NGS, BOR WRO <ngs@usbr.gov>

Comment for NGS-DOI Listening Session - New Technology Solution

1 message

Doug Pitts [redacted] Wed, May 17, 2017 at 5:49 AM
To: ngs@usbr.gov
Cc: Matthew McKean <[redacted]>, Mark Lewis [redacted], Mike Outlaw [redacted], doug.pitts@frontieras.com, [redacted], Kevin Richards [redacted]

A first-of-a-kind coal slurry pipeline opened the Kayenta mine in the early 1970s and, with the construction of NGS shortly thereafter, initiated a period of sustained economic growth for the Navajo Nation, the Hopi and Arizona. New technology can do this again. Frontier Applied Science's (FAS) Solid Carbon Fractionation (SCF) process could be a viable solution to solving the current NGS crisis. It's deployment could keep NGS open, actually increase coal production while reducing carbon emissions, and generate new jobs and economic development for the Navajo Nation/Hopi/Arizona. Unlike renewable energy and more expensive clean coal technologies such as gasification, liquefaction and carbon sequestration, SCF is profitable in the current economic environment without subsidies. SCF can compete with or undercut natural gas as a competitive fuel.

The profits and new capital base from an SCF plant at NGS/Kayenta could be used to fund critical regional infrastructure including a new railroad that would add industrial opportunities to Northern Arizona and, eventually, allow export of a clean, competitive fuel to the Pacific Basin. These latter attributes are consistent with the Trump administration's plan to use energy to reduce US balance of payments and fund US infrastructure. This business model could also work for other potentially stranded coal assets in the US.

A summary of the SCF approach for NGS is attached.

FAS is a technology startup currently focused on funding, from private equity and strategic investors, a $10 million development program that will allow starting design and construction of a commercial facility in 15 months. This facility could be operating in 30-36 months. We do not seek long term subsidies as our technology is self-sustaining. However, we would hope to work with DOI and DOE in providing assistance in our development program.

Thank you.

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www.FrontierAS.com (Ctrl+Click)

Equity Opportunity: https://angel.co/frontier-applied-sciences-1 (Ctrl+Click)

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https://www.linkedin.com/in/doug-pitts-p-e-0a710411/ (Ctrl+Click)

Far better is it to dare mighty things, to win glorious triumphs, even though checkered by failure... than to rank with those poor spirits who neither enjoy nor suffer much, because they live in a gray twilight that knows not victory nor defeat - Theodore Roosevelt

FAS NGS Presentation 050817.pdf
1343K

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Low Cost Clean Fuels Technology
April 2017
(in US$ unless noted)

Solid Carbon Fractionation (SCF) Technology

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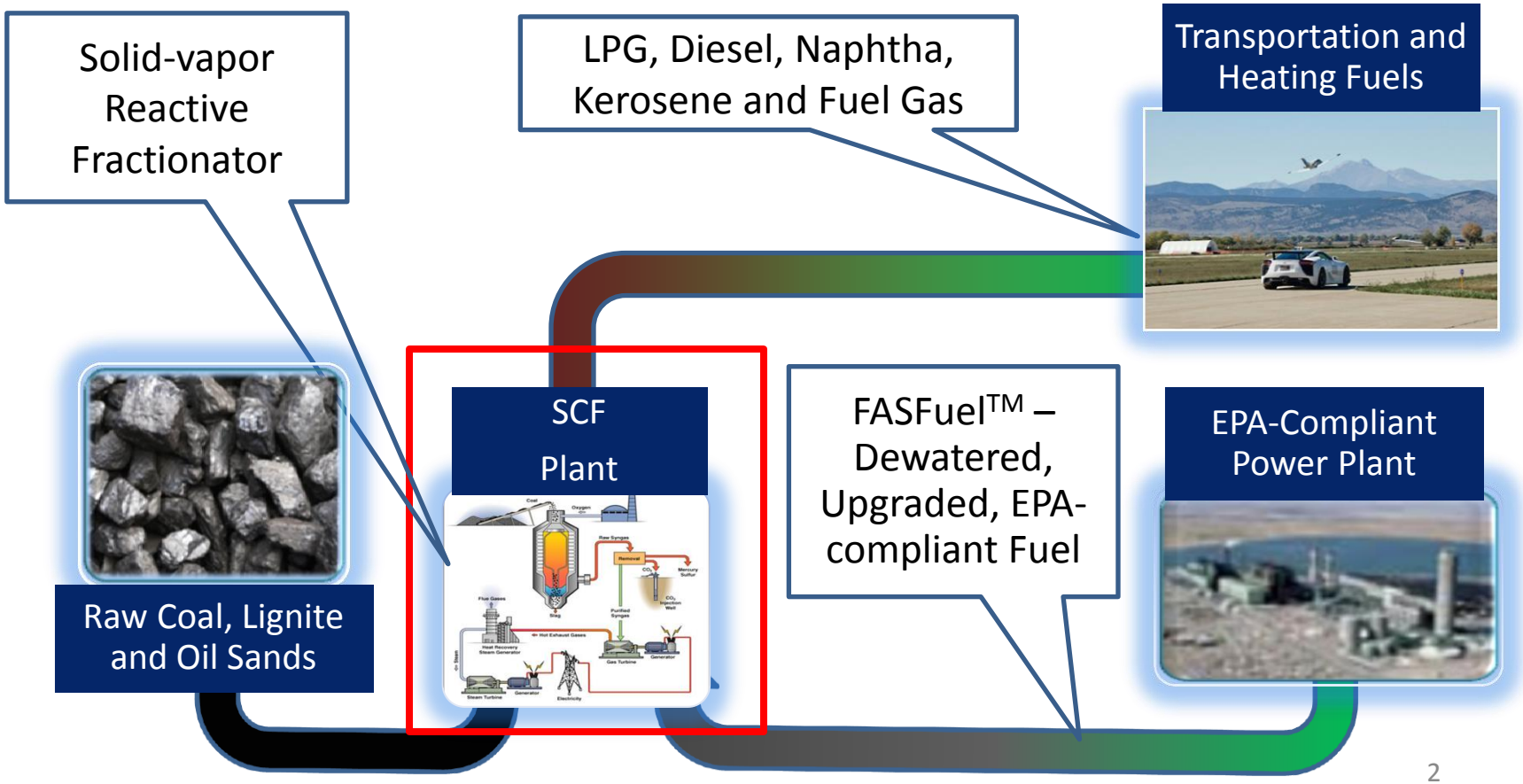
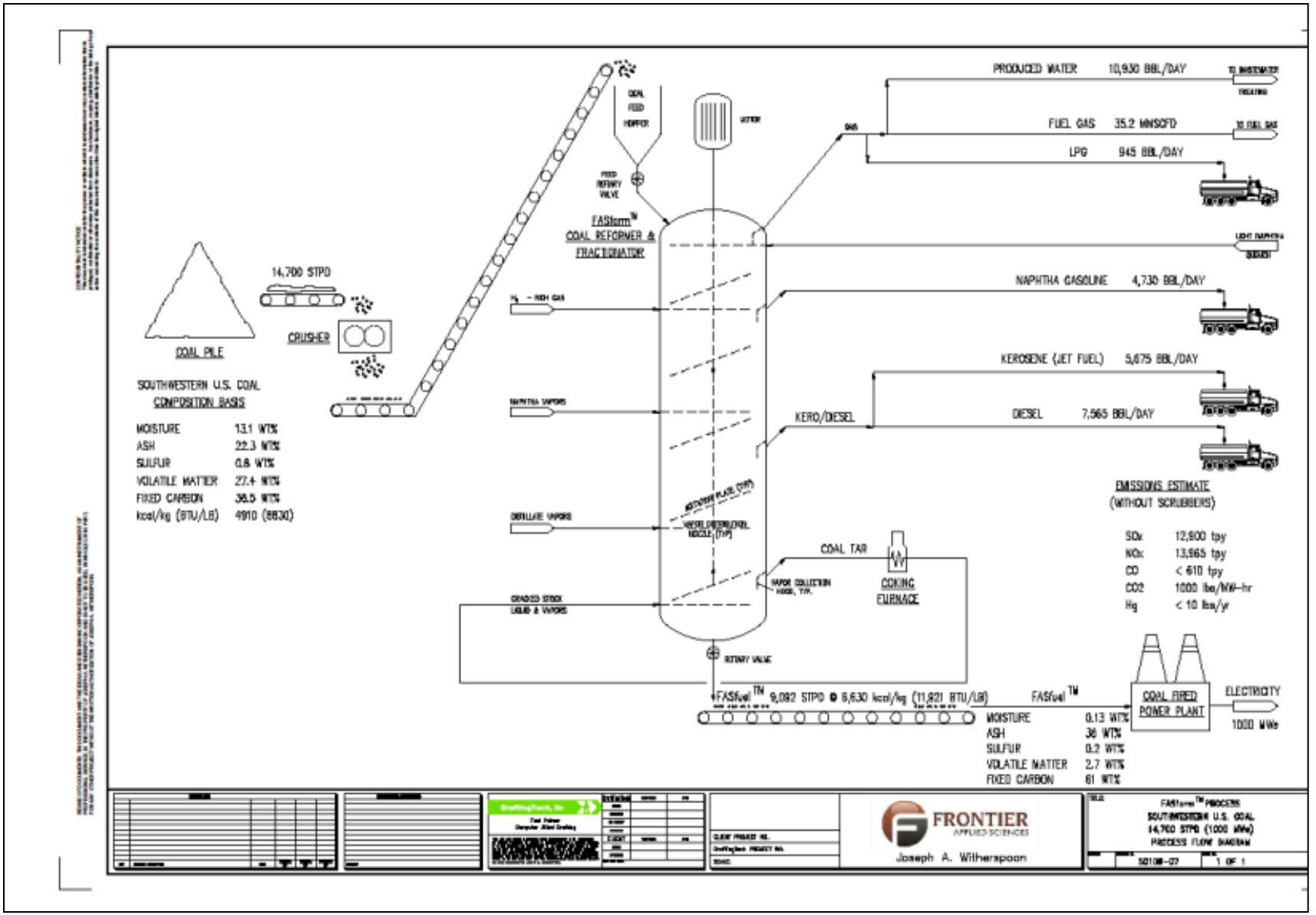
SCF recovers the roughly 30% of existing volatile hydrocarbons in coal as segregated LPG, gasoline, jet fuel and diesel fuel precursors. The roughly 35% of fixed carbon remaining is <u>not</u> converted and remains as a dewatered, high-value, clean solid fuel.



SCF Process Flow Diagram: 14,700 sptd raw coal feed producing solid fuel for 1,000 MWe



First Commercial SCF Plant
3d Rendering: 2,500 stpd raw coal feed

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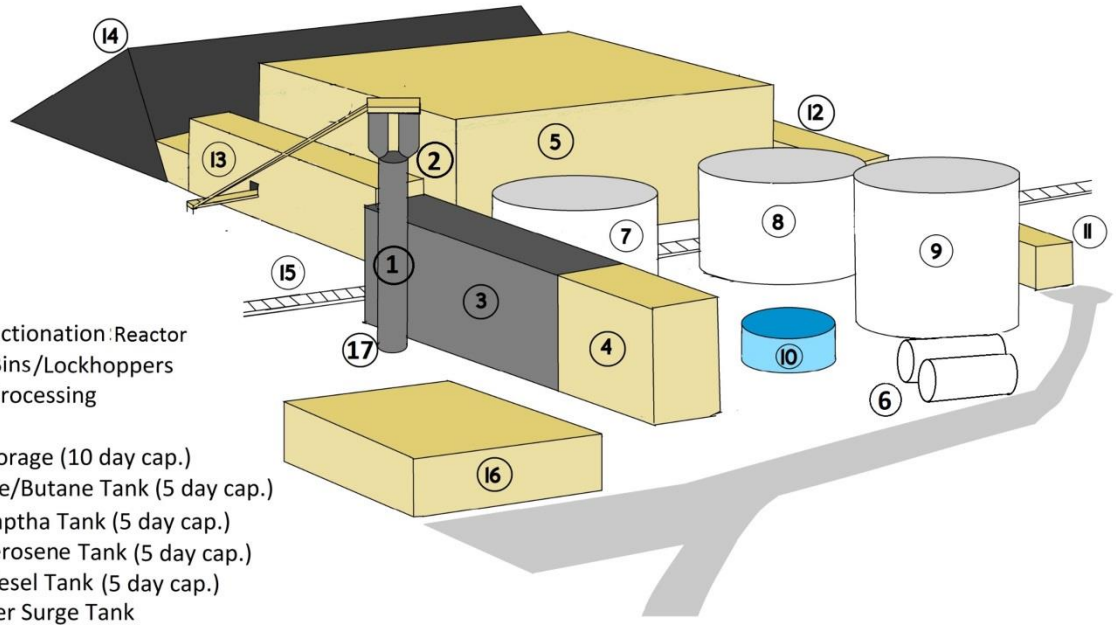
SOLID CARBON FRACTIONATION (SCF)
Rendering based on conceptual design - subject to change in basic/detail engineering

- Support/Access/Maintenance for SCF, Liquid Processing, Utilities will be 5-story structure
- At 37m (121ft), the height is 60-70% of Novo power block
- 100m (328ft) deep x 66m (216ft) wide footprint



1 Solid Carbon Fractionation Reactor
2 Raw Coal Feed Bins/Lockhoppers
3 Liquid Product Processing
4 Utilities
5 Solid Product Storage (10 day cap.)
6 Finished Propane/Butane Tank (5 day cap.)
7 Semi-refined Naptha Tank (5 day cap.)
8 Semi-refined Kerosene Tank (5 day cap.)
9 Semi-refined Diesel Tank (5 day cap.)
10 Produced Water Surge Tank
11 Liquid Product Rail/Truck Loading
12 Solid Product Rail Loading
13 Raw Coal Unloading/Transfer Conveyor to SCF
14 Raw Coal Storage (5 day cap.)
15 Rail Spur (existing)
16 Control Room/Office/Laboratory
17 Solid Product Lockhopper/Cooling and Underground Conveyor to Solid Product Storage

Plant processes 2,270 mtpd (2,500 stpd) raw coal and produces 1,399 mtpd (1,542 stpd) solid product; 206,988 lpd (1,282 bpd) diesel; 155,281 lpd (962 bpd) kerosene; 129,381 lpd (801 bpd) naphtha; 25,887 lpd (160 bpd) propane/butane

Graphic Courtesy of Joseph Pitts, FAS Intern, 7/8/16

SCF Technology

- **Moderate temperature/low pressure thermal cracking process:**
  - **Recovers volatile hydrocarbons and produces dewatered, high energy, clean solid fuel.**
  - **Much less expensive than coal to liquids technologies (<10%/daily liter) – no produced CO_2, no makeup water, no catalysts or toxic waste.**
- **Recovers 1.3 barrels (54 gal – 203 liters) of liquid transportation fuels per short ton raw coal:**
  - **40% diesel, 30% kerosene (jet fuel), 25% naphtha (gasoline), 5% propane/butane (LPG) in segregated, semi-refined product streams.**
- **Produces 0.6 short ton solid fuel per short ton raw coal that meets new EPA emissions guidelines for SOx, NOx, CO and Mercury:**
  - **30%+ reduction in combustion CO_2.**
  - **Solid fuel is dewatered upgrading the BTU/lb content by 35%.**
  - **High energy, clean fuel with low surface/marine transport costs – competitive export commodity in Pacific Basin.**

SCF Technology(2)

- **Extraction of liquid fuels from coal as syncrude is proven since early 1900s.**
- **SCF's continuous fractionation of liquid products will be validated in a 12-15 month, $10 M pilot plant program:**
  - **Proof of Concept and liquid/solid product samples in 3-6 months**
  - **Investor-grade performance test for commercial plants in 12-15 months.**
  - **Negotiating with equity investor for funds.**
- **Recovered inherent moisture to be treated and used for industrial purposes – SCF is "zero discharge" and low footprint.**
- **SCF is very profitable:**
  - **Liquid fuel production cost is less than $25/barrel crude oil equivalent (current WTI crude is $50).**
  - **Solid fuel can be provided to NGS for free and SCF IRR is still 49% due to liquid revenues.**
  - **NGS can compete with natural gas now, but SCF makes it very compelling.**

SCF Technology(3)

- **Patented in Australia, Germany, South Africa, Indonesia, Russia and China.**
  - **Pending in the US, India and Japan.**
  - **Disclosures registered in 139 additional countries.**
- **Frontier Applied Sciences is Arizona-based.**
- **Core FAS team is competent in energy and process applications, technology commercialization and design/construction of capital projects.**
  - **Advisory board brings local relationships, project finance, and knowledge of similar technology ventures.**
- **On the website at www.FrontierAS.com, there is an 8 minute audio clip by Matt McKean, one of our founders and our chairman, that summarizes our technology at http://frontieras.com/technology/learn-more-about-fas-breakthough-technology/ .**

SCF Benefits to Navajo Nation and Stakeholders

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- **Application of SCF to NGS could extend life:**
  - **Improved emissions and reduced carbon footprint.**
  - **Possible similar application to NTEC/Four Corners in NM.**
- **Improved asset base for new NGS investors.**
- **Increase coal mining at Black Mesa by 20%.**
- **Cash flow and collateral for coal export venture and other infrastructure.**
- **Increased regional investment opportunities:**
  - **Smaller, but profitable and scalable, SCF plant can be built at Black Mesa transfer terminal – additional or larger modules can be added to meet all NGS requirements and later exports.**
  - **Clean solid fuel transport to NGS by existing rail system.**
  - **Later liquid fuel refining to finished products can be built at same site.**
  - **Coal export terminal can be built at same site when rail link to BN completed.**

SCF Benefits to Navajo Nation and Stakeholders(2)

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- **More skilled and unskilled jobs – related Navajo Nation and regional economic development.**
  - **Indirect economic benefit of 3 times direct.**
  - **Higher property tax base.**
- **Continuing use of low cost coal will reduce Arizona's dependence on more volatile, imported natural gas and solar/wind.**
- **NGS liquid fuel production could replace 15% of Arizona's fuel imports (only state in the US without a refinery) at lower cost.**
- **Coal and fuel exports could improve US balance of payments and pay for critical US infrastructure.**
- **Lower cost locally-sourced diesel fuel is available for Black Mesa and other SW US mining operations.**
- **Eliminate/mitigate "stranded asset" issue for current NGS owners and ratepayers.**

SCF Has Very Compelling Economics

Only significant profit sensitivity is to crude (product) price.

- **Moderate sensitivity to capital cost.**
- **Low sensitivity to feed stock and O&M costs.**

Scalable First Plant (170 MWe) Annual EBITDA (SW US coal):

WTI Crude $/Barrel	EBITDA - All Equity ($ million)	EBITDA IRR - All Equity %
30	12	23
50	27	44
70	41	64

Note: all debt funding reduces IRR to 17-55%.

Larger Plant (1,000 MWe) Annual EBITDA (range is SW US coal to German lignite – 50% debt):

WTI Crude $/Barrel	EBITDA - All Equity ($ million)	EBITDA IRR %
30	158-323	64-100
50	246-486	94-142
70	334-650	121-182

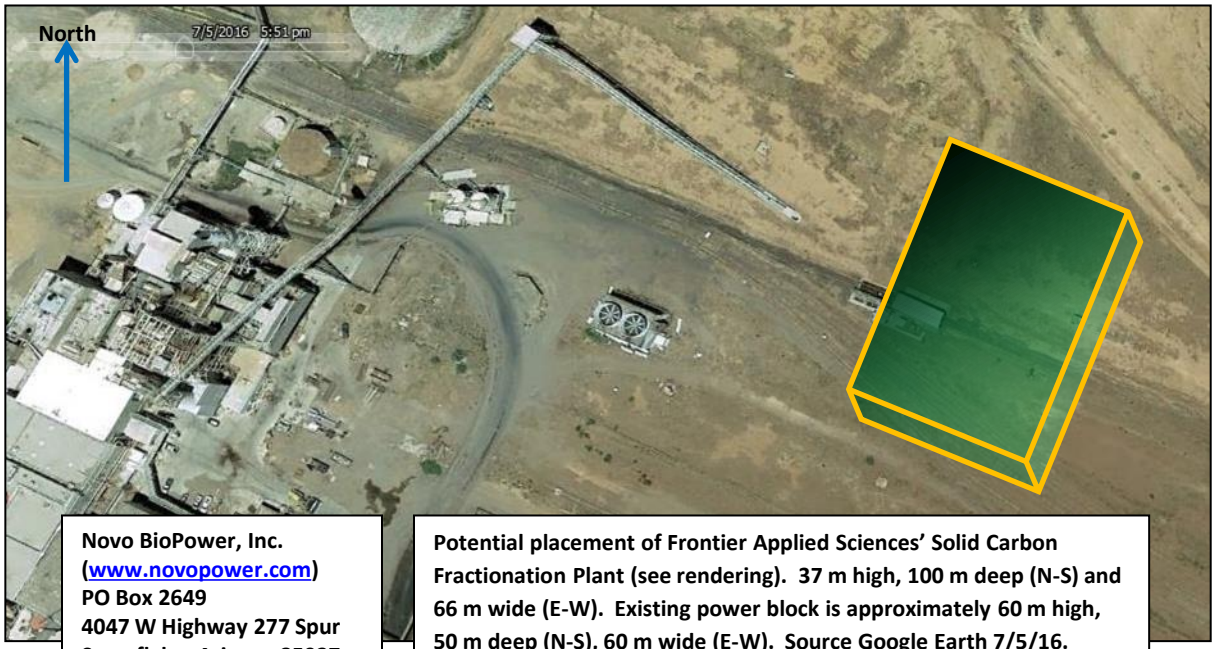
SCF Real World Scenarios

Feed Stock – Solid Fuel for Power Plant in MWe	Raw Coal Feed in million mt/year	Total Semi-refined Liquid Products in million liters/year	Clean Solid Fuel Product in million mt/year	SCF Plant Total Installed Cost in $ million	SCF Plant Annual Gross Revenue in $ million	SCF Plant Annual EBITDA in $ million	SCF Plant EBITDA IRR	EBITDA/ Gross Revenue	Aggregate Liquid Production Cost in $/liter
First Commercial Plant – 170 MWe using SW US sub-bituminous Coal	0.74	166	0.45	$40	$79	$27	44%	44%	$0.20
Existing NGS Coal Plant (US) – 2,250 MWe using SW US sub-bituminous coal	9.70 (current 8.10 raw coal, but no liquid fuels are produced)	2,180	6.00	$300	$1,100	$545	94%	49%	$0.12

Notes: 1. Financials based on fuels from $50/barrel WTI crude
2. NGS Case based on Four Corners Coal

Potential First Commercial SCF Plant Location

- Feb 2015 letter of intent with Novo BioPower for commercial prototype near Snowflake, AZ.
- Novo BioPower, which operates a biomass to energy plant at the site, will be FAS' JV partner.
- Existing rail and truck access, utilities and other necessary infrastructure. An 80 MWe coal-fired power plant operated at the site until 2012 and most of the equipment remains.



Novo BioPower, Inc.
(www.novopower.com)
PO Box 2649
4047 W Highway 277 Spur
Snowflake, Arizona 85937

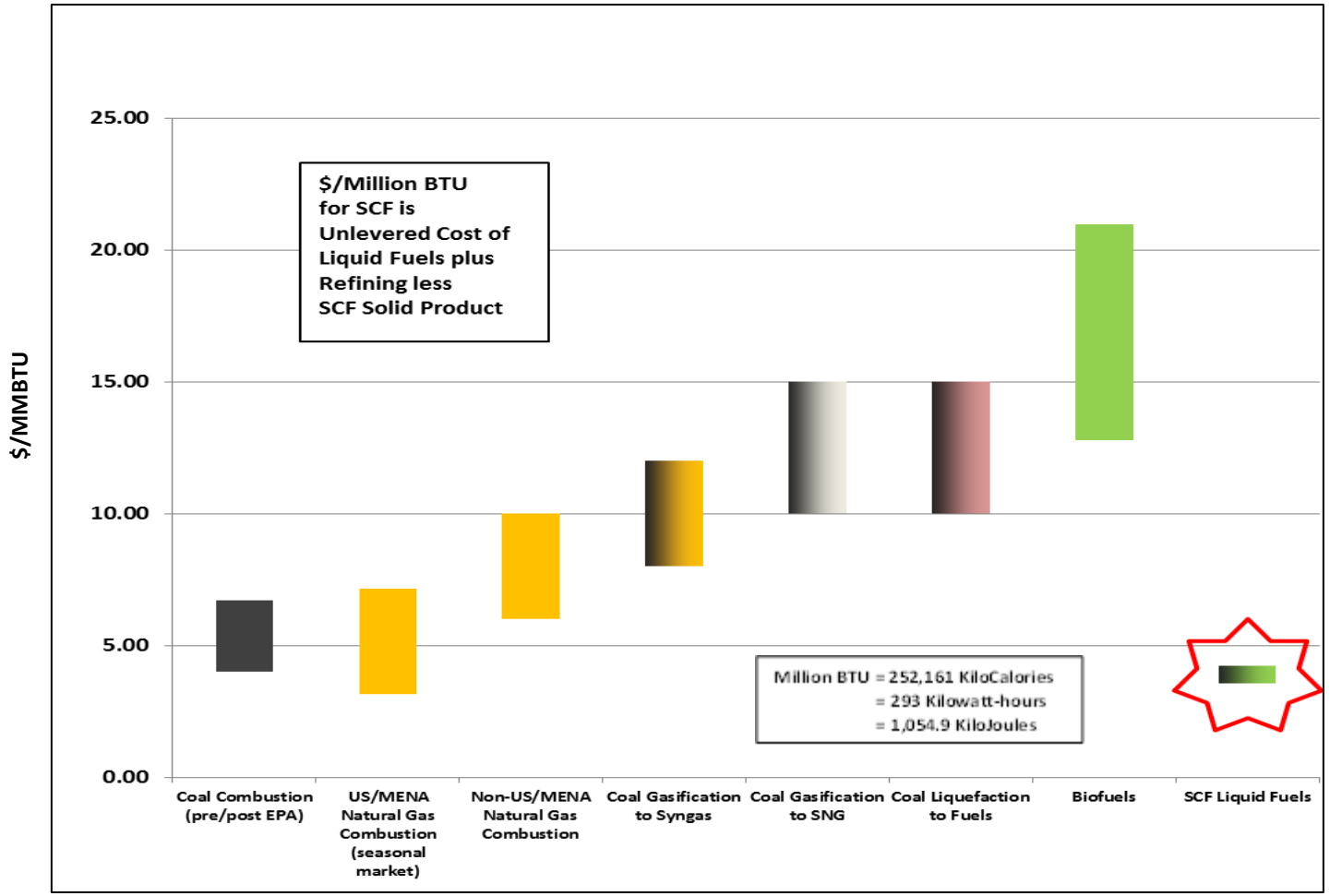
Potential placement of Frontier Applied Sciences' Solid Carbon Fractionation Plant (see rendering). 37 m high, 100 m deep (N-S) and 66 m wide (E-W). Existing power block is approximately 60 m high, 50 m deep (N-S), 60 m wide (E-W). Source Google Earth 7/5/16.

- Plan to build out site as a clean carbon R&D center to develop technology for expedited permitting.
- $50 million investment opportunity generating annual revenue of $79 million, EBITDA of $27 million and $19 million NIAT at $50 crude oil prices - 35% EBITDA IRR at 100% debt (44% all equity).
- Scalable (<10 x carbon feed) size for larger plants that can demonstrate technical and financial viability.
- FAS can build the First Plant at other locations (such as Kayenta for NGS) based on investor preferences.

SCF First Plant (2,500 stpd Process Demonstration Unit or PDU) Uses of Funds and Schedule

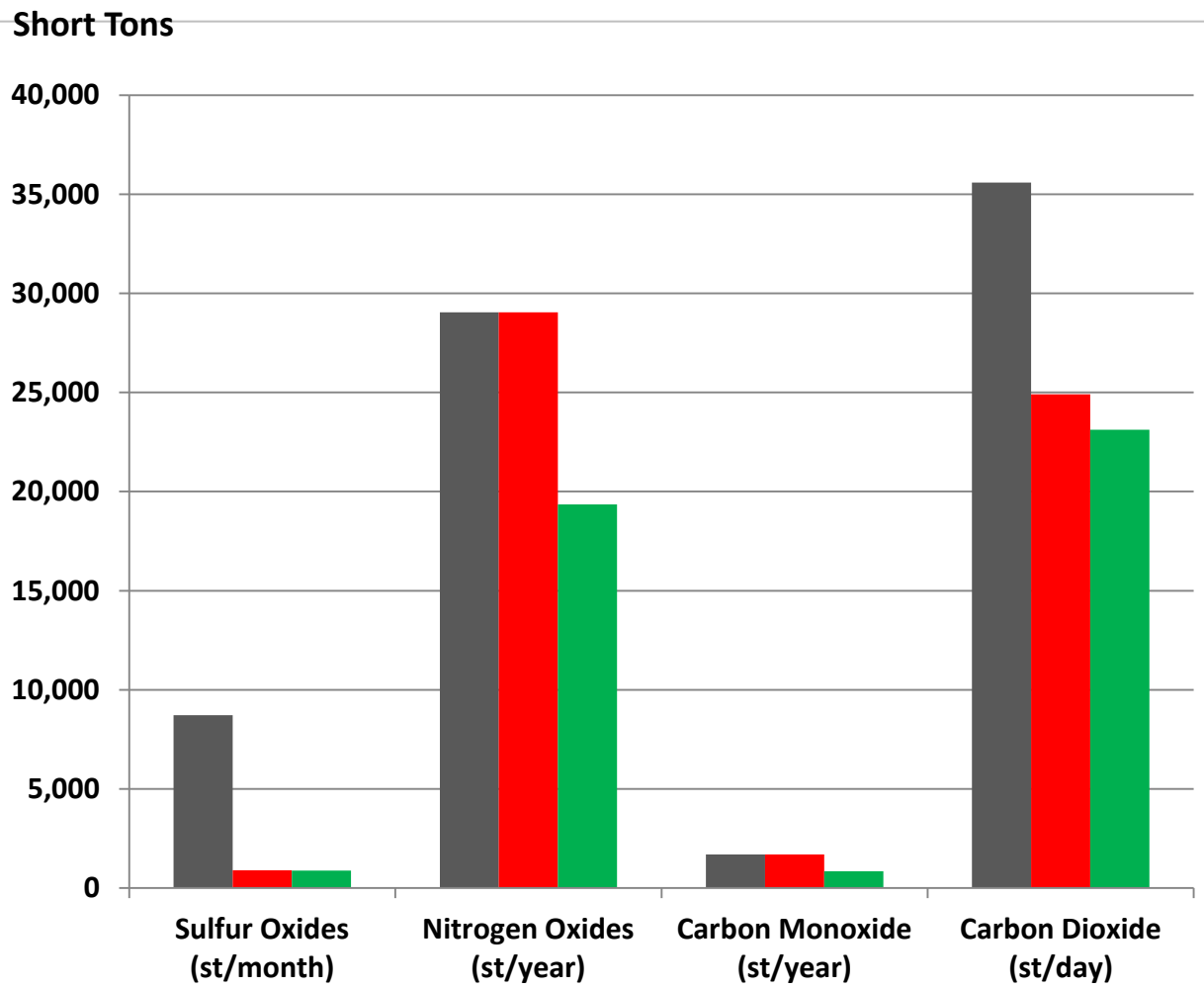
		Quarters from Initial Funding Closing											
		Phase 1 - Development						Phase 2 - PDU Installation/Operation					
Deliverable	Deliverable Cost	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Core Development Team and Overhead (excludes third party)	$9,307,167												
Core Team Headcount (excludes third party)		8.6	9.0	9.3	9.4	10.3	11.1	12.5	12.5	12.5	12.5	12.5	12.5
Expand Intellectual Property	$250,000												
Third Party Feasibility Study	$400,000												
PDU Agreements with Novo Power	$114,000												
Vendor, Pilot and Other Confirming Assessments	$450,000												
PDU Feedstock Purchase and Transportation Agreements	$180,000												
PDU Product Sale Agreements	$180,000												
Front-end Engineering and Design (FEED) and Bankable Documents for PDU	$1,140,239												
Third Party Engineer	$57,071												
Wrap Insurer Engineering Report	$28,565												
Investment Banker Due Diligence	$68,485												
Preliminary PDU Site Improvements	$709,575												
PDU Permitting	$214,024												
Builder's Risk Insurance	$190,000												
PDU Detailed Engineering	$1,853,988												
PDU Equipment and Subcontract Procurement Services	$1,081,114												
PDU Construction Management Services	$1,457,321												
PDU Equipment and Materials Delivery	$16,258,950												
PDU Construction	$13,848,166												
PDU Startup/Initial Operations	$696,334												
PDU Funding Costs	$1,515,000												
Total Funding by Quarter	$50,000,000	$958,687	$742,437	$794,037	$827,320	$1,740,503	$1,829,604	$6,782,759	$9,411,680	$11,879,426	$8,364,707	$4,699,255	$1,969,586
Total Funding by Phase		$6,892,587						$43,107,413					

SCF Comparative Energy/Fuel Costs



With FAS' competitive costs, the market is very large.
SCF/FASForm™ is profitable at crude oil down to $25/barrel.

SCF Solid Fuel Meets New EPA Emissions Standards



Volatile Mercury reduced from 70 lbs/year to less than 10 lbs/year with FASFuel™. Similar results expected for other volatile metals such as Arsenic and Selenium.

Addition of scrubbers further reduces emissions with FASFuel™ for:

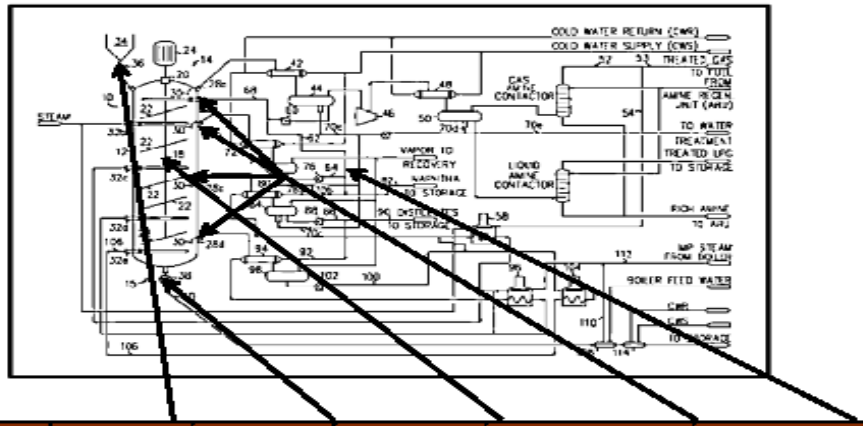
Sulfur Oxides: 90%
Nitrogen Oxides: 90%
Carbon Monoxide: 95%

Data based on Four Corners Power Plant in US.

- **Current Operation (4 Units)**
- **Allowable - New EPA Standards**
- **FASFuel Use**

FASFuel™ *meets EPA new emissions standards on SO_x, NO_x, CO and CO_2 with no other pollutants*

Manageable SCF Risk Profile



Technology Risk	Reactor Feed	FASFuel™ Recovery	Solid-vapor Reactive Fractionator	Liquid Fuels Recovery	Other Unit Operations
Proven Technology and Operations	Lock hopper – proven/low pressure drop	Lock hopper – proven/low pressure drop	Fluidized bed tech in power and metals processing	Vapor draws – proven in refining/industrial	Proven in refining/industrial
Innovation – Operations/Engineering	Proven in power and process sectors	Use of "sticky" material experience in coking and at K-Fuel	Agitation plates	Locks, housings, filters and cyclones for particulates	Proven in power/refining/industrial
Innovation - Process	Proven in power and process sectors	Proven in power and process sectors	Gas/liquid recycle streams for temperature gradient control	Proven in process sector	Proven in process sector

Figure 1 – SCF/FASForm™ Risk Profile (expanded flow diagram in Appendix 1)

SCF Comparison to Coal Liquefaction

Parameter	FAS SCF	Coal Liquefaction or CTL
Operating Temperature	538-649°C (1,000-1,200°F) – standard materials of construction and straightforward construction methods.	816-1371°C (1500-2500°F) requiring special materials and construction methods.
Operating Pressure	3.3-5.5 kg/cm³ (3-5 bar or 45-75 psi) to maintain positive reducing atmosphere.	161-219 kg/cm² (150-200 bar or 2,200-3,000 psi) and requiring special materials and construction methods.
General Process Approach	Thermal cracking – essentially vaporization of volatiles and fractionation/condensation of liquid products. No conversion of the fixed carbon.	Catalytic cracking and conversion of all of the carbon and additional chemical processing of the liquid products.
Key Processes	Solid Carbon Fractionation	POX Gasification, Fischer Tropsch Conversion, Carbon Capture, Use, Storage or Sequestration (CCUS). Indirect coal to liquids - direct liquefaction has different processes, but is similar in complexity and cost.
Number of Total Unit Operations	6 focused on liquid product separation and stabilization.	20-25 depending on process.
Technology Status	Extraction of volatile hydrocarbons from coal is proven. SCF'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, and the likely need for CCS.
Capital Cost	US$ 6-9,000/daily barrel (US$ 36-55/daily liter) of liquids excluding debt.	US$ 90-115,000/daily barrel (US$ 570-725/daily liter) of liquids (Alter-NRG in Alberta was US$ 112,500/daily barrel (US$ 710/daily liter) in 2007 - another confidential source was US$ 90-115,000/daily barrel depending on production in 2015).
Operating Cost	Other than direct O&M costs which are roughly similar at US$ 3-4,000/daily barrel (US$ 22-27/daily liter) liquids, there are only nominal requirements of natural gas for startup and a small amount of makeup water. Fuel gas recovered in process is used for most of the process energy requirement. As the consumables are low and the number of unit operations is small, the total unit O&M costs are expected to be lower.	Requires external energy up to 10% of that in produced fuels. Water requirements are high at 5-6 liters/daily liter (210-260 gallons/daily barrel) liquids. The process is complex requiring catalysis and handling of hazardous materials.
Products	Produces fuel gas used internally, and semi-refined propane/butane, naphtha, kerosene and diesel products requiring only hydro-treating (reforming for naphtha to gasoline) as well as a dewatered, EPA-compliant, higher energy solid fuel (essentially 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	US$ 0.45-0.55/gallon (US$ 0.10-0.13/liter) finished products for large scale plants at 30,000 bpd (4-5 million liters) liquids and 1,000 MWe from solid fuel).	US$ 1.60-1.90/gallon (US$ 0.42-0.50/liter) finished products. Unless there are strategic reasons for use (e.g., South Africa), crude prices of over US$ 90/barrel are required to make this viable.
Footprint and Environmental Impact	Small footprint due to simple process and zero discharge system. SCF is a net water generator from the inherent moisture removed. No carbon dioxide or ash other than that contained in coal feed is produced. In fact, net carbon dioxide emissions from combustion of solid product are 20-30% less due water removal and higher efficiency.	Larger footprint due to number of processes/unit operations and complexity with gaseous and water emissions. Toxic catalysts are used and ash is produced. Large amounts of water (5-6 liters/daily liter or 210-260 gallons/daily barrel fuels) are required. Significant carbon dioxide is produced requiring CCUS for permits.

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