



GAS TECHNOLOGY INSTITUTE 美国燃气技术研究院

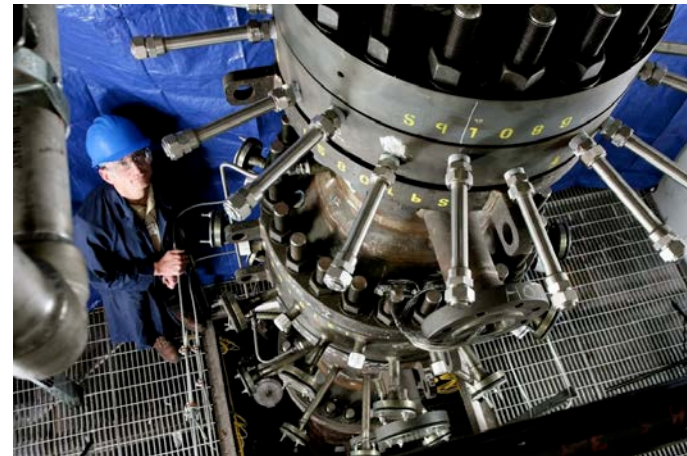
Advanced Clean Energy Technology Development for China Market

面向中国市场的先进清洁能源技术开发

2017 China – U.S. Clean Coal Industry Forum, Morgantown, WV

Don Stevenson
Executive Director, R&D
Gas Technology Institute

1 December 2017



Topics 报告内容

- GTI Overview 美国燃气技术研究院 (GTI) 简介
- R-GAS™ Coal Gasification Project Collaboration with China
R-GAS™ 煤气化示范项目与中国企业的合作
- CarboLock™ Hollow Fiber Membrane Contactor (HFMC) CO₂ Capture Technology
中空纤维膜 (CarboLock™) 二氧化碳捕集技术
- Oxygen-Fired Pressurized Fluidized Bed Coal Combustion Technology (Oxy-PFBC)
燃氧加压流化床煤炭燃烧 (Oxy-PFBC) 技术
- Supercritical Transformational Electric Power (STEP) for Indirect Coal-Fired Power Cycles
实现间接燃煤动力循环的超临界转换发电 (STEP) 技术
- Summary 总结

GTI Overview 美国燃气技术研究院(GTI)简介

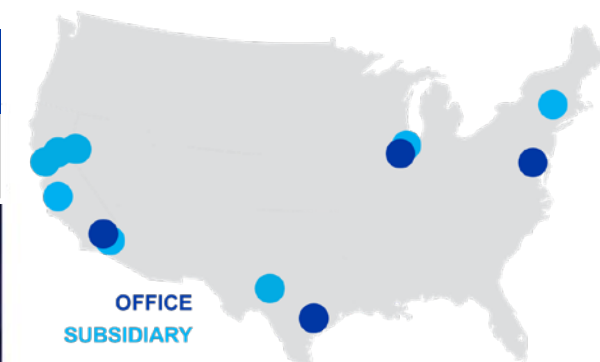
FOR A BETTER ENVIRONMENT AND A BETTER ECONOMY 改善环境、促进经济

SUPPLY 供应

CONVERSION 转化

DELIVERY 运输

UTILIZATION 利用



Independent not-for-profit covering entire gas value chain
独立的非营利机构业务覆盖整个燃气能源产业价值链



RESEARCH & DEVELOPMENT

研发



PROGRAM MANAGEMENT

项目管理



TECHNICAL/ ANALYTICAL

技术/分析



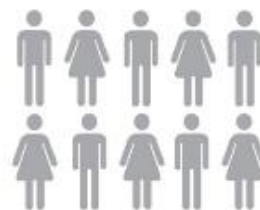
CONSULTING

咨询



TRAINING

培训



EMPLOYEES

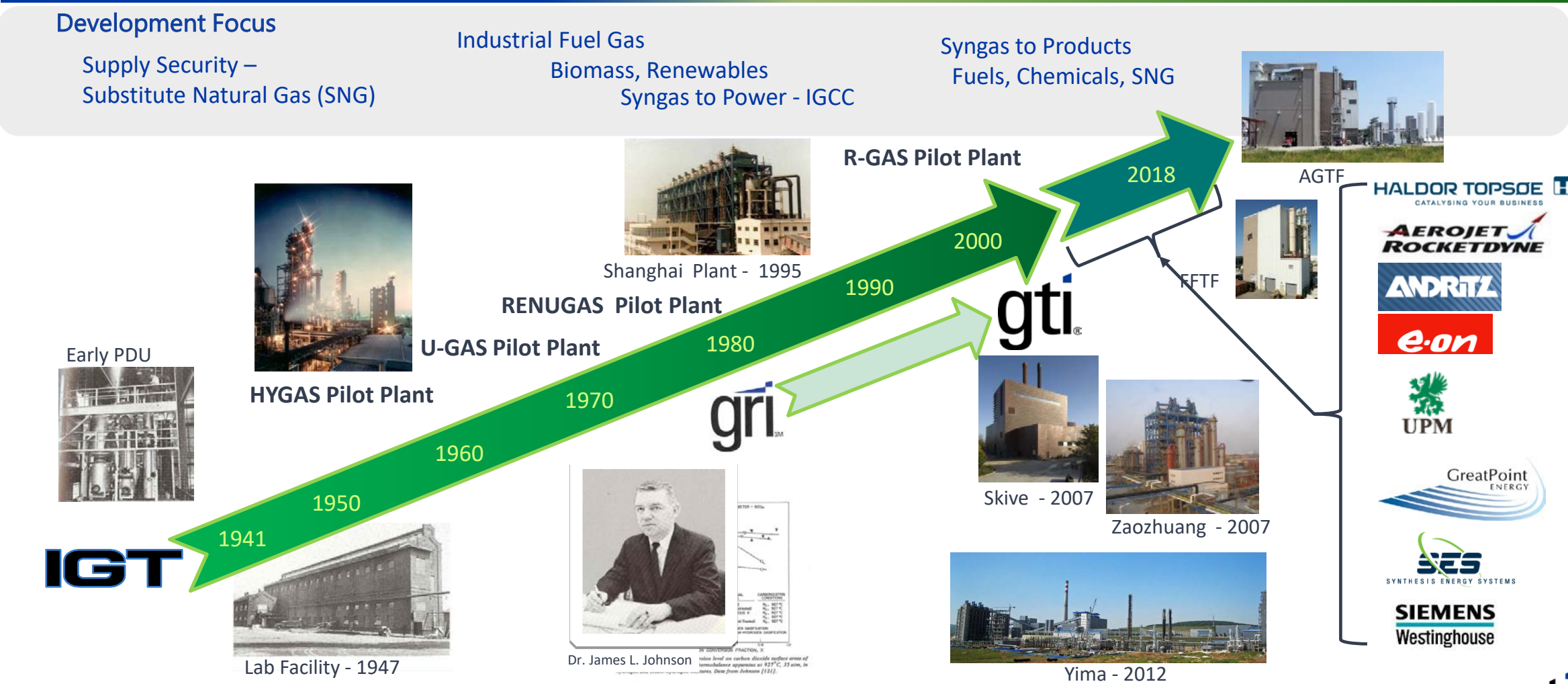
员工



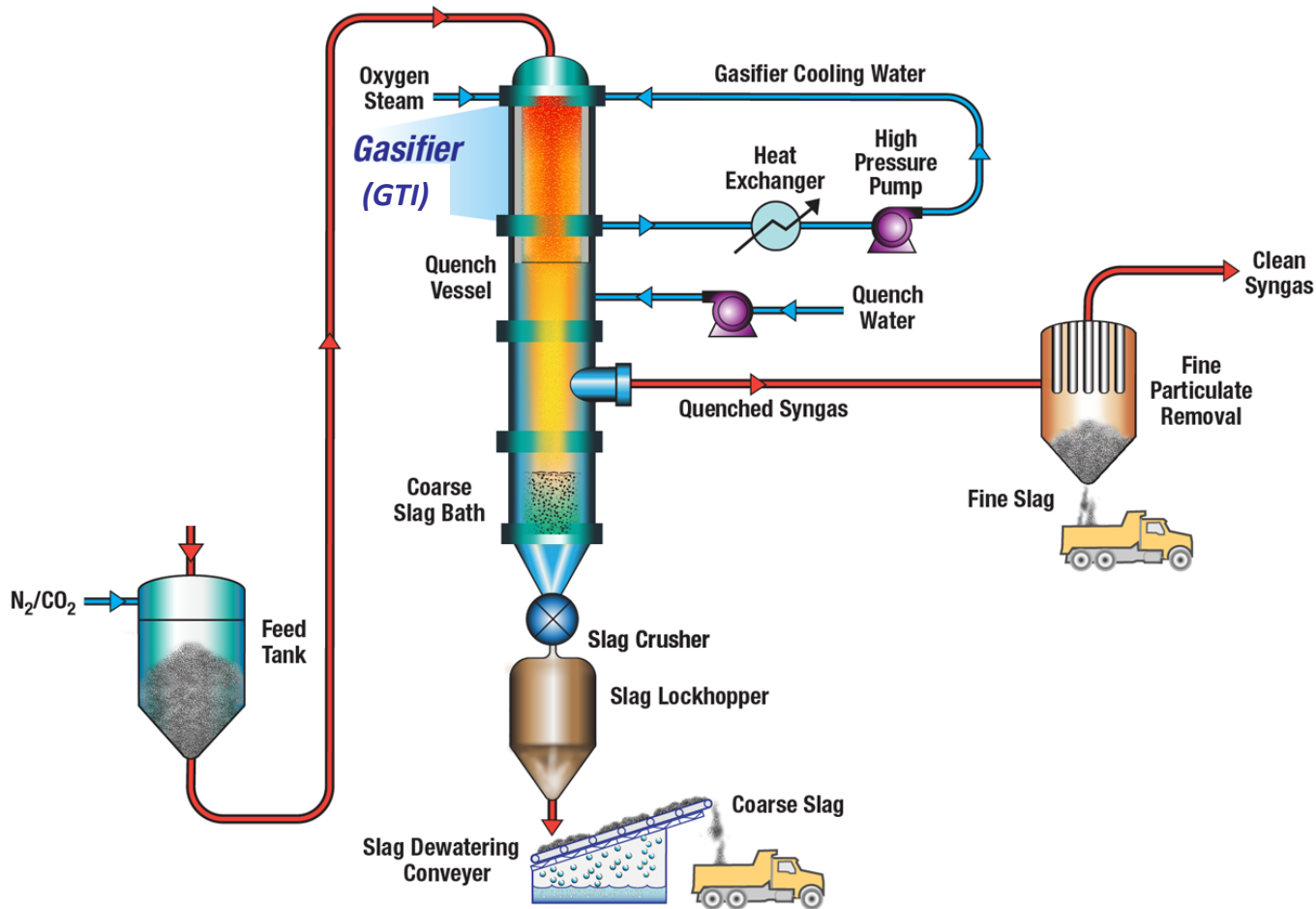
World-class facilities
headquartered in Chicago
全球领先的实验设施
总部位于芝加哥

GTI Gasification Development History

GTI 气化技术的发展历程



R-GAS™ Gasification System R-Gas™气化系统



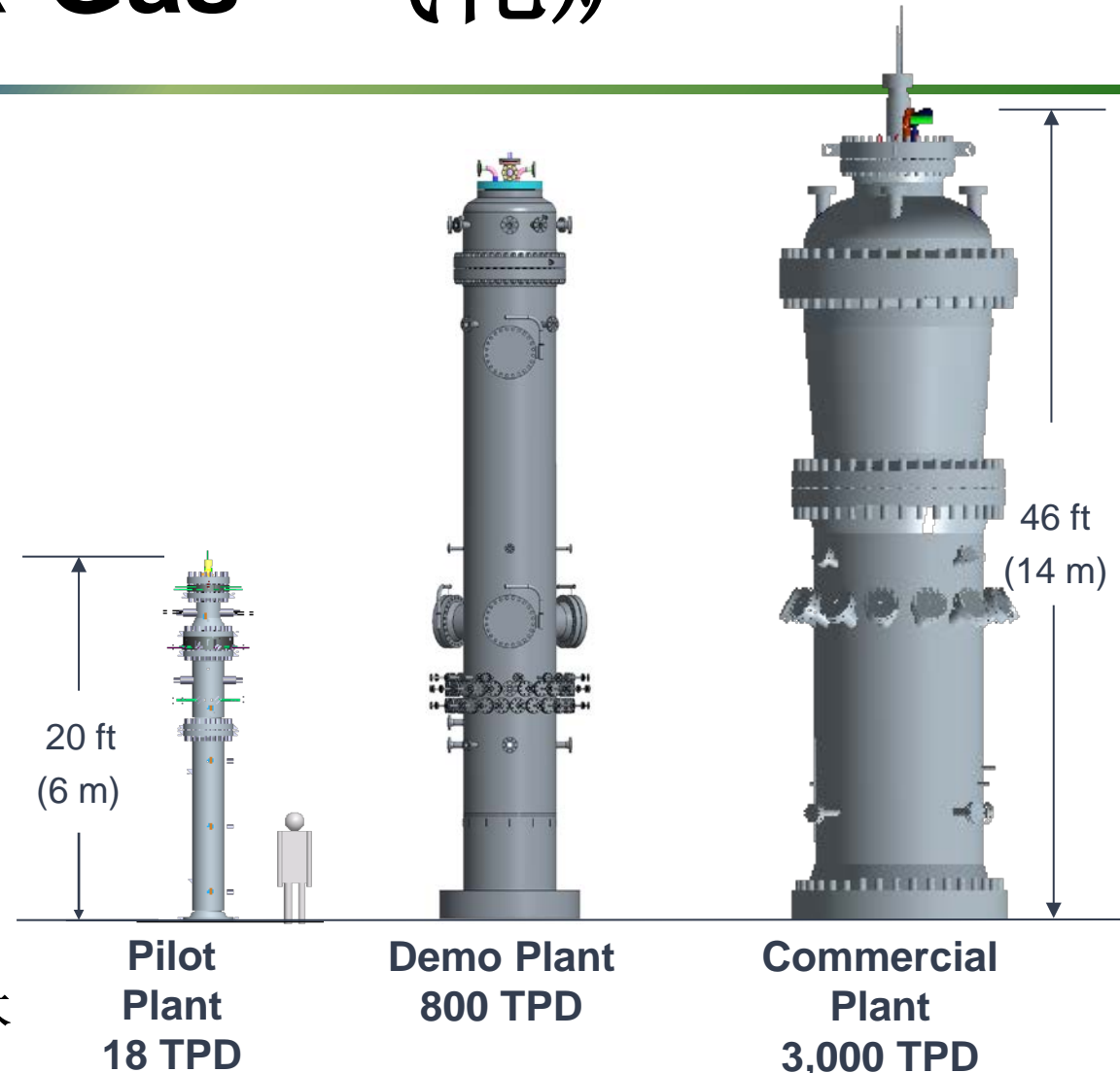
R-GAS™ Attributes 优势特性:

- Dry feed for high efficiency, feedstock flexibility 高效灵活的干粉进料
- Rapid mix injector + plug flow reactor for 90% smaller volume 高效混合烧嘴和塞流式反应器大幅减小设备尺寸
- Advanced cooling design for robust thermal margins, long component life 先进的冷却设计保障设备安全使用寿命
- Eliminates black water system for conventional coal processing 避免传统煤气化系统的黑水处理系统
- Long MTBF, short MTTR for high availability 故障少、修复快，可用性高

R-GAS™ Gasifier

R-Gas™ 气化炉

- 90% smaller reactor volume allows for factory integration and enables modularization 大幅减小炉体尺寸，便于装置集成和模块化配置
- High temperature operation enables gasification of high ash fusion temperature and high ash coals 高温运行解决了高灰熔点高灰煤气化难题
- Reduced water usage 用水量降低
- CGE: 2-4% > than other dry feed
7%-9% > than slurry 气化效率提高
- 15-25% lower CAPEX & OPEX 节省成本



800 TPD GTI-Yangquan Demonstration Plant

GTI-阳煤 800 吨/天 气化示范装置

Project Status 项目状态

- >\$75MM demonstration plant investment 项目投资
- FEED initiated July 2017 前端设计开始
- Design & construction 2018 工程设计及施工
- Commissioning 2019 试车运行



gti[®]

Gas Technology Institute
Des Plaines, IL, USA

Gasifier Technology Developer
气化技术开发方



Selected Demo Site (Qingxu)



Yangquan Coal Mining Group
阳煤集团
Taiyuan, Shanxi, China

Plant Owner & Project Developer
业主及项目开发方



**East China Engineering
Science and Technology Co.**
东华科技
Hefei, Anhui, China

Design Institute (EPC)
设计单位 (EPC承包方)

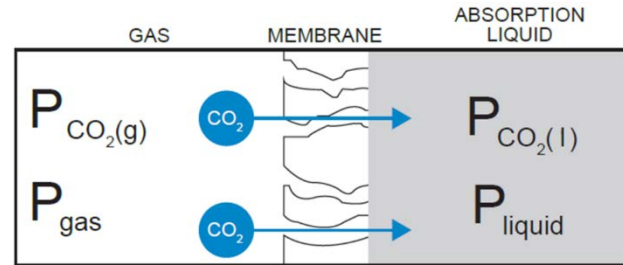
Carbolock™ for CO₂ Capture 二氧化碳捕集技术

Lower CAPEX and OPEX 投资成本更低

- High packing density results in >100x increase in mass transfer coefficient and smaller equipment
高填充密度得以百倍提高传质效率并减小设备尺寸
- >30% reduction in weight 设备重量减轻三成
- Modular – scales easily 模块化设备易于放大装置规模
- Uses commercial (aMDEA) and advanced solvents
技术工艺使用先进的工业溶剂

Applications 应用广泛

- Natural gas fired flue gas CO₂ capture 天然气烟气处理
- Natural gas sweetening and LNG feed prep 天然气脱硫及LNG来料处理
- Pre-combustion CO₂ capture 燃烧前CO₂捕集
- Separation of CO₂ from hydrogen in refineries 炼厂氢气脱除二氧化碳
- Biogas separations 生物气分离工艺
- Dehydration of natural gas 天然气脱水处理



- CO₂ permeates through membrane, reacts with solvent; CH₄ or N₂ do not react and have low solubilities in solvent
二氧化碳经膜渗透后与溶剂反应；甲烷和氮气不反应且溶解度低
- High contact surface area (~3,000 m²/m³) enable an increased volumetric mass-transfer rate
高接触面积提高体积传质速率



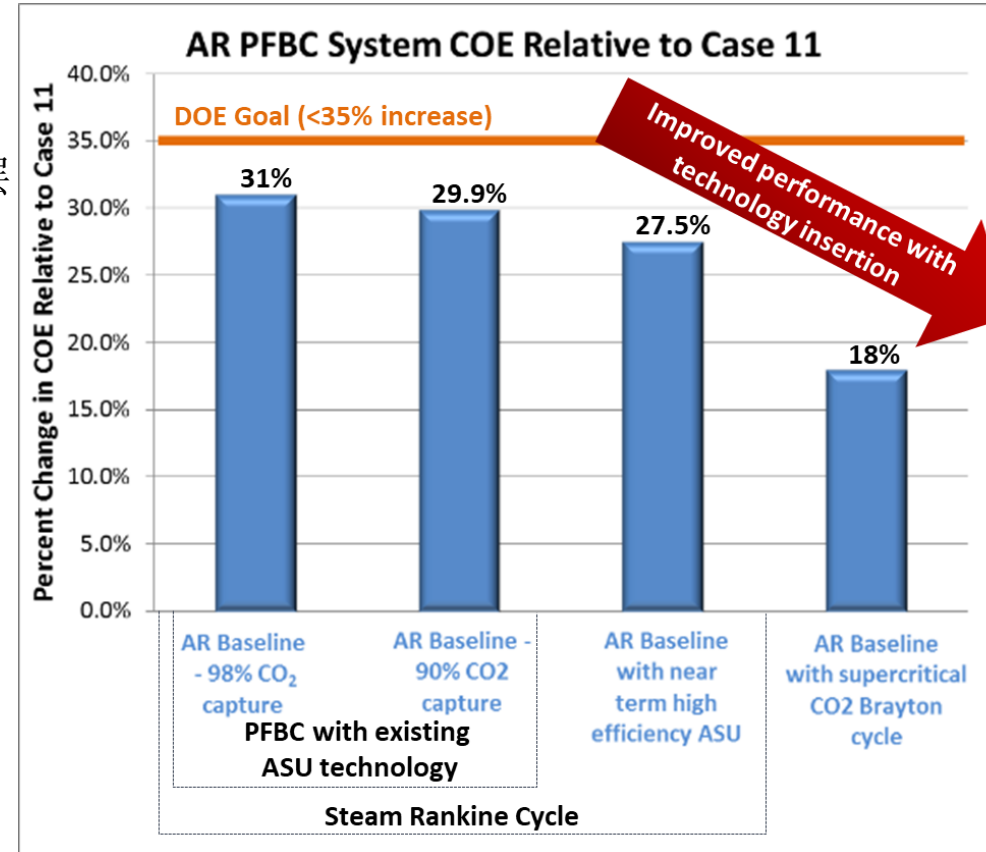
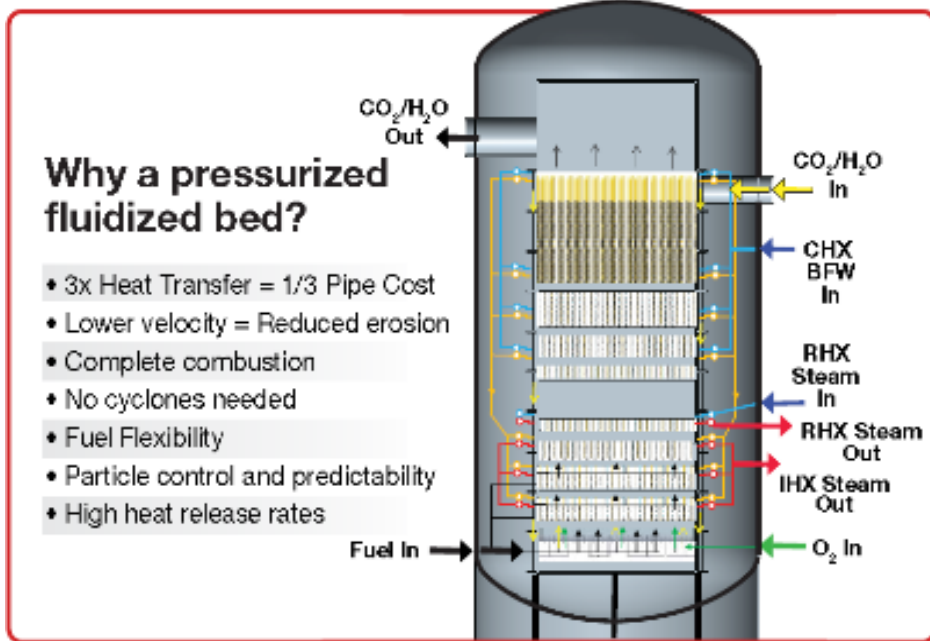
NCCC PSTU system
(0.5 MW_e, packed column)

GTI Carbolock™ system
(0.5 MW_e)

Oxy-PFBC Coal Combustion

燃氧加压流化床煤炭燃烧 (Oxy-PFBC) 技术

- High power density reactor for coal-fired electric power or steam with near-zero emissions 利用高功率密度的反应器实现接近零排放的燃煤发电或燃煤锅炉运行
- In-bed heat exchanger for ultra-compact combustor 采用床层内置换热器实现超小尺寸的燃烧装置
- 1/3 the size and half the cost of traditional boiler 较传统锅炉设备尺寸降低三分之二，成本减半



- No net increase in COE for CO₂ prices/credit > \$30/ton, or \$18/ton with SCO₂ 不增加电力成本

Supercritical CO₂ (sCO₂) Power Cycles

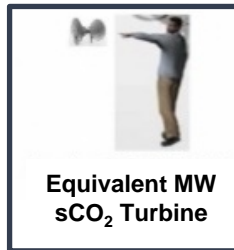
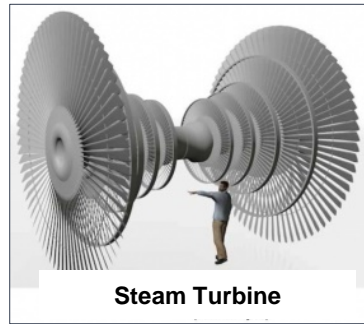
超临界二氧化碳(sCO₂)动力循环技术

Motivation - sCO₂ power cycles offer economic and environmental benefits
利用sCO₂技术提高经济效益和环保性能

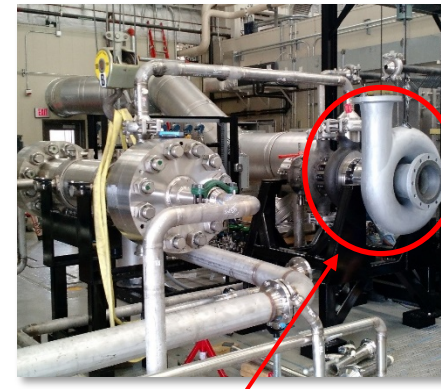
- Lower costs relative to steam cycles
成本低于蒸汽循环
 - 2-5% point efficiency improvement **效率更高**
 - 3-4% reduction in LCOE **度电成本更低**
- Reduced emissions, fuel, and water usage
排放、燃料消耗及用水量得以降低

STEP Program Summary 项目概述

- Goal - design, build, and operate a 10 MW_e sCO₂ pilot plant
项目目标：设计、建设并运行一个10 MW_e sCO₂ 示范装置
- Advance high-temp sCO₂ cycle from TRL 3 (concept) to TRL 7 (pilot) **将高温sCO₂循环由技术理念推进至示范运行阶段**
- Sponsored by U.S. DOE with \$80MM funding **能源部提供资金**
- Roles: GTI (prime), SwRI (host site), GE (key turbo-machinery supplier) **项目方：GTI(主导), SwRI(场地), GE(主要透平机械)**
- Project duration **2017-2022** **项目工期**



Application 应用案例	Turbine Temp 透平温度	Efficiency 效率	Scale 规模
Fossil Fuel -Fired Power	>700°C	>50%	100-1,000 MW _e
Concentrated Solar Power	>700°C	~50%	10-100 MW _e
Biomass -Fired Power	400-600°C	25-35%	5-30 MW _e
Waste Heat Recovery	300-550°C	20-30%	4-20 MW _e



14 MW sCO₂ Turbine
 715°C/250 bar inlet
 (existing GE-SwRI SunShot design)



sCO₂ Compressors
 existing GE O&G product

Compact Recuperator Concepts

- Printed circuit heat exchangers
- Micro-tube designs
- Compact plate/frame designs

Summary 总结

- Several new clean coal technologies suitable for China market advancing toward commercialization

多个适合中国市场的新型清洁煤技术正在向商业化应用积极推进

- R-GAS™ gasification demonstration project underway

R-GAS™ 煤气化技术的工业示范项目正在进行中

- Carbolock™, Oxy-PFBC and sCO₂ Power Cycles present promising opportunities in China

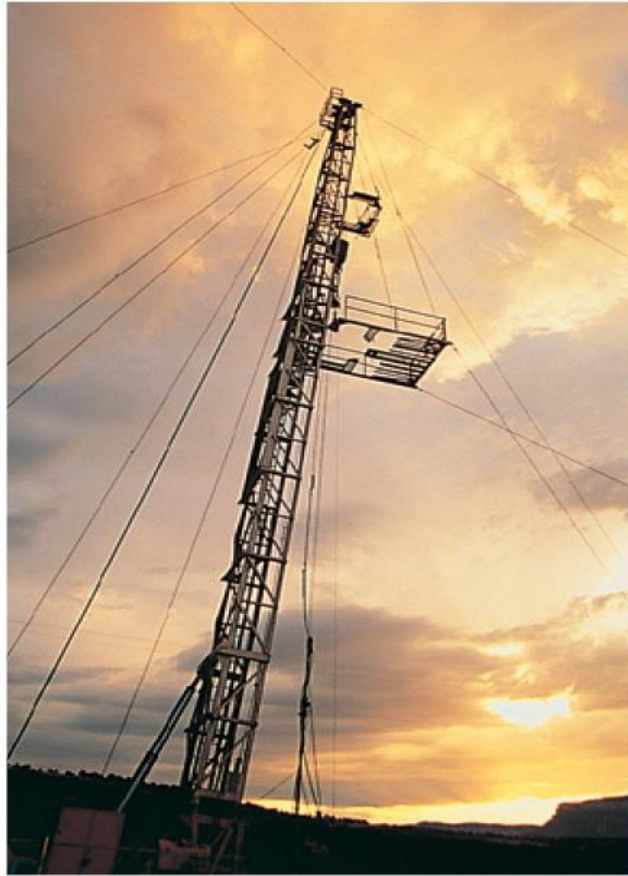
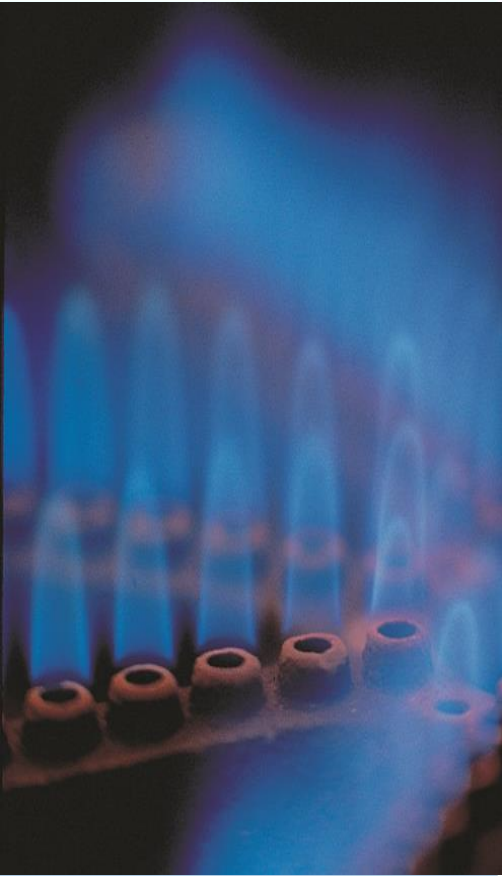
Carbolock™, Oxy-PFBC 和 sCO₂ 发电等先进技术在中国的推广将大有可为

- Strong collaboration on R-GAS™ demonstration plant project with Yangquan and ECEC provides template for further cooperation

R-GAS™ 示范项目上与阳煤和东华院的紧密协作为进一步合作提供借鉴模式

Turning Raw Technology into Practical Solutions

将先进技术理念转化为实际解决方案



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