



### **Description:**

- Frontier Applied Sciences, Inc. (FAS) has patented a unique technology, trademarked FASForm™, that employs Solid Carbon Fractionation™ using a Solid-vapor Reactive Fractionator™ to generate low cost, environmentally-compliant products from the most abundant and extensively used energy sources in the world: coal, lignite, oil sands and other solid high carbon resources.
- For each metric ton of feed stock, FASForm™ recovers 228 (US coal) to 310 (lignite) liters of low cost, segregated liquid hydrocarbon transportation fuels. In addition, 0.62 (US coal) to 0.47 (lignite) metric tons of an EPA-compliant, dewatered, high energy solid fuel or coke is recovered in the same unit operation.
- Like high volume, horizontal hydraulic fracturing (“fracking”) of oil and gas reservoirs, FASForm™ will revolutionize the world’s energy markets. Its feed stock is more diverse and accessible, it is more environmentally sustainable, and its breakeven costs and risk profile are lower than fracking.

### **FASForm™ Competitive Advantages:**

- FASForm™ is a simple, low impact approach that capitalizes on stable feed stock, processing and capital costs, to achieve acceptable profitability at liquid transportation fuel prices equivalent to less than \$20/barrel crude. Returns at higher crude prices are very attractive.
- Crude oil price is the only significant factor affecting profitability. FASForm™ is only moderately sensitive to capital cost and nominally sensitive to feed stock price.
- This is a zero discharge system that provides net environmental improvement to the full energy cycle. Complementary to the expanded use of carbon-free energy, FASForm™ is a rational solution to use an existing asset base to meet the Paris climate accords of 2015 (COP 21), the Clean Power Plan of 2015, and similar greenhouse gas reduction initiatives in other industrialized countries.

### **Investment and License Opportunities:**

FAS is seeking investment in its first profitable plant or a country or region-specific license. These options could be combined.

- Investment: FAS is seeking funding for the US\$50 million development, construction and startup of a scalable and profitable 2,500 short ton or st (2,230 metric tons or mt)/day raw coal to clean fuels facility at a secured site in Arizona (First Plant) for an equity share in FAS and the plant.
  - The development and implementation schedule is 24-36 months.
  - Phase 1 cost for pre-construction bankable documents is \$7 million with the potential for conventional project finance for Phase 2, the First Plant EPC, for the remaining \$43 million.
  - This site is likely expandable to 15,000 st/day or more. Other sites consistent with investor priorities can still be considered.
- License: FAS is also seeking long term, exclusive licensor(s) to deploy FASForm™ technology into specific countries for a success-based license fee and a royalty on gross revenue.
  - A FEED package will be developed for specific projects, technology enhancements will be included for the term, and FAS’ technology and capital project development and execution team will be available for technical assistance.



### **Potential Returns:**

- Investment: The First Plant investment will have priority, venture-level returns from FAS and a special purpose company that will generate \$82 million in revenue, \$25 million in annual earnings before interest, taxes, depreciation and amortization (EBITDA) and an EBITDA internal rate of return (IRR) of 43% at product prices equivalent to \$50/barrel WTI crude.
  - First Plant investors will also receive a stake in FAS and its planned rollout of 6 larger plants by 2023.
    - By Year 20 (planned plant life is 30 years), FAS could be generating nearly \$5 billion in EBITDA and have an expected enterprise valuation of nearly \$19 billion.
    - The capital cost of larger plants (15-25,000 st/day) ranges from \$155-210 million with EBITDA IRRs two to three times that of the First Plant.

## Frontier Applied Sciences Summary

- Assumed market share in the first 20 years is less than 2% of current market allowing excellent growth potential.
- License: The returns to licensors are all profits less royalty from plants built using FASForm™ technology in that country.

### **Technology:**

- Simple, low cost partial pyrolysis process using a specially-designed fluidized bed reactor operating in a reducing atmosphere (no combustion or CO<sub>2</sub>) at slightly positive pressure and moderate temperature.
- Volatile hydrocarbons are recovered at yields validated by prior art. Only nominal amounts of fixed carbon are converted.
- Operates 24/7 matching the operating reliabilities of the product end users.
- Continuous generation of segregated products is a unique and disruptive change to existing, proven technology.

### **Products:**

- The First Plant using Southwest US sub-bituminous coal will yield:
  - Over 44 million combined gallons (166 million combined liters)/year of semi-refined propane/butane (LPG precursor - 5% of total), naphtha (chemical feed stock or gasoline precursor - 25%), kerosene (jet fuel precursor - 30%) and diesel (40%) as segregated streams with an aggregate production cost of \$0.81/gallon (\$0.21/liter), and
  - Nearly 530,000 st (454,000 mt)/year of a clean, dewatered, high energy solid fuel that can replace non-complaint raw coal and lignite in power and industrial plants at less than current generation costs in a 170 MWe (85,000 households) power plant and meet proposed EPA emissions rules. It can also be sold as petroleum and, possibly, metallurgical coke.
- Liquid and solid product yields vary with feed stock, but are comparable. Low rank coals and lignite are the cheapest to procure and have the highest product yields.
- The First Plant is a single module. Larger commercial plants of 6-10 times the First Plant size will have multiple or larger modules and transportation fuel production costs in the \$0.39-0.47/gallon (\$0.10-0.13/liter) range.
- FAS has assessed multiple feed stocks representing a range of what is possible with FASForm™. The following table summarizes plants that can produce sufficient solid product to generate 1,000 MWe in standard super-critical coal-fired power plants.

Feed Stock	Feed (million mt/year)	Total Liquid Products (million liters/year)	Clean Solid Fuel (million mt/year)	Raw Coal to Solid Fuel Upgrading (Kcal/kg)
SW US Sub-bituminous Coal	4.35	991	2.68	4,901 to 6,622
German Lignite	5.89	1,828	2.74	4,135 to 6,472
SE Asian High Moisture Coal	7.25	1,630	2.39	3,529 to 7,416

### **Risk Mitigation:**

- The extraction from coal of its volatile hydrocarbon component as synthetic crude has been proven since the early 1900s. The Solid Carbon Fractionation innovations are the continuous, in-process fractionation of the extracted hydrocarbons into separate fuels streams. These innovations are grounded in straightforward refinery and fluidized-bed reactor engineering and FAS has conducted bench testing to validate them.
- FAS's team has nearly 100 years of experience in technology commercialization, energy project development and complex project execution.
- The largest risk – liquid fuel product market - is dependent upon crude oil prices. The FASForm™ plants summarized above have EBITDA IRRs of 48-81% at \$20/barrel crude.

### **Target Markets and Customers:**

- FAS is targeting Australia, Canada, China, Germany, India, Indonesia, Japan, Russia, South Africa, the UK and the US based upon intellectual property position, market and enabling politics.

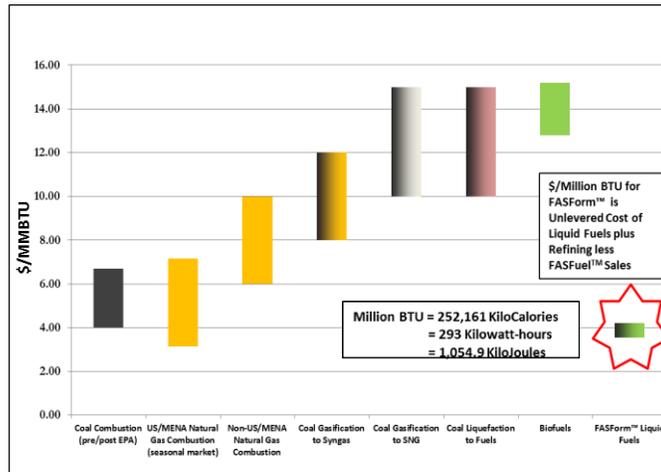
# Frontier Applied Sciences Summary

- Target customers are energy companies seeking new transportation fuel sources; large volume fuel buyers such as refineries and airlines seeking long term price hedging; utilities or independent power producers (IPPs) with significant fossil fuel-fired power generation capacity and regulatory challenges; metallurgical companies seeking lower priced coke resources; and coal, oil sands and other high-carbon resource mining companies seeking to enhance their product value and expand their sales.

## Intellectual Property:

- Patents have been granted in South Africa, China, Russia and Germany (the latter extending to the rest of the European Union - Austria, Belgium, Bulgaria, Croatia, Republic of Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the UK).
- Applications are pending in the US, Canada, Australia, India and Indonesia.
- Disclosures have been made in another 139 countries under the International Patent Cooperation treaty.

## Synthetic and Fossil Fuels Comparative Costs:



## FASForm™ is not Coal Liquefaction or Gasification:

Parameter	FASForm™	Coal Liquefaction or CTL
Operating Temperature	1,000-1,200°F – standard materials of construction and straightforward construction methods.	1500-2500°F requiring special materials and construction methods.
Operating Pressure	3-5 bar (45-75 psi) to maintain positive reducing atmosphere	150-200 bar (2,200-3,000 psi) and requiring special materials and construction methods.
Process	Partial pyrolysis with only minor chemical reaction – essentially vaporization of volatiles and fractionation/condensation of liquid products. No conversion of fixed carbon.	Chemical conversion of all of the carbon and additional chemical processing of the liquid products.
Technology Status	Extraction of volatile hydrocarbons is proven. FASForm™'s innovation is continuous production of segregated liquid fuels and solid fuel in the same reactor.	Process has been proven and operated on a large scale. However, the product cost is prohibitively high due to capital and operating cost.
Capital Cost	Less than \$10,000/daily barrel of liquids.	\$125-150,000/barrel of liquids (Alter-NRG was \$112,500/daily barrel in 2007).
Operating Cost	Other than coal, nominal requirements of natural gas for startup and only makeup water. As the number of unit operations is small, the direct O&M costs are low.	Requires large amounts of external energy and water. The process is complex requiring higher direct O&M costs.
Products	Produces semi-refined fuel gas, propane/butane, naphtha, kerosene and diesel products as well as a dewatered, EPA-compliant, higher energy solid fuel (the fixed carbon).	Direct liquefaction produces a synthetic crude mixture that requires substantial additional refining. Indirect liquefaction can produce segregated liquid products with additional and expensive Fischer-Tropsch processing of gasification syngas. No usable solid products are produced.
Liquid Product Cost	\$0.45-0.55/gallon finished products. First Plant will be \$0.75/gallon due to small scale.	\$1.60-1.90/gallon. Unless there are strategic reasons for use (e.g., South Africa), crude prices of over \$100/barrel are required to make this viable.
Footprint and Environmental Impact	Small footprint due to simple process and zero discharge system. No carbon dioxide or ash is produced.	Larger footprint due to complexity with gaseous and water emissions. Toxic catalysts are used and ash is produced. Significant carbon dioxide is produced.