

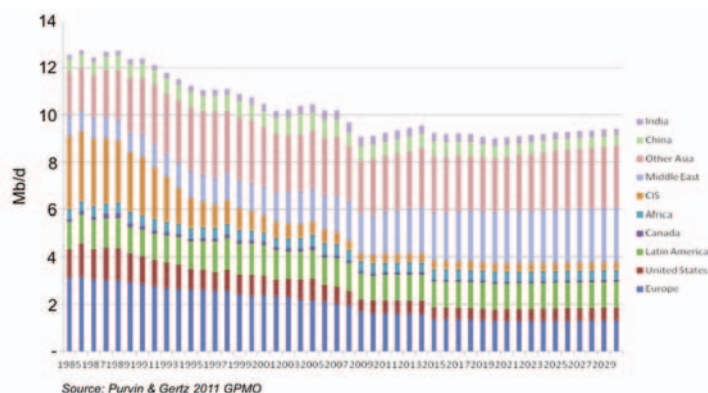


RTP GREEN FUEL: AN OVERVIEW FOR RENEWABLE HEAT AND POWER

Fossil fuel oil has long been burned to generate heat and power in industrial, institutional and residential environments. While usage has been declining over the years, there are still places where replacements have not been practical or compelling. Today, there is a renewable alternative that improves the emissions profile, economics and carbon footprint of these applications. Through Envergent's RTP™ (Rapid Thermal Processing) technology, lignocellulosic biomass, such as forest and agricultural residues, are converted to RTP green fuel, a renewable liquid fuel that can be used to generate heat and power.

Burning fuel oil in heat and power generation applications can be problematic due to SO_x, NO_x and particulate emissions. In addition, the CO₂ emissions, or carbon footprint, from burning fossil fuels are high. While its use continues in industrial, institutional and residential applications in certain sectors, it has been declining. **Figure 1** projects that residual fuel oil usage will level off around 9 million barrels/day through 2030. High taxation, emissions trading (i.e. the EU Energy Directive) and conversion to natural gas all contribute to the reduction. It is projected that production and availability of heavy fuel oil will decline further as demand decreases, resulting in an increase in price. That will present an economic challenge, and a potential supply issue, to those that continue to use this type of fuel for their energy needs. Envergent's solution to these growing challenges is its RTP process.

Figure 1 - Overall Residual Fuel Oil Demand by Region, 1985-2030



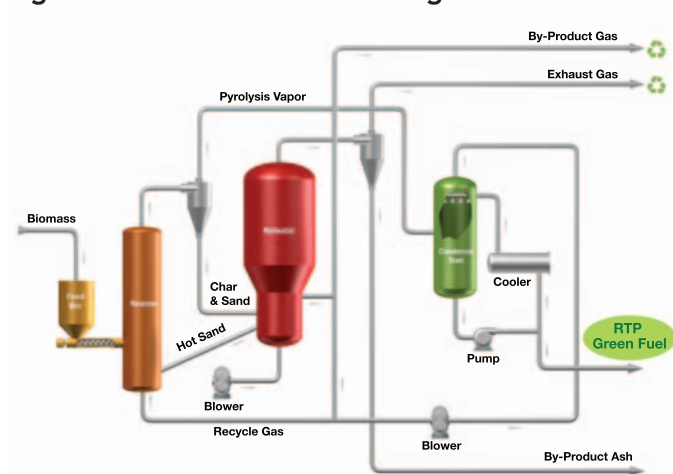
ENVERGENT'S RENEWABLE SOLUTION

RTP is a thermal conversion process known as fast pyrolysis, which is the rapid heating of biomass in the absence of oxygen. The process shown in **Figure 2** utilizes a circulating transported bed reactor system, in which sized and dried biomass is contacted with circulating hot sand in the reactor. The pyrolytic vapor is rapidly quenched to produce a high yield of liquid fuel, or RTP green fuel.

RTP green fuel is a renewable liquid fuel that can be produced in a cost-effective manner and, relative to fossil fuel oil, can be burned with an improved carbon footprint and reduced particulate and SO_x emissions.

RTP green fuel is a unique way to leverage the renewable benefits of biomass in a liquid form, which has the advantage of higher energy density compared with gas or solid fuels, especially on a volumetric basis.

Figure 2 - RTP Process Flow Diagram



As Table 1 shows, the volumetric energy density of RTP green fuel is nearly two times greater than that of wood pellets.

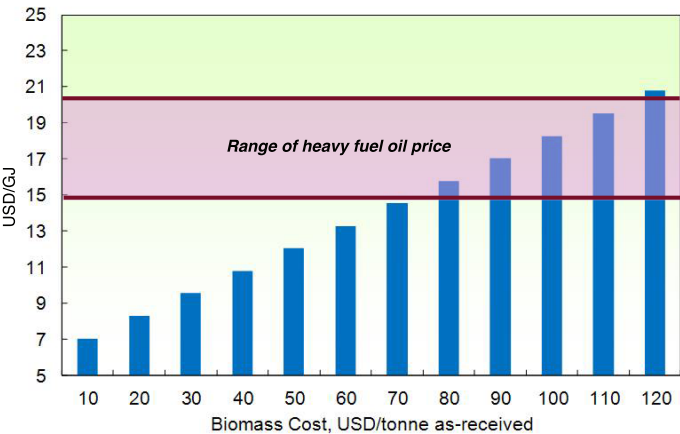
Table 1

	Moisture, Wt-%	Energy Density by Mass (LHV, MJ/kg)	Energy Density by Volume (LHV, MJ/m³)
Wood Chips	40	12	7680
Wood Pellets	<10	18	11,700
RTP Green Fuel	~20	17	20,400

This results in improved logistics and carbon footprint of transport from fuel source to consumer. In addition, a liquid fuel is more easily integrated with existing fuel handling and delivery infrastructure, and allows the decoupling of biomass conversion from energy generation in both location and time.

The price of RTP green fuel can be very attractive compared with heavy fuel oil, depending largely on the cost of the biomass feedstock used to produce it. Incentives to replace fossil fuels or CO₂ reduction targets improve the economics further. Figure 3 shows the impact of biomass feedstock price on the manufacturing cost of RTP green fuel, and demonstrates that this renewable fuel can be produced cost-competitively with heavy fuel oil on an energy equivalent basis, even without incentives.

Figure 3 - RTP Green Fuel Production Cost



RTP GREEN FUEL PROPERTIES

RTP green fuel is produced from the thermal decomposition of biomass via the RTP process. This technology transforms solid biomass into a storable and transportable fuel that is a dark liquid with an appearance similar to light petroleum oil. It is a



water-soluble, oxygenated fuel consisting of depolymerized components of biomass. Typical properties are shown in Table 2.

Table 2

Property	Typical Values
Gross Calorific Value, MJ/kg	16 to 19
Net Calorific Value, MJ/kg	15 to 17
Water Content, Wt-%	15 to 30
Solids Content, Wt-%	0.5 to 2.5
pH	2 to 3
Specific Gravity	1.1 to 1.3
Ash Content, Wt-%	0.1 to 0.25
Flash Point, °C	45 to 99
Pour Point, °C	-23 to -30

The energy content, or calorific value, on a per mass basis, of RTP green fuel is typically very close to that of the biomass from which it was made. This means, on a volume basis, the energy content of RTP green fuel is roughly half that of typical fossil fuel oils. Therefore, and as shown in Table 3, roughly twice the volume of RTP green fuel is required for an equivalent energy input to a boiler or furnace.

Table 3

Fuel	MJ/Litre	Btu/US Gallon
Heavy Fuel Oil (No. 6)	40.4	144,800
Light Fuel Oil (No. 2)	39.3	141,000
Ethanol	23.5	84,000
RTP Green Fuel	19.9	71,500

RTP GREEN FUEL IN THERMAL APPLICATIONS

RTP green fuel can be used in a variety of applications such as space heating, residential or district heating, industrial process heating (furnaces, kilns or boilers) and electrical generation. It can be fired on its own, or co-fired simultaneously with other fuels such as fossil fuel oil, coal, waste fuels and biomass. Every unit of energy that is provided using RTP green fuel comes from a sustainable, renewable source with a corresponding improvement in emissions to our environment.

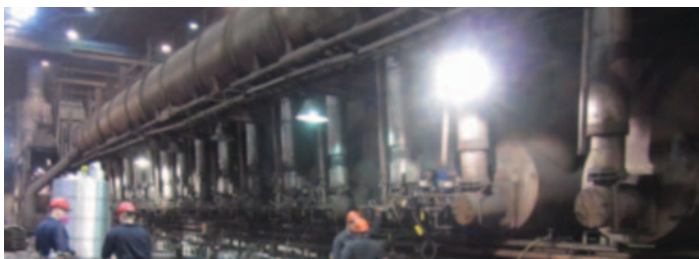
Envergent Technologies has supported customers in their transition to use RTP green fuel commercially. We have also conducted many demonstrations in different environments where RTP green fuel was burned successfully. The types of equipment used included fire-tube package boilers, water-tube high pressure boilers, furnaces and kilns.



Packaged Boiler



Water-Tube Boiler



Industrial Furnace

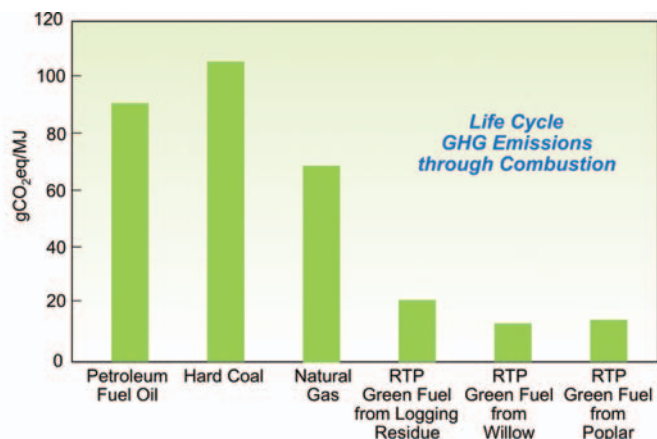
RTP green fuel can be utilized in different types of burners that are typically seen in industrial applications, including pressure atomization (often with air or steam atomizing media), rotating cup, and direct injection. Generally, the fuel is handled in a fashion similar to heavy fuel oil, although less preheating is typically required.

Envergent works with several major boiler and burner vendors, and can assist in contact with an appropriate equipment and service provider to meet your needs.

EMISSIONS FROM THE COMBUSTION OF RTP GREEN FUEL

RTP green fuel is a truly renewable fuel that can be produced on a sustainable basis. It is produced from biomass that grows in the short-term so when it is burned it is considered CO₂ neutral. This has a positive impact in reducing net greenhouse gases in our atmosphere. Specifically, as a substitute for fossil fuel oil in burner applications, RTP green fuel reduces carbon emissions up to 90% and sulfur emissions in excess of 95%. **Figure 4** compares carbon emissions of RTP green fuel to traditional fossil fuels from

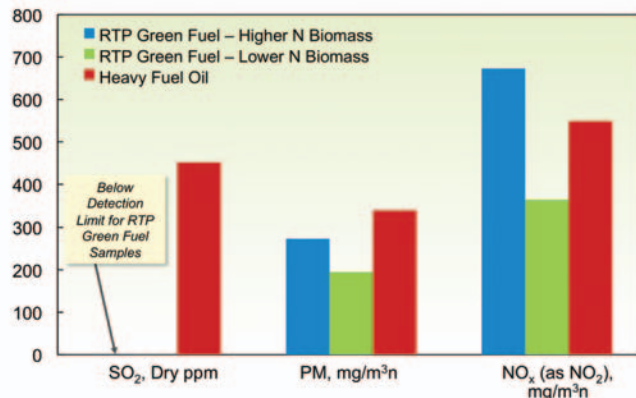
Figure 4 - Comparison of GHG Emissions - Cradle to Delivered Energy, and Burned



production through combustion.

Other hazardous air pollutants such as SO_x are dramatically reduced when burning RTP green fuel. NO_x emissions can also be lower than heavy fuel oil, depending on the level of nitrogen in the biomass feedstock. **Figure 5** shows the SO_x, NO_x and PM emissions for RTP green fuel made from biomass with two

Figure 5 - Emissions Corrected to 3% O₂



different nitrogen contents, compared to heavy fuel oil.

CONCLUSION

The production of RTP green fuel from lignocellulosic biomass has been commercially practiced for 25 years. RTP green fuel offers the unique opportunity to generate renewable energy from biomass in the liquid form, with its inherent logistical and environmental benefits, in addition to the benefits relative to burning heavy fuel oil.

Envergent Technologies stands ready to evaluate your project and support your production and utilization of RTP green fuel to generate renewable energy.

ABOUT ENVERGENT TECHNOLOGIES

RTP technology is delivered by Envergent Technologies, a joint venture between Honeywell's UOP and Ensyn Corporation, combining nearly 100 years of refining and process technology development from UOP and more than 25 years of commercial RTP experience from Ensyn. The technology is currently in use in several commercial biomass processing plants in the U.S. and Canada. Ensyn is a producer of renewable liquid fuels and chemicals from non-food biomass with more than 30 million gallons produced to date. UOP is a leading licensor and supplier of process technology, catalysts, adsorbents and services to the petroleum refining, petrochemical, gas processing and biofuels industries.

