

# RadMax Technologies, Inc.



## Innovative Rotary Technology

Engines

Compressors

Expanders

Pumps

Gensets

- Headquartered in Spokane, WA, a wholly owned subsidiary of publicly traded REGI US, Inc. (OTBC:RGUS)
- Research and product development company developing a family of more energy-efficient and environmentally friendly devices for powering, compressing, pumping and gas expanding applications
- Based on our patented RadMax<sup>®</sup> rotary sliding vane technology

[www.radmaxtech.com](http://www.radmaxtech.com)



## Developing Power Producing Products for Large Markets that Reduce Environmental Impact and Increased Process Efficiency

1. Reduced methane emissions from the production of oil and natural gas
2. Low cost “green” power generation from “lost” energy at pressure reduction points at oil and natural gas wells and pipelines
3. Improve air conditioning / refrigeration cycle efficiency resulting in reduced power requirements
4. Water desalination and process water remediation
5. Direct Air Capture (DAC) of CO<sub>2</sub> and water

- Oil & Gas Production
  - Methane reduction (pneumatically operated devices, flaring)
  - Increased process efficiency (NG recompression station)
  - NG well site power generation (200 Watts – 1.5 MW)
    - NG sales line compressor engine fuel flow energy recovery
    - Reduce use of feedstock for power generation
    - Reduce purchased power
- Natural Gas Pipelines and Distribution
  - City gate instrumentation power
  - Reduce purchased power / sale of excess power generation
  - Gas storage facility power generation
- Refrigeration and A/C
  - Increased A/C and refrigeration system's efficiency (*modified cycle patent applied for*)

- Industrial
  - Power generation for NG or other gases flow
  - Improved steam use efficiency (*modified cycle patent applied for*)
- Utilities
  - Power at new and existing natural gas city gates
  - Power smart meters
  - Inexpensive and dependable standby power production
- Power Generation
  - Geothermal
  - ORC
  - Synfuel / Biofuel
  - Process waste energy

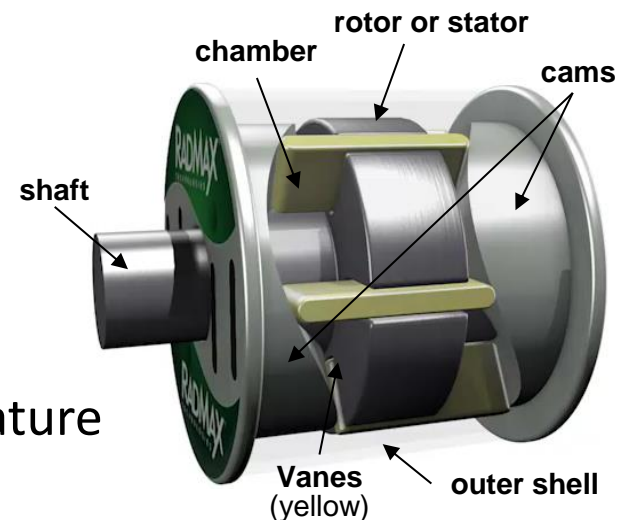
- Water Processing
  - Water desalination
  - O & G industry process water treatment
  - Third world water/power
- Fuel Cell
  - Waste heat recovery
- Direct air capture (DAC) of CO<sub>2</sub> and H<sub>2</sub>O
- Hybrid Vehicle Reduced Emissions Brayton Cycle Engine
- Working with DOE National Laboratories

Vanes form chambers between each pair of two vanes on both sides of the rotor

The chamber volume between the vanes change as the vane follows along the cam profile results in alternately compressing and expanding fluids at both cam locations

## Key Advantages

- Compact design with high output to size and weight ratios
- Simple operation, low parts count with few moving parts
- Rotary motion input and output porting, no complicated valving systems
- High internal compression, expansion and pump ratios
- Able to operate in wide pressure and temperature ranges
- Easily scalable from small to very large



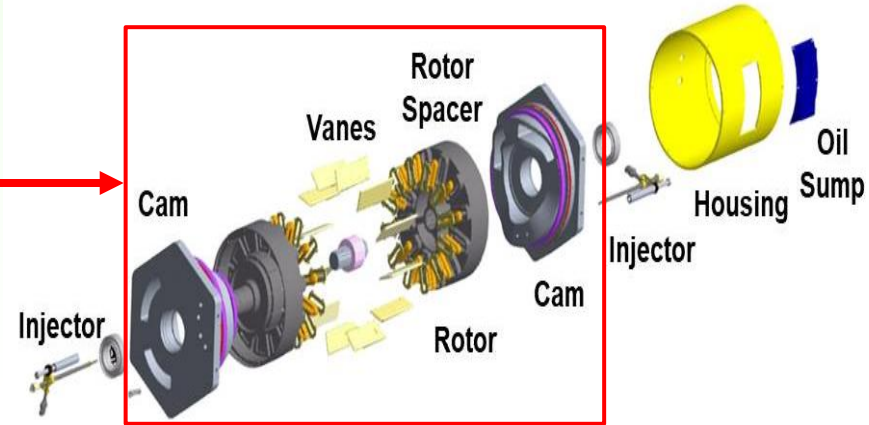
Patented “common rotary core” easily configured into a family of devices for use in a broad and diverse range of global industries, markets & applications

### Potential Product Configurations:

- Compressed gas expanders / generators
- Compressors
- Internal & external combustion engines
- Pumps

### Only RadMax devices can:

- Easily scale from small to very large
- Combine multiple devices on a single shaft in a single device
- Combine multiple functions on a single shaft in a single device



Expander

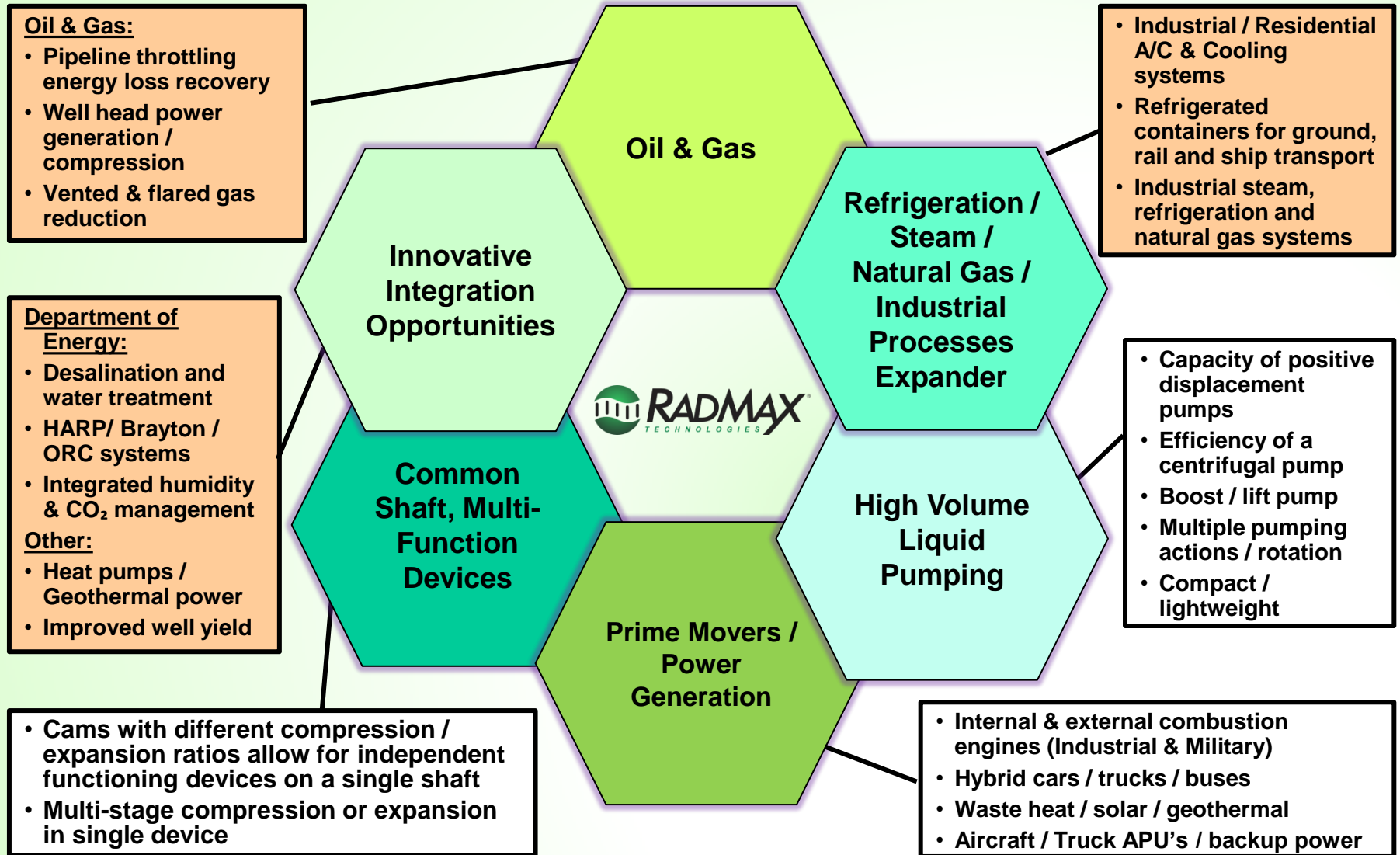
Compressor



# Active Patents & Filings

IP Type	Country	Number	Filing Date	Status	Description
Patent	US	7,896,630	2/13/2007	Approved 3/11/2011	"Axial Vane Rotary Device and Sealing System"
Patent	CA	2,496,157	2/8/2005	Approved 6/25/2013	"Vane Type Rotary Apparatus with Split Vanes"
Patent	US	10,418,880	8/4/2017	Approved 9/17/2019	"Electricity Generator and Methods for Generating Electricity"
Patent	US	10,662,774	8/4/2017	Approved 5/26/2020	"Prime Mover Assemblies and Methods"
Patent	US	15/946,068	4/5/2018	Applied For	"Rotary Devices Having Variable Compression and Expansion Ratios"
Patent	US	15/946,147	4/5/2018	Applied For	"Prime Movers, Pumps and Compressors Having Reciprocating Vane Actuator Assemblies and Methods"
Patent	US	16/258,929	1/28/2019	Applied For	"Modified Two Phase Steam Cycle"
Patent	US	16/284,923	2/25/2019	Applied For	"Modified Two Phase Refrigeration Cycle"
Trademark	US	5,715,644	9/30/2011	Approved 4/2/2019	"RADMAX"

**Have identified about 10 additional areas for possible patents**



# Product Development Focus On Gas Expander Opportunities

## RadMax Gas Expanders offer the opportunity to:

- Use energy more efficiently by:
  - Capturing “free energy” otherwise lost during throttling gas depressurization
  - Extracting energy from low temperature and pressure sources not viable for competitive technologies
  - Retro-fit existing systems to increase efficiency and reduce operation costs
  - Reduce natural gas (methane) venting
- Generate billions of kWh of electricity without the use of additional fuel eliminating millions of tons of CO<sub>2</sub> and other GHG emissions annually



Prototype Refrigerant Expander-Generator



# Differences From Other Expander Technologies

Turbine, screw, piston and other types of expanders have been used for many years, primarily for high flow, high pressure applications. However, RadMax expanders are:

- Both rotary and positive displacement
- Have flexible operating parameters
  - Can operate over a wider range of flows, pressures and temperatures
  - Operates at lower speeds
  - Two-phase fluid handling
- Flexible configuration
  - Independently functioning cam modules along a single shaft
  - Easily scalable from 1 kW to 1.5 MW, or by adding multiple cams



**RadMax expanders are able to bring the benefits associated with gas expansion down to lower-level application/use levels not achievable with other types of expanders**

# RadMax High Pressure Natural Gas Expanders



**Low Flow  
Model X6**



**High Flow  
Model X7**

# RadMax Low Pressure Expanders



**Low Flow  
Model X4**

- Prototype shop
- Stage 6 - 7 development level; field testing natural gas expanders in Texas
- First commercial sale in mid 2021; profitable by 4Q 2021 utilizing third party manufacturing
- Working with the DOE National Laboratories network on developing new refrigerant based expanders and compressors
- Working with several production, utilities and OEM companies to provide funded demonstration projects for expanders and compressors



# Current Expander Projects in the Oil & Gas Industry

1. Natural gas pneumatic controller emissions reduction
  - Canada NGIF grant
  - Demonstration projects in Texas and Alberta
  - Commercial product in 2021
2. Power generation at natural gas pressure reduction locations
  - Demonstration projects in Texas and Alberta
3. Power generation from depleted natural gas wells
  - NREL
4. LNG boil off gas (BOG) compressor for marine engines fuel conversion
  - South Korea





- Recompression of normally vented gas back into the downstream flow
- Increased efficiency of recirculation at compressor stations
- Increased drip yield (removing liquids from gas) by using expander instead of throttling valve
- Cogeneration from NG compressor engine fuel flow
- Providing power for other processes like process water treatment and mineral extraction



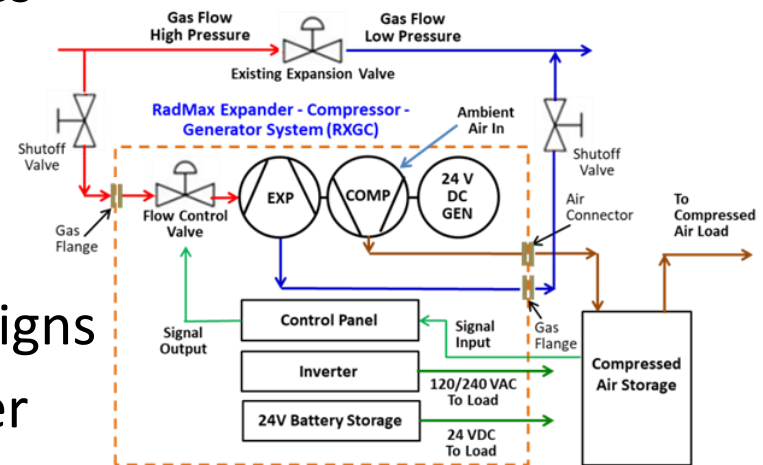
# Targeted Market

## Methane Emissions Reduction

- About 650,000 producing natural gas wells and 3 million miles of natural gas distribution lines in North America
- Millions of NG wells worldwide and pipeline distribution systems use the pressure of the NG to pneumatically power control valves, pumps and other devices
- Methane venting from these devices account for about one-half of the NG industry's methane emissions in North America
- Many countries are now regulating the reduction in these types of emissions
- RadMax is working the North American natural gas industry to develop an expander that generates power at pressure reduction points to drive converted pneumatic controllers to use electricity or compressed air thus eliminating these types of methane emissions

# RadMax Natural Gas Micro Auxiliary Power Unit

- Generates 1 – 10 kW of electricity and/or compressed air at existing NG pressure reduction locations
- Used to drive electric or compressed air for pneumatic controllers, electronic equipment, lighting, communications, etc.
- Eliminates methane emission from pneumatically operated devices
- Provides a low cost, constant and dependable source of power at locations where electricity is not economically available
- Low and high pressure and flow designs
- Field testing with major NG producer



# Targeted Market

## Energy Capture From Natural Gas Pipelines

- Tens of millions of horsepower are used to compress gas in natural gas pipelines in the US
- Gas pressure is reduced typically through “throttling” pressure reducing valves at various pressure letdown points all along the system
- Approx. 30% of the energy spent to compress the gas to deliver it to final destination is lost through pressure reduction and other throttling processes
- About 20% of the energy spent to compress natural gas, or approx. 2/3 of the lost throttling energy, is recoverable and can be converted to electricity through the use of RadMax expander-generators
- Generated power can be used to reduce methane emissions, or power electronic equipment, lighting, communications and other devices at the site



# Natural Gas Distribution Power Generation

## Electric power generation potential at example natural gas pipeline pressure reduction points with RadMax expander-generator

	Main Line Letdown	Commercial Feed	Neighborhood Feed
Gas Flow Rate	20.25 MMSm <sup>3</sup> /d	1.27 MMSm <sup>3</sup> /d	0.20 MMSm <sup>3</sup> /d
Upstream Pressure	3,481 psia	725 psia	348 psia
Required Downstream Pressure	870 psia	218 psia	29 psia
Gas Temperature With Normal Preheating	15 C°	15 C°	15 C°
Required Expander Outlet Temperature	10 C°	10 C°	10 C°
Required Expander Inlet Gas Temperature*	104 C°	82 C°	155 C°
Additional Preheat Required to Achieve Required Expander Gas Inlet Temperature (approx.)**	94.25 GJ/hr	5.35 GJ/hr	2.02 GJ/hr
Expander Shaft Power (85% expander efficiency)	26,181 kW	1,487 kW	562 kW
<b>Electricity Generated (90% generator efficiency)</b>	<b>23,563 kW</b>	<b>1,338 kW</b>	<b>506 kW</b>
Cost of Additional Preheat Gas (USD\$2.00/GJ)	US\$ 188.50 /hr	US\$ 10.70 /hr	US\$ 4.04 /hr
Value of Generated Electricity (US\$0.10/kWh)	US\$ 2,356.30 /hr	US\$ 133.80 /hr	US\$ 50.60 /hr
<b>Net Value of Electricity Generated</b>	<b>US\$ 2,167.80 /hr</b>	<b>US\$ 123.10 /hr</b>	<b>US\$ 46.56 /hr</b>

**Notes:** Analysis based on NIST data from REFPROP software and proprietary RadMax models

8/2020

\* Extracting work from the gas flow by the expander significantly reduces the gas outlet temperature. This is the required expander gas inlet temperature in order to achieve the desired expander gas outlet temperature.

\*\* Amount of preheat gas required to achieve the required inlet gas temperature.

# Targeted Market

## Vapor Compression Cycle Efficiency Improvement

### 900 billion kWh of electricity used in US for A/C and refrigeration in 2016

- Generated about 500 million metric tons CO<sub>2</sub> emissions
- Replacing the expansion valve found in every a/c and refrigeration system with a RadMax expander-generator can increase overall system efficiency by 5% - 20% saving:
  - 50 – 150 billion kWh of electricity (\$5 – \$15 billion)
  - Over 100 million metric tons of CO<sub>2</sub> emissions



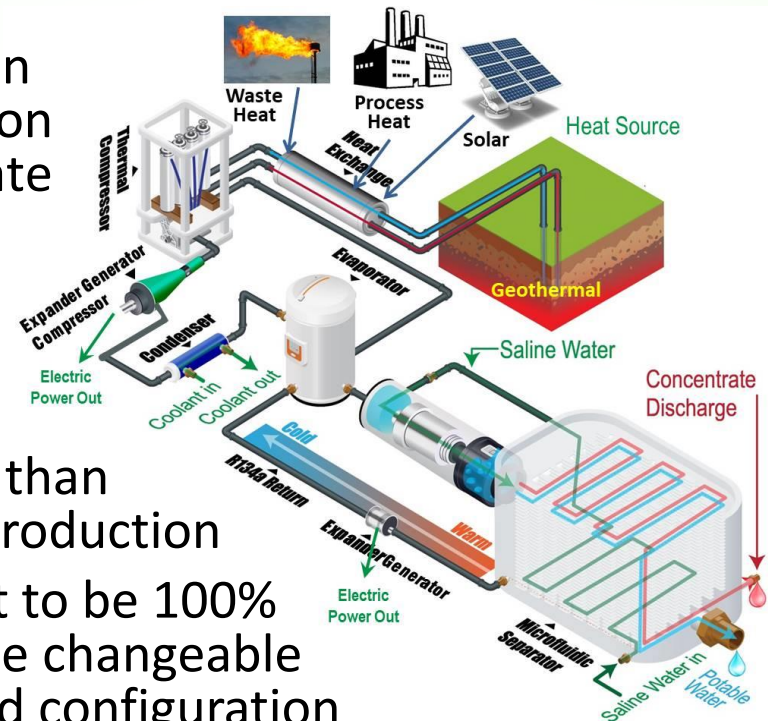
### Global Market

- About 100 million new units in 2016
- Expected to grow to 700 million units per year by 2030 and 1.6 billion units by 2050
- All of these units can benefit from RadMax expander and compressor technology



## PNNL Developed and Patented Microfluidic Solar Thermal Power Generating Desalination and Water Treatment System

- A continuous, scalable, low cost process to desalinate and/or remove water contaminants in produced waters and that also simultaneously produces electric power
- Combines a low quality heat source driven power generation cycle with a refrigeration cycle used to crystallize and then dissociate gas hydrate to generate potable water
- Revenue generated from power sales can reduce the levelized cost of water to as low as  $\$0.20/\text{m}^3$  ( $\$0.76/1,000 \text{ gal}$ )
- Thermal energy input requirement is less than  $40 \text{ kW}/\text{m}^3$  ( $150 \text{ W}/\text{gal}$ ) of potable water production
- Proposed option allows for system output to be 100% power generation or desalination, or some changeable combination deployable in a skid mounted configuration
- RadMax expanders add functionality and about 20% to the system's efficiency

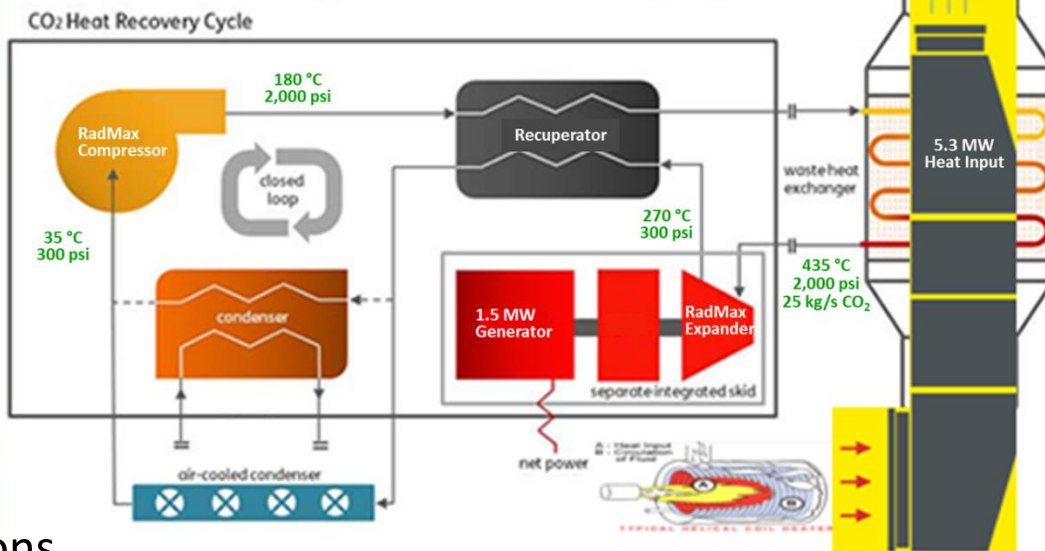


# Targeted Market

## Bio-Waste Energy Production

- CO<sub>2</sub>-based Brayton cycle power generating system that minimizes operating and regulatory issues, reduces capital costs and water use, and provides increased efficiency compared to steam Rankine cycle systems
- CO<sub>2</sub> working fluid provides higher heat capacity and more electricity production from the same thermal input as steam
- RadMax positive displacement expander can be used in both superheated and supercritical states to generate power rather than just the supercritical state used by turbines
- Can use both low and high quality heat sources:
  - Syngas
  - Waste Process Heat
  - Solar
  - Nuclear
  - Geothermal
  - Flare Gas
- Working with Canadian bio-waste syngas production company on 1,500 kW development project for refuse and agriculture applications

### RadMax Variable Output 500 – 1,500 kW CO<sub>2</sub> Heat Recovery Power Generating System

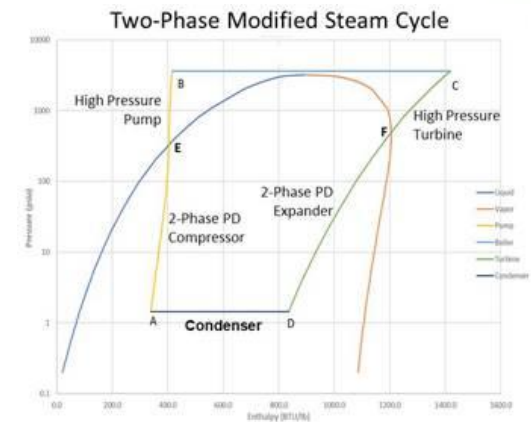
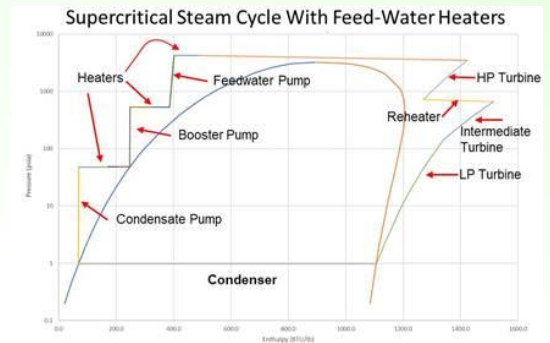




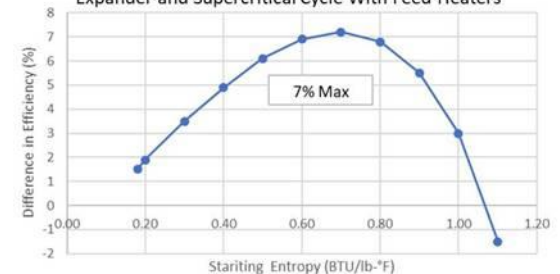
# Improved Steam Rankine Cycle Efficiency\*

- Steam power plant overall cycle efficiency can be increased by about 7% for plants with feed water heaters by replacing low pressure water pumps and turbines with two-phase (vapor-liquid) pumps, compressors and expanders
- Two-phase devices allow pumping and expansion processes to proceed within the liquid-vapor dome permitting selection of optimum start and end states
- Less complicated approach and requires less capital equipment than other current methods
- Potential for smaller and less expensive, sub-critical plants to be as efficient as larger plants
- Can result in more, smaller efficient plants built closer to the demand thus reducing distribution system loads and creating a more secure and responsive grid

\* Patent pending



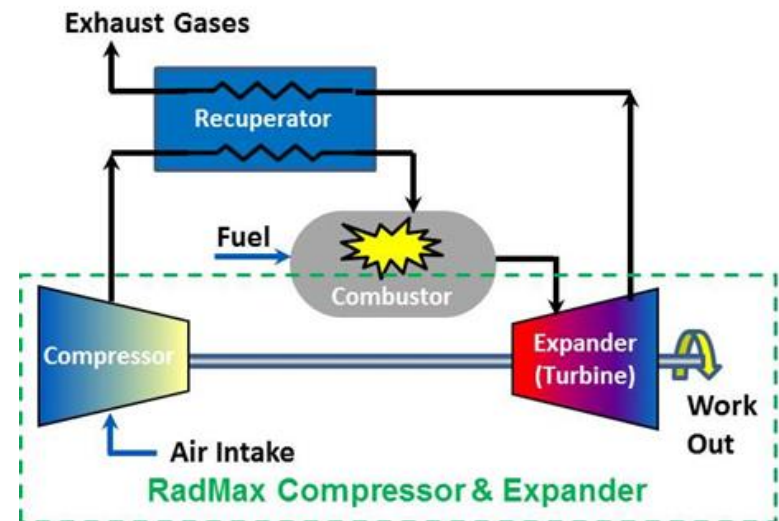
Difference in Efficiency Between Using 2-Phase Compressor & Expander and Supercritical Cycle With Feed Heaters



# Targeted Market

## RadMax Positive Displacement Combustor Engine (PDCE)

- RadMax PDCE is a Brayton cycle engine consisting of:
  - RadMax expander and compressor
  - Existing high efficiency and low emissions continuous combustion combustors
  - Commercially available Recuperators (heat exchanger)
- Can provide same power as comparable IC engine for about 75% of the fuel cost, one third of the emissions, and half the size and weight\*
- Can potentially produce electricity in hybrid vehicles at about the same life cycle emission level and cost as current average grid values
- Intermediate step in reducing fossil fuel emissions over the next couple of decades until alternative energy sources and required infrastructure are available and in place



\* Based on preliminary estimates and modeling

## RadMax Technologies, Inc.

7520 N. Market St., Suite #10  
Spokane, WA 99217

(509) 474-1040

**OTCQB:RGUS**

Paul W. Chute, CEO  
pchute@radmaxtech.com

www.radmaxtech.com  
info@radmaxtech.com