

**LPP = Lean, Premixed & Prevaporized**



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

# The Problem LPP Solves

**Urgent Need Exists in the Power Industry and Energy Markets to . .**

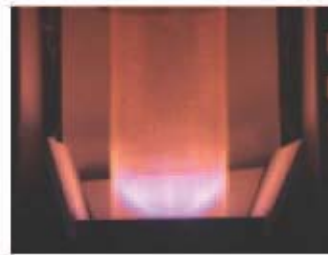
**Burn Liquid Fuels at or Below Natural Gas Emission Levels**

Conventional Liquid  
Fuel Flame



The Problem

Natural Gas  
Flame



The Goal

Liquid Fuel (Biodiesel)  
Using the LPP System



The Solution

Many firms have attempted to solve the problem of burning liquid fuels cleanly (e.g. GE, Siemens, United Technologies), but have traditionally concentrated on modifying the combustor hardware.

LPP Combustion solved this problem by focusing on modifying the fuel, allowing it to be cleanly burned in combustor hardware designed for burning gaseous fuels.

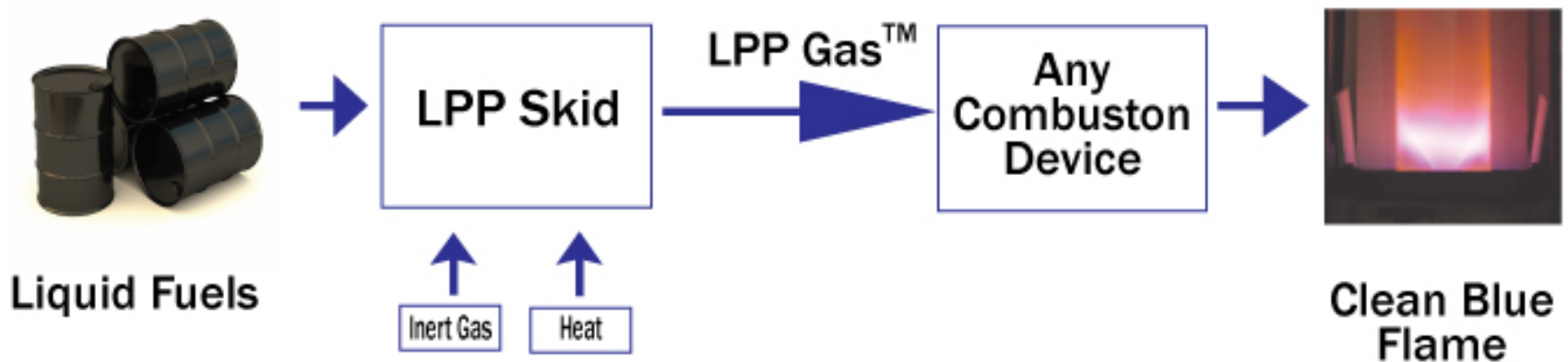
***LPP = Lean, Premixed & Prevaporized***

*US Patents: 7,089,745 & 7,322,198. Other Patents Pending.*

# The Patented Solution

**LPP** = **L**ean, **P**remixed & **P**revaporized

- The LPP Combustion System Vaporizes Liquid Fuels And Creates A Substitute Natural Gas (LPP Gas™)
- This LPP Gas™ Can Then Be Burned With Low Emissions In Place Of Natural Gas In Virtually Any Combustion Device
- Burning Biodiesel, The LPP System Creates A Low-Emissions, Renewable Energy Power Plant With No Net CO<sub>2</sub> Gas Emissions



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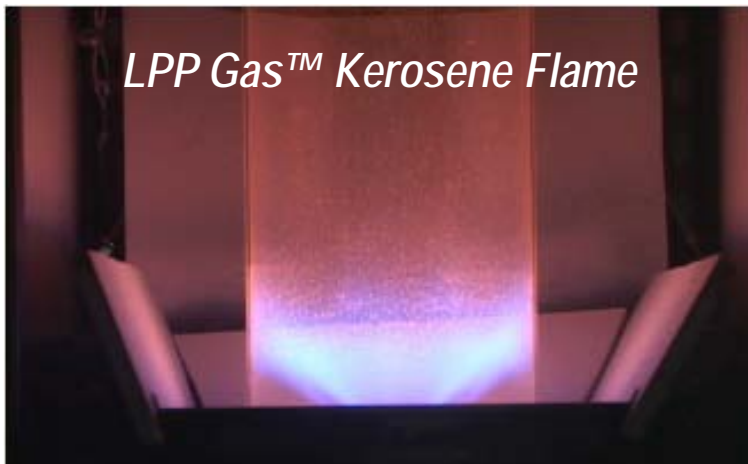
# The Result

## Same Gas Turbine Combustion System



The LPP System Provides Clean Energy from Liquid Fuels:

- Provides Flexible Liquid Fuel Source While Reducing Emissions, Meeting or Exceeding Environmental Requirements
- Process Uses Existing Equipment and Infrastructure
- Reduces Equipment Maintenance Cost
- Provides Rapid Customer Payback



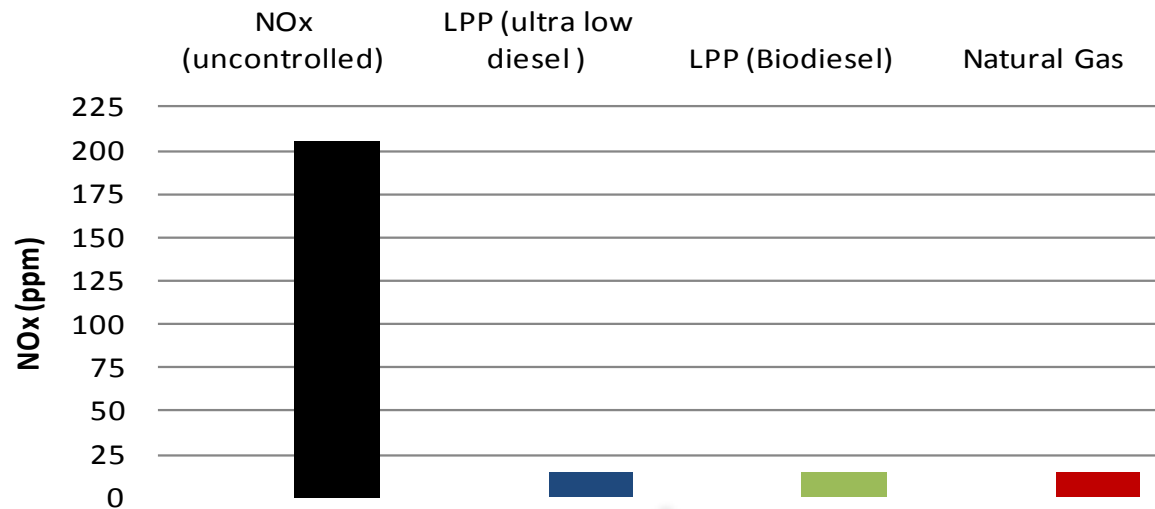
# LPP is Liquid Fuel Agnostic

- No. 2 Heating Oil
- No. 2 Diesel Fuel Oil
- Kerosene
- Coal Derived Liquids
- Byproduct Streams
  - Natural gas condensate
  - Naphtha
- Biodiesel
  - ASTM spec
  - Non-ASTM spec
- Bioethanol
  - Anhydrous (<0.5% water)
  - Hydrous (5% water)
- Biobutanol
- Biomass Derived Liquids

# LPP Emissions Performance

- Utilize any light liquid fuel to produce synthetic natural gas
- Criteria pollutant emissions (NO<sub>x</sub>, CO, & PM) reduced by 90%
- NO<sub>x</sub>, CO, SO<sub>x</sub>, & PM comparable to natural gas emission levels
- Use existing natural gas burners w/o combustor hardware modifications

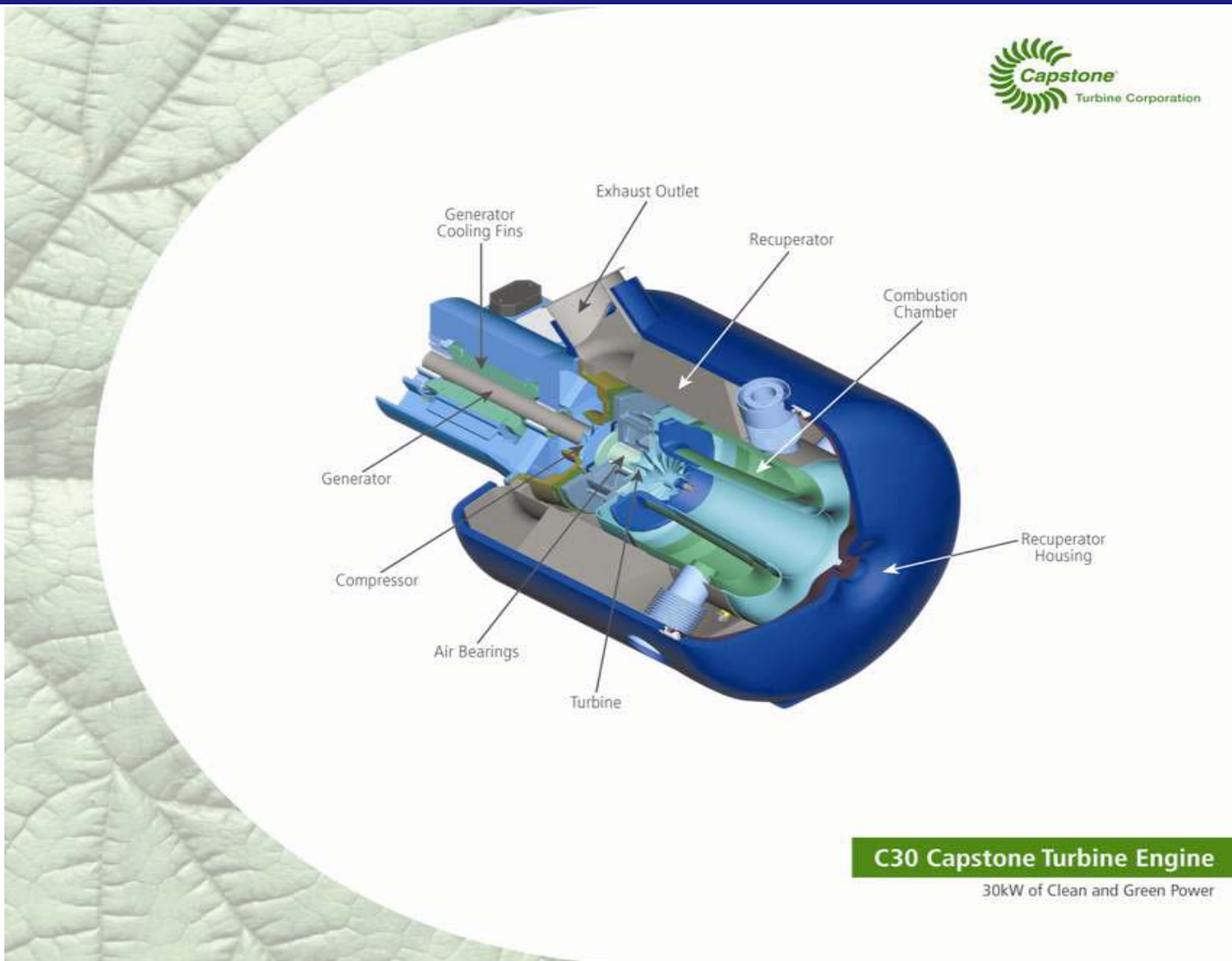
## NO<sub>x</sub> Emissions



*The LPP System reduces NO<sub>x</sub> emissions without increasing CO emissions*

# LPP Combustion Demonstration

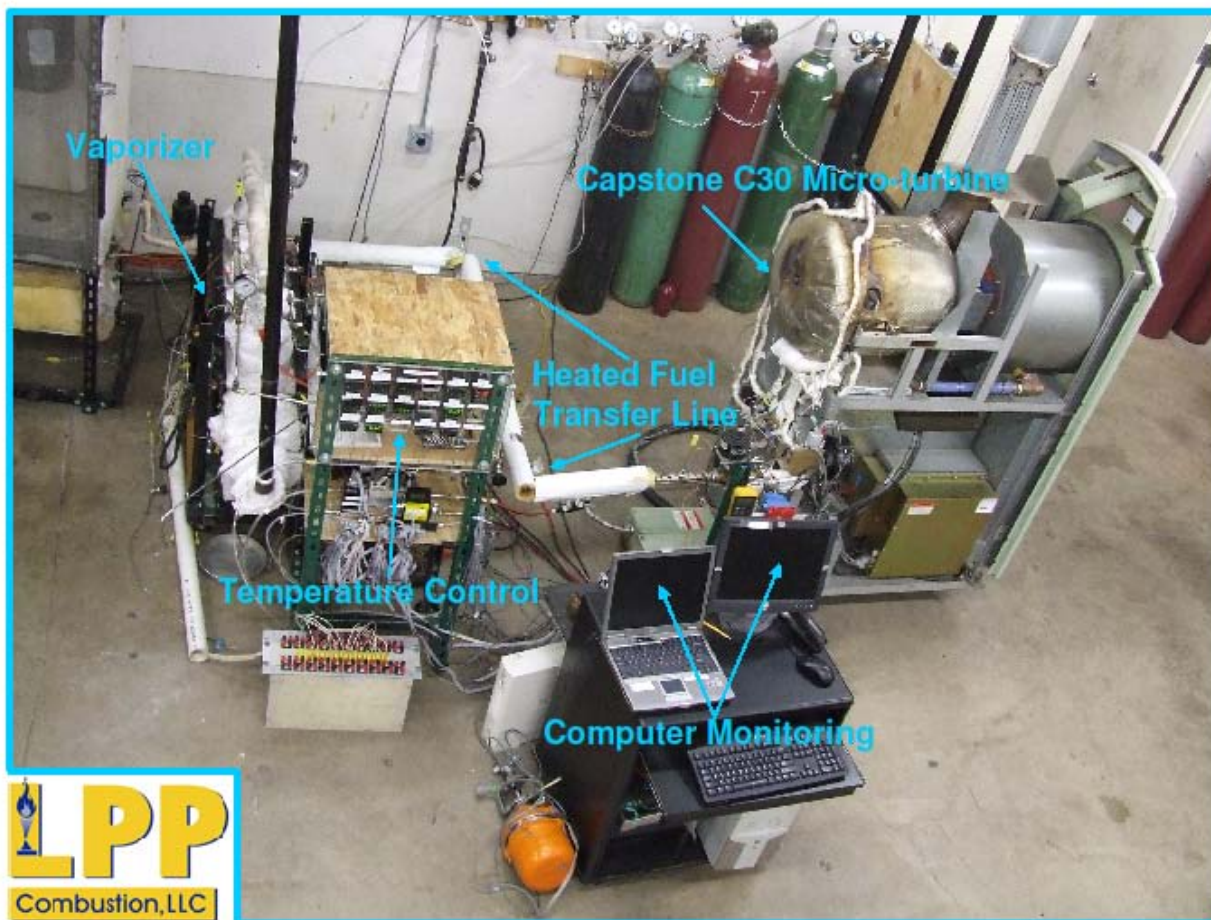
- **Currently operating a Capstone C30 gas turbine at LPP Combustion facility in Columbia, MD**
  - 30 kW power generation gas turbine which utilizes diffusion (<65% load) and Dry Low Emission (>65% load) natural gas combustion system
  - More than 1000 hours of operation on LPP Combustion system to date including more than 50 “black starts”
- **Burning a variety of liquid fuels including bio-ethanol, natural gas condensates, naphtha, isopropyl alcohol, acetone, toluene, gasoline, kerosene, JP8, S8, diesel, heating oil, and biodiesel**
- **Generating Green Energy on the local utility (BGE) grid through a “net metering” agreement!**



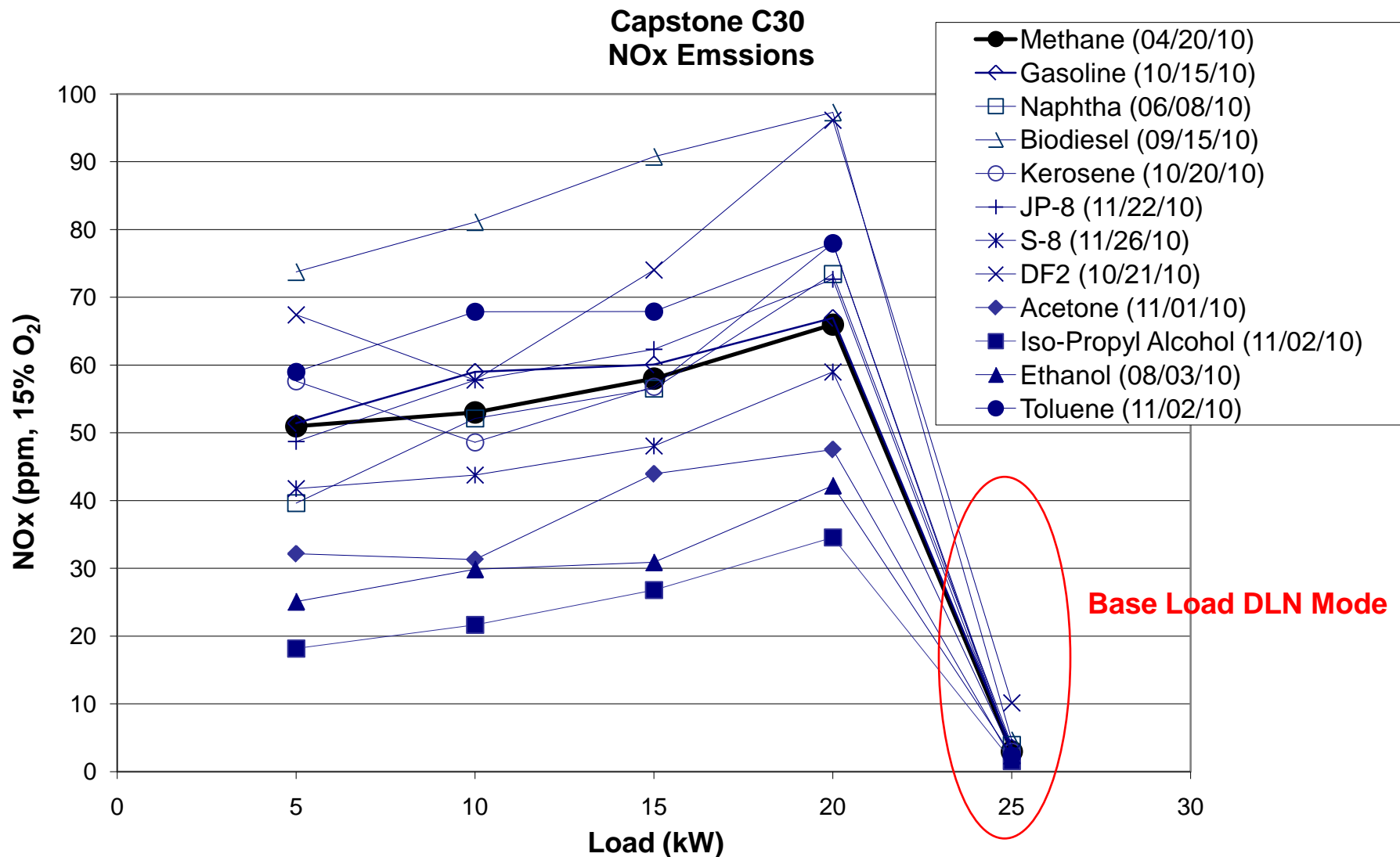
**C30 Capstone Turbine Engine**  
30kW of Clean and Green Power



# LPP Combustion Demonstration



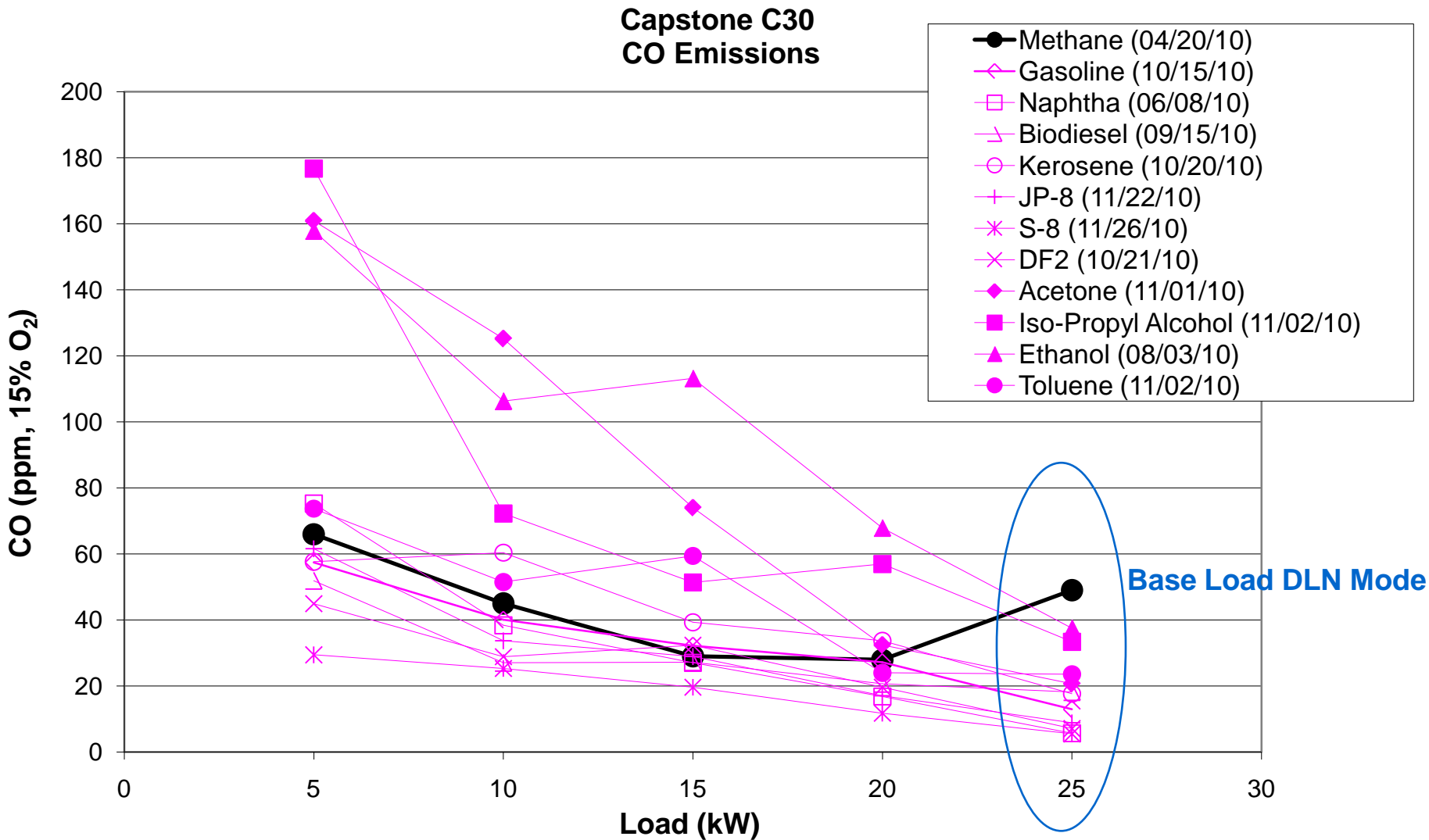
# LPP Combustion Demonstration



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# Customer Value Proposition

- **Urgent Need to Generate Clean Energy While Improving Fuel Efficiency**
  - Tightening Emissions Requirements >>> Domestic and International
  - Pressing Need to Reliably Accommodate Alternative/Renewable Liquid Fuels as Energy Suppliers Seek Fossil Fuel Independence
- **LPP Generated Gas Uses Existing Equipment and Infrastructure**
- **Reduces Equipment Maintenance Cost**
- **Provides Flexible Liquid Fuel Source While Reducing Emissions, Meeting or Exceeding Environmental Requirements**
- **Rapid Customer Payback**

# LPP Gas™ (Heating Oil) vs. Heating Oil

*LPP Provides Fuel Flexibility And Savings for Power Suppliers*

		2008 (Present)	
		Heating Oil (LPP)	Heating Oil
<b>Gas Turbine Data</b>	Electrical Generation Capacity (MW)	126	126
	Heat Rate (Btu/kWh (LHV))	7,544	7,719
	Operating Hours	8,040	8,040
	Fuel Usage (MMBtu/year (HHV))	8,121,935	8,310,871
	Net Electrical Generation (MWH)	1,012,236	1,012,236
<b>Fuel Costs</b>	Fuel Cost (\$/gal.)	\$1.65	\$1.65
	Annual Fuel Cost	\$96,550,386	\$98,796,374
<b>Equipment Maintenance &amp; Operational Costs</b>	Equipment Maintenance Cost	\$1,000,500	\$3,600,000
	Pollution Cleanup Operating Cost		\$1,993,175
<b>Capital Expenditure</b>	Equipment Cost	\$10,050,000	\$7,915,635
	Net Equipment Cost	\$2,134,365	
<b>Production Cost Comparison Summary</b>	Total Power Production Costs per Year	\$97,550,886	\$104,389,549
	Net Power Production Savings per Year	\$6,838,663	
Payback Period for the LPP System vs. the Alternative		0.31 years	

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# Customer Value Proposition

**Fuel Processing Skid provides \$6MM savings per year for 126MW Combined Cycle Power Plant through:**

- **Fuel Flexibility**
  - Same emissions and performance for a range of liquid fuels
- **Clean Use of Liquid Bio-Fuels**
  - Natural gas level emissions from bio-ethanol and biodiesel
- **Increased Plant Efficiency**
  - 1%-3% improvement in heat rate means 1%-3% reduction in fuel costs
- **Reduced Equipment Maintenance Costs**
  - 2.5 to 4 times less maintenance from lower flame luminosity and elimination of water addition
- **Reduced Exhaust Emissions Costs**
  - Natural gas level emissions w/o water addition or SCR
- **Rapid Customer Payback**
  - 4-6 months for a new plant: 18 months for retrofit

## LPP Combustion Enables “Dispatchable” Renewable Energy

- As electric power demand changes over a 24-hr period, power plants stand-by to “dispatch” power to the grid on demand
- Gas turbine power plants can be “dispatched” to provide power to the grid on short notice based on demand from the grid
- Because of variations in weather, wind and solar power are not always available to the electric power grid on demand
  - Wind and solar power are not “dispatchable”
- Gas Turbines equipped with an LPP Combustion system can burn biofuels as cleanly as natural gas to provide on-demand, clean, “dispatchable” power generation to the grid
- “Dispatchable” renewable power from gas turbines can compliment the intermittent power from wind and solar generation

## Biodiesel (LPP Gas™)

• Initial Price (B100)		\$3.99/gal
• Federal PTC (\$0.01/kWh)	- \$0.16/gal	\$3.83/gal
• State REC (MA, \$0.20/kWh)	- \$3.25/gal	\$0.58/gal
• Carbon Credits* (EU, \$30/ton)	- \$0.23/gal	\$0.35/gal
• <b>Final “Net” Fuel Price</b>		<b>\$0.35/gal</b>
• <b>(Natural Gas Equivalent)</b>		<b>(\$2.91/MMBtu)</b>
		<b>(\$0.021/kWh)</b>

Biodiesel LHV = 120,200 Btu/gal

Biodiesel prices are for B100 out of the Midwest

Combined cycle gas turbine heat rate = 7,312 Btu/kWh

\* Carbon credits based on US equalization with EU market

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# Scaling of LPP Technology

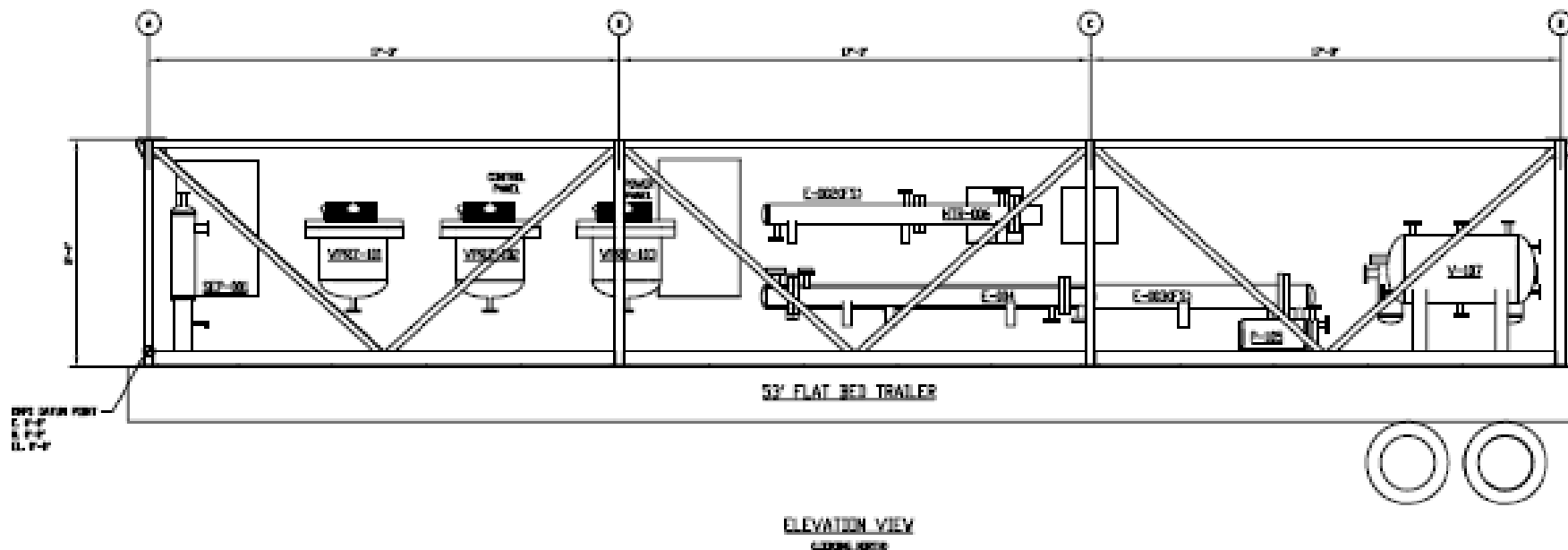
- LPP Technology Demonstrated Over Four Orders of Magnitude
- LPP is a Fuel Technology that is Inherently Scalable
- Modular Design Easily Expandable
- No Technical Barriers to Scaling of LPP System to Larger Applications
- System Can Be Sized for:  
30 kW (microturbine) to  
230 MW (Utility turbine)
- Pricing will vary with scale: \$100 (large system) - \$300/kW (small system)



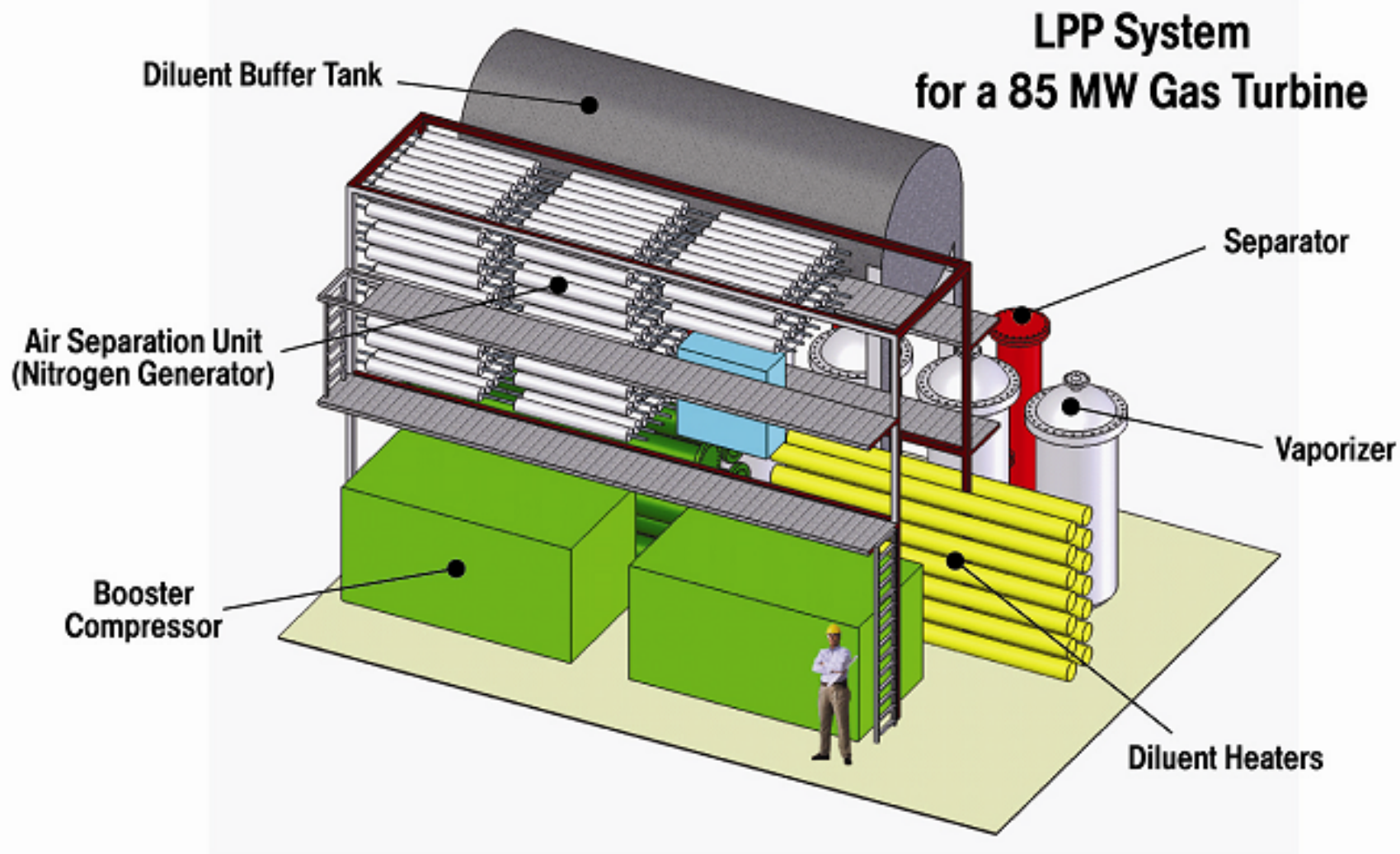
Solar Turbines Taurus 60 Mobile Gas Turbine System  
(Photo courtesy of Solar Turbines)

# LPP Skid Schematic

## LPP Combustion fuel preparation skid for a Solar Taurus 60/70



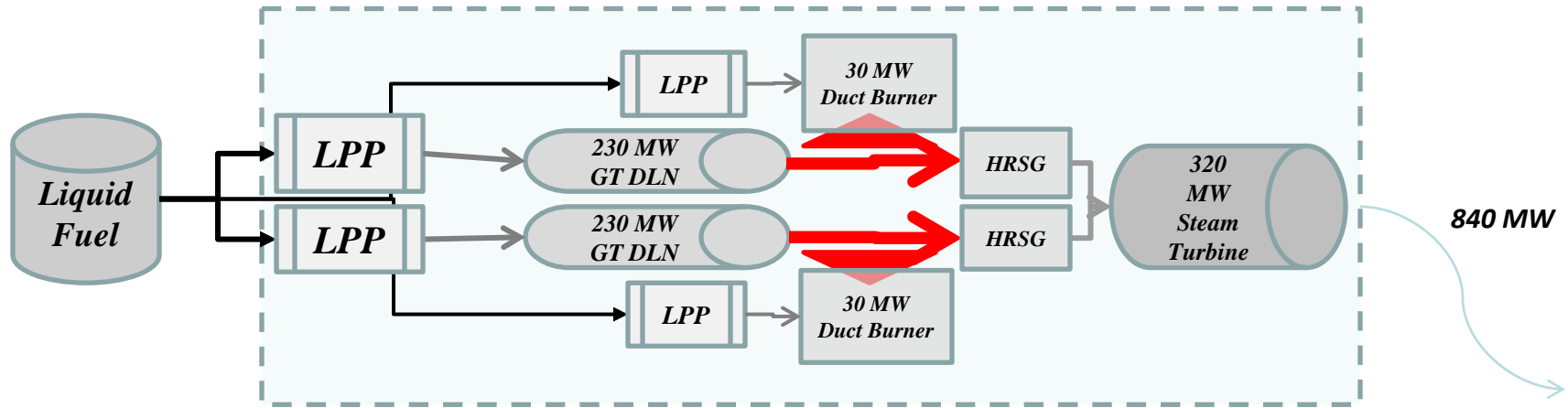
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# 2-on-1 Power Plant



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