sCO_2 Power – Status and Outlook for Technology Maturation

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Working with Industry and Governments to Build and Demonstrate Low-Cost, Low-Carbon, Efficient Energy Systems

FOR A BETTER ECONOMY AND A BETTER ENVIRONMENT

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PROGRAM MANAGEMENT

TECHNICAL/ ANALYTICAL

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TRAINING

COMMERCIALIZATION

400+ EMPLOYEES

World-class piloting facilities headquartered in Chicago area

sCO_2 Power Cycles

Promise:

- **Efficient, Cost effective, Compact, Scalable, low water, low-carbon power generation**

Challenges:

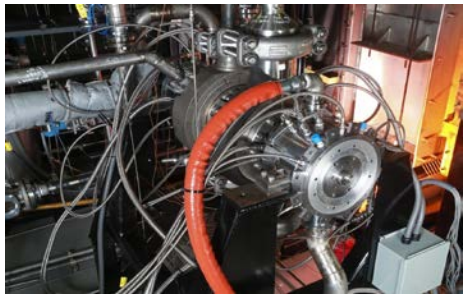
- **Operability, Transients, Turbomachinery aerodynamic performance, seals, recuperator size & durability, materials, cost**

STATE OF DEVELOPMENT

EPS100 Echogen ~3.1 MWe, ~270ºC

STEP (late '22) **10 MWe, 500 & 715ºC**

NetPower LaPorte TX, 25 MWe, ~1150ºC



Sunshot SwRI/GE 1 MWe ~715ºC

Versatile Technology – Broad Applicability:

Concentrated Solar

Fossil Fuel

Geothermal

Nuclear

Energy Storge

Waste Heat Recovery

Challenges to mature sCO_2 Power Cycles

Key focus points to mature sCO_2 power technology:

- Performance & Operability
- Cost
- Component readiness

STEP project contribution


Concentrated Solar


Fossil Fuel


Geothermal


Nuclear


Energy Storge

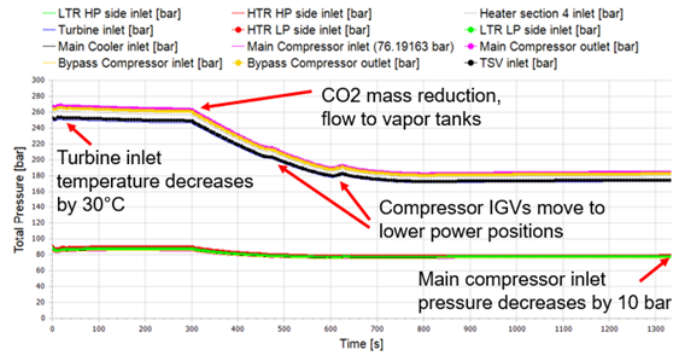

Waste Heat Recovery

Performance and Operability

- **Test verification**
- **Models – static and dynamic**
- **Simulators for operators**
- **Scale-up:**
  - Turbine efficiency improvement
  - Specific costs ($/KW) improvement

STEP 10 MWe Pilot Demonstration Facility

GTI sCO_2 FlowNex® dynamic model with GE Mark VI simulator



GTI AspenPlus® steady state modeling

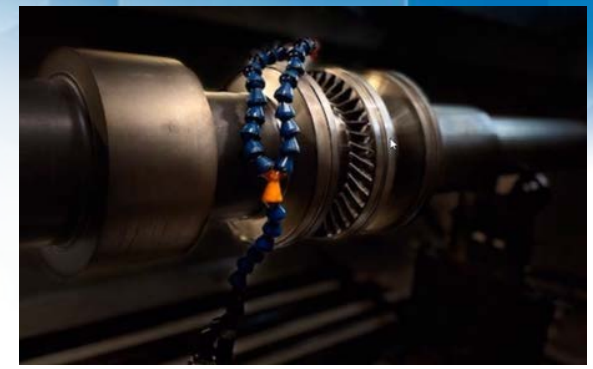
Model Names	Cycle Configuration	Description	Load %	Net Power Level (MWe)	Cooler Exit Temperature	Turbine Inlet Temperature	Cycle Efficiency
133	Simple	Simple cycle minimum load case	Min	2.5	35°C	500°C	22.6%
136	Simple	Simple cycle maximum load case	Max	6.4	35°C	500°C	28.3%
151	Recompression	Baseline case	100%	10.0	35°C	715°C	43.4%
152	Recompression	"Hot" Day Case	70%	6.6	50°C	675°C	37.4%
153	Recompression	"Cold" Day Case	100%	9.9	20°C	525°C	36.8%
154	Recompression	Partial load case using inventory control	40%	4.0	35°C	715°C	37.0%
155	Recompression	RCBC at 500°C turbine inlet temperature	70%	6.9	35°C	500°C	32.5%
157	Recompression	Partial load case using TSV throttling (transient condition)	40%	4.2	35°C	715°C	30.8%
157a	Recompression	Partial load case using TSV throttling	40%	3.9	35°C	675°C	29.6%

Cost

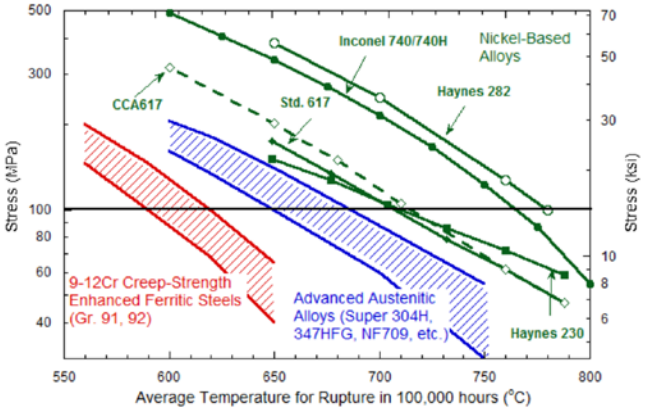
- **Mature supply chain**
  - Confidence with experience (performance, manufacturing processes, time & costs, and equipment reliability
- **Material Options**
  - 740H, H282, IN625, IN617,etc
  - Mfg and repair
- **Plant arrangement**
- **Improved components** (next slide)

IN740 Welding for STEP heater to ASME PVC

Haynes 282 casting for STEP TSV



5-axis EDM STEP turbine



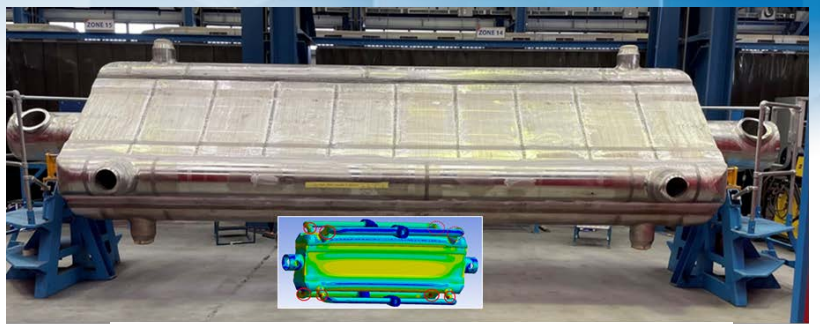
Adv Alloys - ASME allowable stress *

Compact arrangement example
Echogen EPS100

* Courtesy J. Shingledecker, EPRI

Component readiness

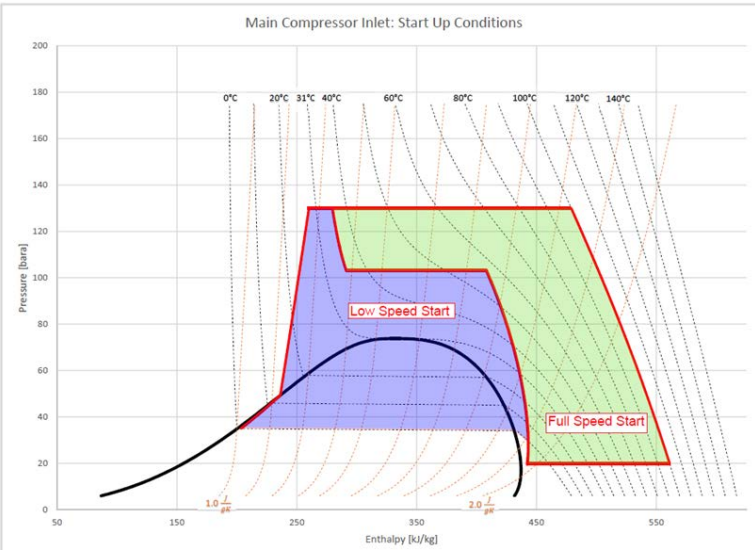
- **Power Turbine**
  - Seals, thermal mgmt, aerodynamics, OEM product development
- **Compressor**
  - Flexibility, 2-phase start-up, OEM confidence
- **Heat Exchangers**
  - Scale-up, fabrication experience, integrity
- **Valves**
  - Operational experience, seals, materials choices



STEP HTR – 316S – 49 MW_{th}, 600°C

STEP 715°C Haynes 282 TSV

STEP Compressor IGVs



Compressor start-up with liquid phase CO_2

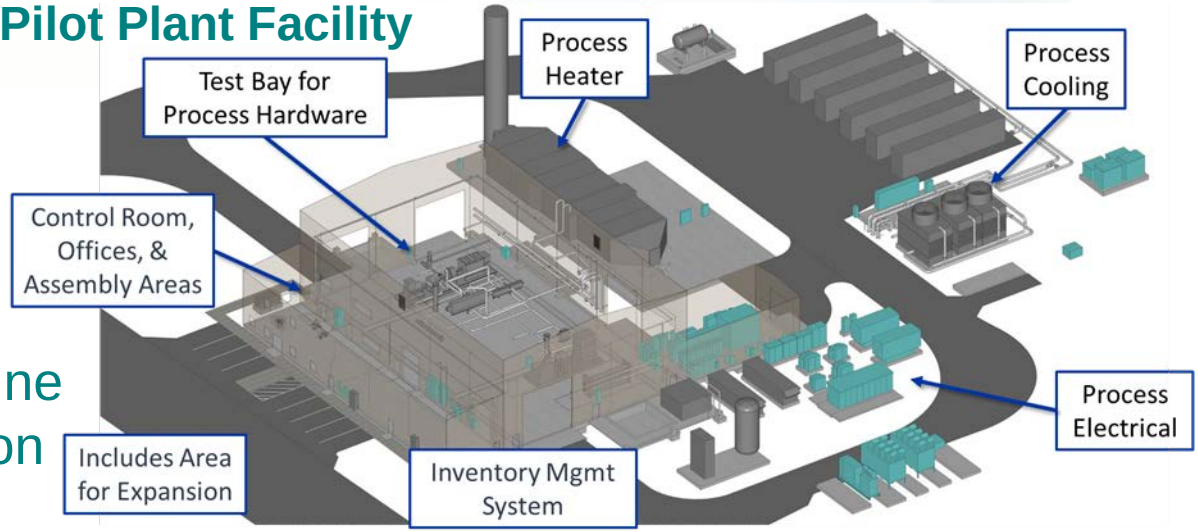
STEP Project

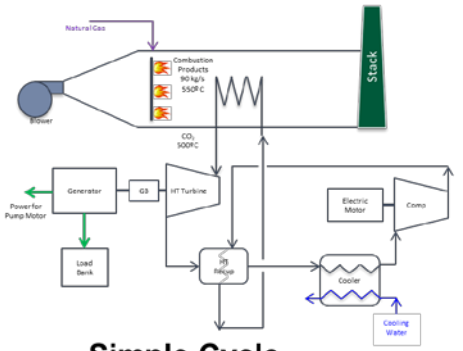
Scope:

Design, construct, commission, operate 10 MWe sCO_2 Pilot Plant Facility
- reconfigurable to accommodate other testing

Objectives:

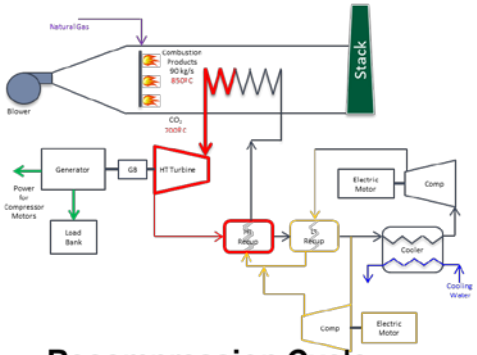
- **Demonstrate pathway** to efficiency **> 50%**
- **Demonstrate operability** at **500ºC** & **≥700°C** turbine inlet temperature with 10 MWe net power generation
- **Verify System Performance & Operability**:
  - Quantify component and system performance
  - Demonstrate operation across control parameters
  - Measure transient response through start-up, load change, and shutdown





Simple Cycle
- Shortest time to initial data
- Controls & safety
- Component performance
- Steady & transient cycle data

T_{iT} 500ºC, 250 bar



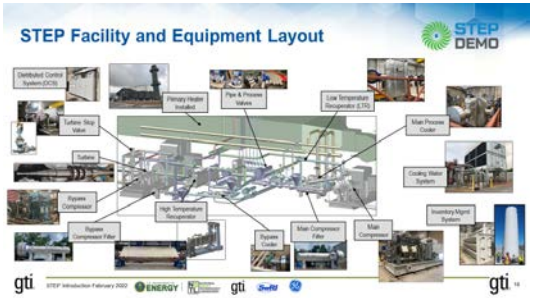
Recompression Cycle
- Inventory management
- Starting transients
- Parallel compressor control
- SOA component efficiencies
- Cycle efficiency > 50%

T_{iT} 715ºC, 250 bar

sCO_2 Technology Maturation – Summary

STEP pilot contribution & future needed [High Temperature Indirect sCO_2 power]

Technology	STEP pilot	Future	
Perf. Verification	☺	with commercial products	key objective for STEP
Plant Operability	☺	with commercial applications	key objective for STEP
Static & Dyn. Modeling	☺	refine with data	Developed and validated on STEP
Supply Chain	😐	gain experience & confidence	Immature now and should come with market
Materials (design & use) 740H welding 282 casting 625 welding	😐 ☺ 😐 ☺	gain experience	STEP applying ASME available and guidance
Plant Arrangement	☹	with commercial application	STEP arrangement flexible not compact
Turbine	😐	commercial products	STEP turbine is technology development not product development
Compressor	☺	gain experience & confidence	STEP compressor specification evolved with learnings
Heat Exchangers	☺	gain experience & confidence	STEP heat exchangers push scale
Valves	☺	gain experience & confidence	STEP valves adapted from steam plants



Gratefully Acknowledging the Support from U.S. DOE-NETL and Project Partners

Turning Raw Technology into Practical Solutions

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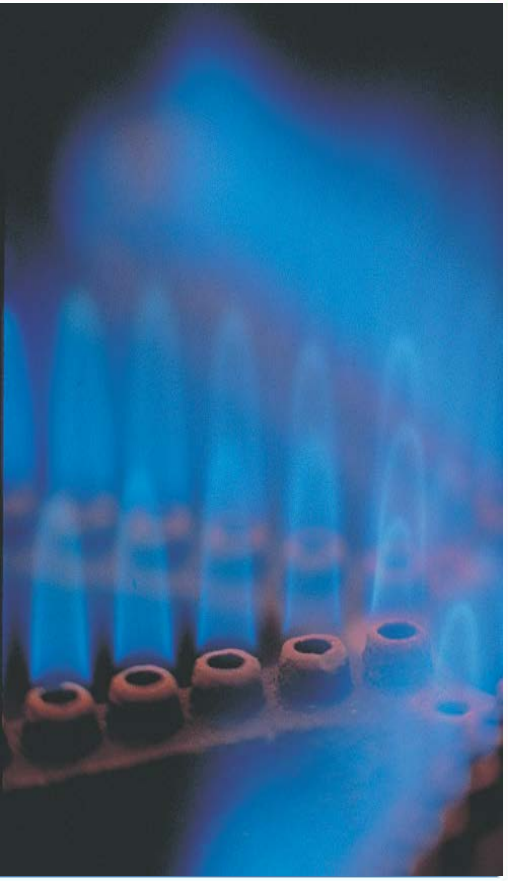
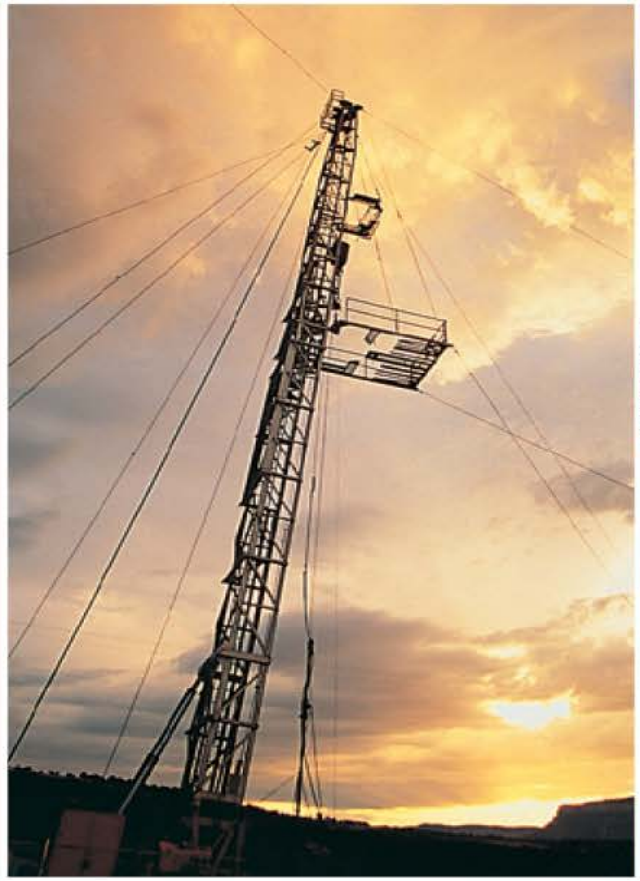
www.STEPdemo.us





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