Pratt & Whitney
A United Technologies Company

Pratt & Whitney Rocketdyne

PRATT & WHITNEY ROCKETDYNE

Power • Propulsion • Optimization

Clean Energy Solutions from 50 Years of Rocket Engine and Energy Experience

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Key Business Themes

- **Reduce emissions & environmental impact**
- **Increase energy security & reduce oil imports**
- **Improve efficiency, reliability & maintain-ability**
- **Reduce capital & operating costs**
- **Team with energy industry leaders**
- **Technology leadership**

COMPACT GASIFICATION SYSTEM

Pilot Plant Gasifier

Product
- Gasification System to convert low-value feedstock (coal, petcoke, biomass) into syngas

Benefits
- 90% size reduction (gasifier)
- 50% lower cost (gasification system)
- 80-85% cold gas efficiency
- 99% carbon conversion
- 99% availability (gasification system)

Feed System and Pump Test Facility at EERC

Pilot Plant at GTI

Dry Solids Pump

Markets
- Hydrogen for refineries and oil sands upgraders
- Synfuels and chemicals production
- Electric power generation (near zero emissions)

Status
- Proof of Concept demonstrated in 1980s
- Teamed with industry and government leaders to develop and commercialize technology
- Pilot plant built and operating (18 TPD)
- Feed system test facility operating
- Dry solids pump under development

Next Step: Build and operate Demo Plant

IN-SITU OIL RECOVERY TOOLS

Demonstrated DHSG Hardware

Product
- Highly-compact, surface and downhole combustion tools to enable improved hydrocarbon recovery (e.g., steam for heavy oil recovery) and in-situ upgrading (e.g., oil shale)

Benefits
- Enabling technology for production of heavy oil from deep, off-shore, North Slope (permafrost) reservoirs
- In-situ production and upgrading of oil shale and oil sands
- Potential for CO_2 sequestration

Markets
- Heavy oil
- Oil sands and oil shale
- Natural gas

Status
- Downhole steam generator (DHSG) demonstrated in 1980s in California oil field
- Improved concepts defined based on current requirements
- Working with oil industry to develop and commercialize technology

DHSG Injector

Water-Cooled Combustion Chamber

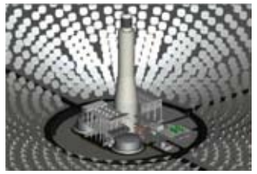
Next Steps: Build and operate full-scale commercial prototype tools in test-well environments

CONCENTRATED SOLAR POWER TOWER WITH THERMAL STORAGE

Solar Two Demo Plant
- *40 MWt*
- *10 MWe*

Product
- Solar power plants with molten salt energy storage under an exclusive worldwide license with SolarReserve

Benefits
- Renewable / green energy
- Energy storage / power on demand
- High temperature / high efficiency
- Competitive pricing



Commercial-Scale Plant (535 MWt, 50 to 250 MWe)

Status
- Demonstrated technology with the "Solar Two" Demo Plant in the 1990s
- Licensed technology exclusively to SolarReserve to develop commercial-scale projects
- SolarReserve has signed PPAs; permitting of 535 MW thermal plants in progress
- DOE contracts to reduce cost of electricity

Next Step: Construct commercial plants

SOLARRESERVE

ZERO EMISSION POWER & STEAM (ZEPS™)

Product
- Zero emission system to produce steam, power, and CO_2 with oxygen-fired, fluidized bed combustor

Benefits
- Produces steam for heavy oil recovery using low value feedstock (petcoke, coal, biomass)
- Produces pure CO_2 for Enhanced Oil Recovery (EOR)
- Produces electric power with zero emissions

Test Facility that Demonstrated Long Life in-bed Heat Exchanger

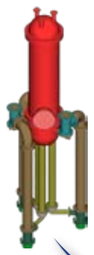
Staged Coal Combustor Plant for Steam Production

Markets
- Heavy oil production (once-through steam)
- Light oil production (CO_2 floods)
- Electric power generation

Status
- Long-life, in-bed heat exchangers demonstrated in 1980s
- Concept modified for oxygen-firing instead of air
- Working with oil company launch customer and industrial gas company to develop the technology

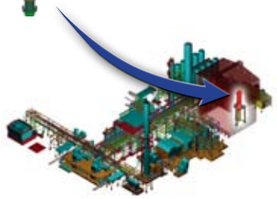
Next Steps: Build and operate Pilot/Demo Plants

HYDROGEN GENERATOR



Product
- System for large-scale production of hydrogen from natural gas and other feedstock
- Replaces Steam Methane Reformers (SMR)

Benefits
- Compact one-step process, 90% size reduction
- 30-40% lower equipment costs
- 15-35% increased H_2 efficiency
- Concentrated CO_2 for sequestration



Current Technology

Pilot Plant

Demo Plant

Markets
- H_2 for refineries, bio-refineries and chemicals
- H_2 for field upgrading of oil and oil sands
- CO_2 and N_2 for oil well pressurization, enhanced recovery of oil and coal bed methane

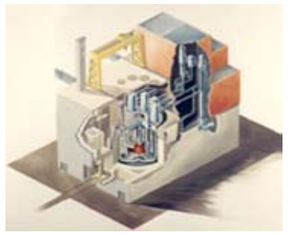
Status
- Proof of Concept tests completed
- Teamed with major SMR provider to commercialize technology
- Pilot Plant built and operating (20 MSCFD)
- Demo Plant defined (5 MMSCFD)

Next Step: Build and operate Demo Plant

ADVANCED ENERGY TECHNOLOGIES

- Liquid metal and molten salt heat transport systems
- Liquid metal nuclear systems integration
- Turbine generator rotating machinery using alternate working fluids, such as super critical CO_2
- High temperature heat recovery using molten salt and thermal storage

Liquid Metal Pump Assembly



Liquid Metal Technology

Supercritical CO_2 Cycle Turbine and Compressor