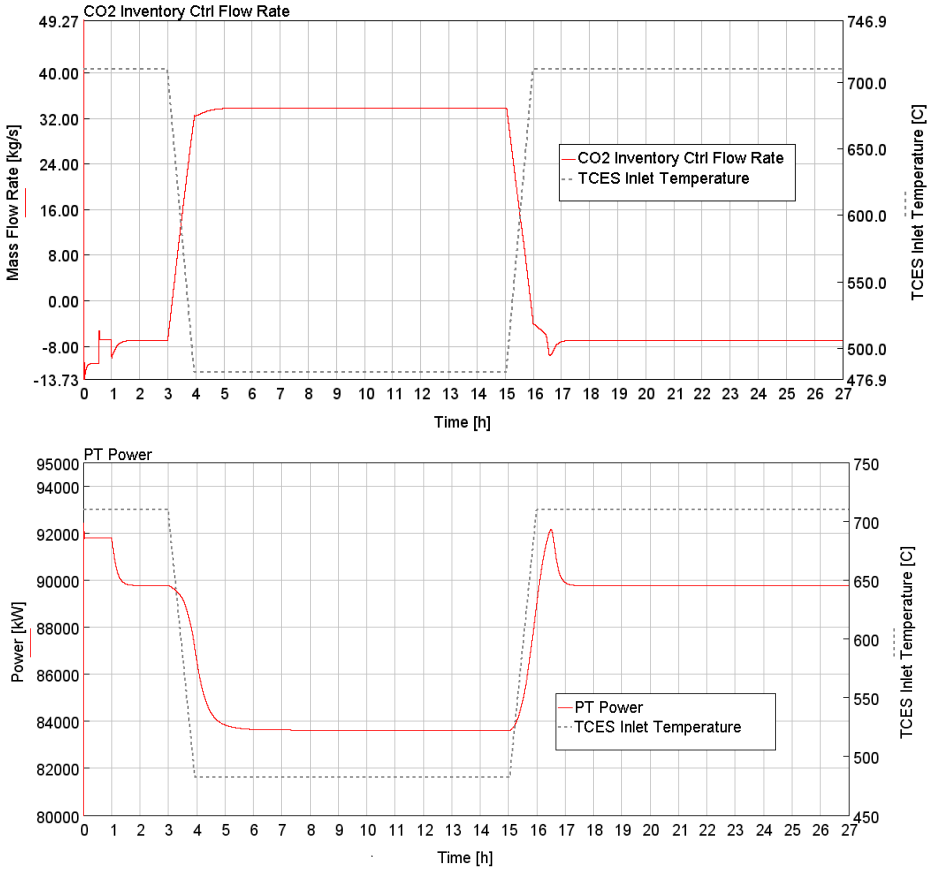




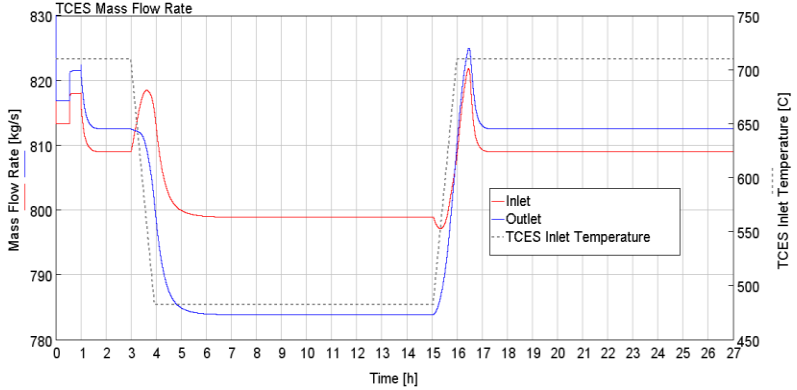
TCES-sCO$_2$ Combined Model

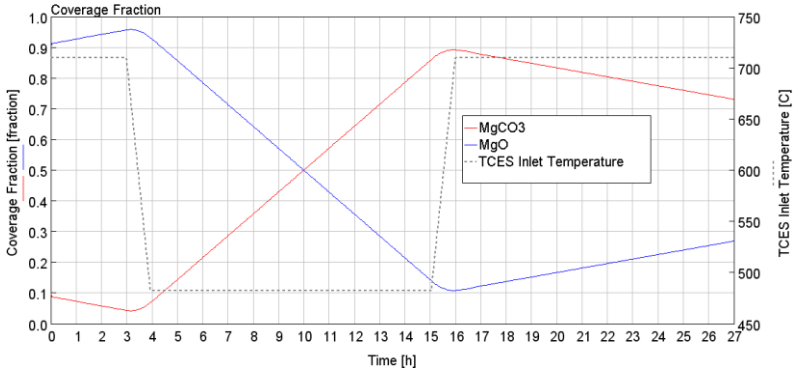


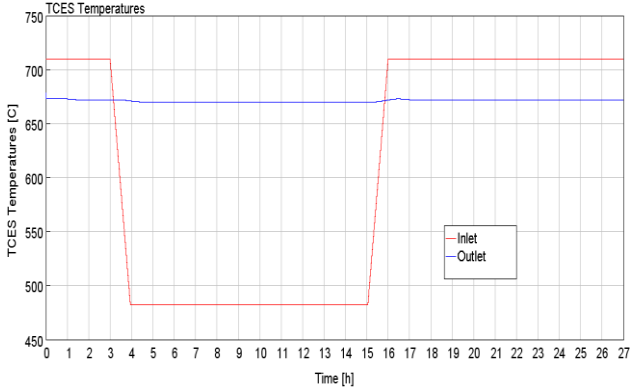
TCES-sCO$_2$ Combined Model Results



TCES-sCO_2 Combined Model Results







Program status

- Sorbent formulation / recipe for cyclic test selected, and toll manufacturer quoting sample and production runs
- Reactor design complete, in fabrication
- Test cell modifications complete and tested
- Cyclic testing scheduled for 3/2021 - 5/2021
- Full-scale reactor conceptual design 1/2021 – 7/2021