Funding Opportunity Announcement (FOA) Number: DE-FOA-0001992

Project Narrative

Project Title	Experimental Validation and Continuous Testing of an On-Purpose High-Yield Pitch Synthesis Process for Producing Carbon Fiber from US Domestic Coal
FOA Area of Interest 2B	Producing High-Value Solid Products from Domestic U.S. Coal
Applicant Information	Ramaco Carbon 1101 Sugarview Dr. Sheridan, WY 82801
Technical Contact	Dr. Matthew J. Targett (b) (6) [redacted]
Business Contact	Carla Ash, CPA (b) (6) [redacted]
Sub-Recipient Information	Axens North America, Inc. 650 College Road East Princeton, New Jersey 08540
Technical and Business Contact	John Duddy (b) (6) [redacted]

Cost	**Federal Cost**	**Non-Federal Cost Share**	**Total Cost**
Applicant	$414,616	$103,654	$518,270
Sub-Recipient	$468,749	$117,188	$585,937
Total	$885,365	$220,842	$1,104,207

Table of Contents

1. Project Objectives

The overall objective of the project is to scale the development of on-purpose production of high-quality carbon fiber precursor material from U.S. domestic coal in order to significantly lower the production cost of carbon fibers. This is based on the hypothesis that low severity direct coal liquefaction (LS-DCL) synthesis of coal tar pitch can dramatically increase coal tar pitch yields, improve the quality of pitch, and enable the utilization of low cost western US coals which heretofore have not historically yielded high amounts of suitable coal tar pitch by other conventional means such high or low temperature pyrolysis. Achieving such cost reductions take advantage of a secure, plentiful domestic coal feedstock, and may significantly expand the market for pitch based carbon fiber. This objective will be accomplished by pilot-scale processing and characterization to develop a process(es) that can then be evaluated for technical and economic feasibility prior to future scale up. To achieve this goal, the project aims to:

- investigate the effectiveness of using LS-DCL, as a continuous process processing innovation to synthesize coal-tar-derived pitch, targeted for use as a carbon-fiber precursor
- qualitatively evaluate the use of this mesophase pitch to produce carbon fibers

- determine any modifications to the coal-to-tar processes that aid in the production of mesophase pitch optimized for carbon fiber production or further reduce their overall cost
- assess the engineering and economic impact of using LS-DCL and associated processes to produce carbon fibers from coal

A few points should be noted at the outset. First, to the best of our knowledge this is the first coal based "On-Purpose Pitch Process (OPPP)" on the planet. All other processes have produced pitch as a by-product of making coal to town gas, steel, fuels or chemicals. Second, coal pitch plants based on the processes described below can be built at coal mine sites and thereby realize significant logistics cost savings and employ miners and manufacturers in coal mining communities. Third, Mitsubishi and Nippon have proven that there is a significant market for the material characteristics of coal pitch based carbon fiber at prices that greatly exceed those of PAN based carbon fiber. Fourth, pitch can also be a precursor to carbon foam, synthetic graphite, graphene and other high value carbon products that have desirable thermal and electrical conductivity attributes. (b) (4) [redacted] which currently holds 96% of the total carbon fiber precursor market.

2. Merit Review Criterion Discussion

Introduction

Ramaco Carbon's proposed project, "Experimental Validation and Continuous Testing of an On-Purpose High-Yield Pitch Synthesis Process for Producing Carbon Fiber from US Domestic Coal," teams with Axens North America, Inc. Ramaco Caron has coal resources and a demonstrated vision, commercial interest and commitment to utilize coal resources to produce high value carbon-based products. Axens is a world-leader in technology development and licensing. Axens owns the H-Coal® process technology and the pilot plant facilities (at Axens wholly owned HTI) used to develop the technology. Indeed, both of the principals of this project were involved with the H-Coal pilot plant in Catlettsburg, Kentucky in the 1970s and 1980s. The fully commercial scale Shenhua Direct Coal Liquefaction Plant, located in China, was designed and started by Axens, and uses technologies licensed by Axens and HTI. (b) (4) [redacted]

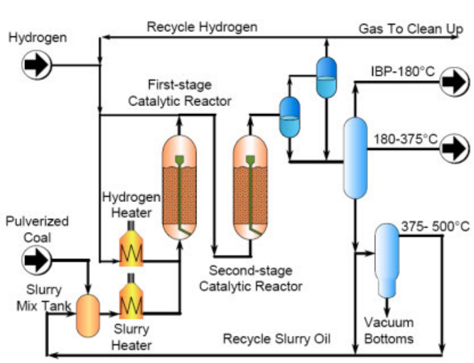
[redacted] This proposed project will provide needed testing to optimize the low-severity direct coal liquefaction conditions and validate the suitability of the carbon fiber precursor to manufacture high-yield, high-quality carbon fiber from coal.

Merit Review Criterion 1: Scientific and Technological Merit (40%)

- **Feasibility and Technology Description**

This project proposes to evaluate and demonstrate the potential of direct conversion of coal to produce a precursor suitable for producing carbon fiber. The objective is to maximize the yield of carbon fiber from coal via direct coal liquefaction. Direct coal liquefaction processes convert coal into liquids by directly breaking down the organic structure of coal. Since liquid hydrocarbons have a significantly higher hydrogen-carbon molar ratio compared to coal, DCL technologies use hydrogenation processes (with application of solvents and/or catalysts in a high pressure and temperature environment). DOE has a long history of support and success in the development of direct coal liquefaction technology. [1] [redacted]

[redacted]



[redacted]

However, this historical development was directed towards the production of liquid transportation fuels, with high levels of hydrogenation in order to increase the H/C atomic ratio the liquid fuels produced.

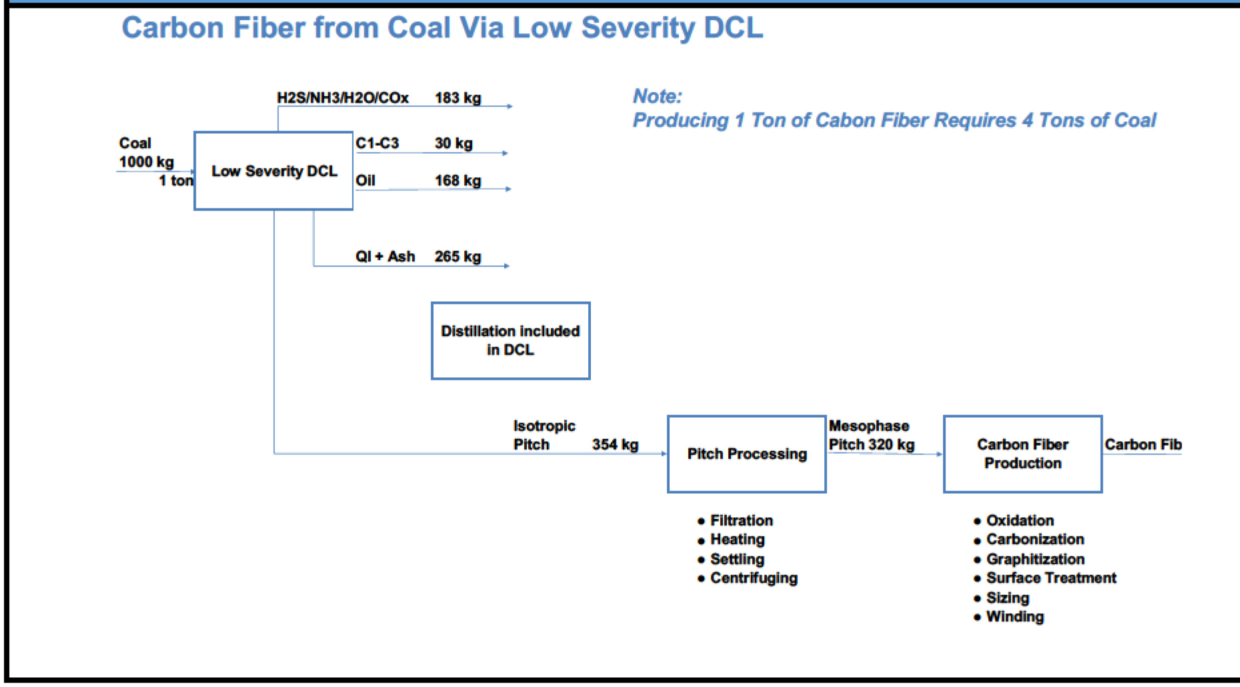
The key element to this proposed project is to demonstrate that a low-severity direct coal liquefaction process, that is soundly based on all of the H-Coal development and learnings to date, with maximum yield of carbon fiber feed precursor, can produce high quality carbon fibers. (b) (4) [redacted] As shown in the comparison below, ***the low-severity direct coal liquefaction doubles the reactor through-put, at 25 °C lower operating temperature and only one-third the operating pressure***. ***With the low severity process conditions, the product selectivity is dramatically altered, increasing the yield of the carbon fiber precursor (pitch) by an order of magnitude.***

Table 1 – Comparison of H-Coal and Low-Severity DCL		
	H-Coal	**Low-Severity DCL**
Solvent: MAF Coal Feed Ratio	Base	Base
Space Velocity (ton coal/hr/m3 reactor volume)	Base	2 * Base
Reaction Temperature, °C	Base	Base - 25
Pressure, bar	Base	Base / 3
Yield, Moisture-Free PRB Sub-bituminous coal	**DCL**	**Low-Severity**
$H_2S/NH_3/H_2O/CO_x$, W%	20.4	18.3
C1-C3, W%	8.6	3.0
Distillate Liquid Fuel, W%	57.9	16.8
Carbon Fiber Precursor (Pitch), W%	4.0	37.7
Unconverted Coal + Ash, (Quinoline Insoluble), W%	16.4	26.5
Total (100 + H2 Consumption)	107.3	102.3
Carbon Fiber Precursor (Pitch) Properties		
Specific Gravity		1.092
Carbon, W%		88.7
Hydrogen, W%		8.3
Sulfur, W%		0.3
Nitrogen, W%		1.6
Oxygen, W%		1.1

(b) (4) [redacted]

(b) (4) [redacted]

Figure 2



Each ton of carbon fiber produced requires only 4 tons of coal, (b) (4) [redacted]

- **Emphasis Area of R&D**

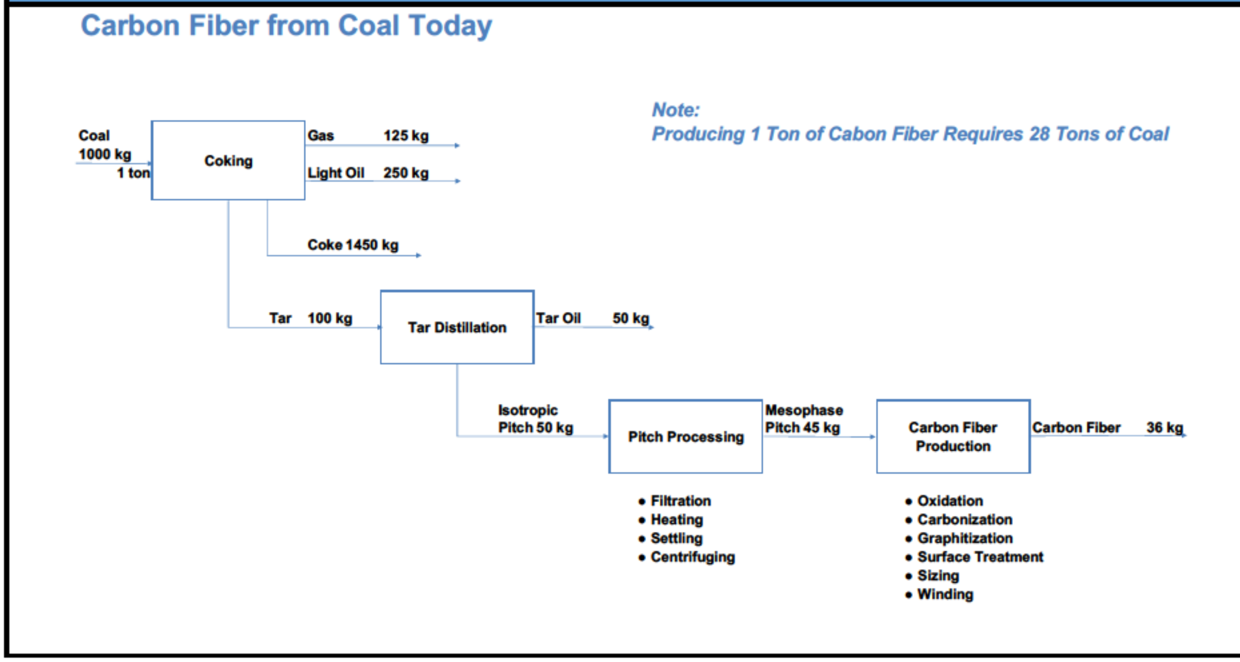
The critical emphasis area of this R&D is to prove that the pitch product produced from a low-severity direct coal liquefaction process is able to produce high quality carbon fiber in high yield and selectivity

- **Advancing the State-of-the-Art**

Carbon fiber production from coal today is based on coal tar pitch derived for coking of coal, and it is only produced in small area of Japan by Mitsubishi and Nippon as a by product of their steel making activities

(b) (4) [redacted]

Figure 3



(b) (4) [redacted]

- [redacted]

[redacted]

ton of carbon fiber. The cost of PAN is subject to the variability of the price of oil and gas and has varied between $15/lb (2013) and about $5/lb (currently). (b) (4) [redacted] The analysis is provided to assess if (1) LS-DCL can be competitive with PAN-based processing, and (2) is there potential for a significant competitive advantage for LS-DCL.

(b) (4) [redacted]

The first observation from this analysis is, there is a tremendous value proposition in coal as a carbon fiber feedstock. Coal prices range from $10/short ton for PRB coals up to $50-75/short ton for eastern thermal coals. PAN at $5/lb results in a cost of $10,000/short ton. By comparison the cost of coal in inconsequential compared to PAN especially when net carbon fiber yields are considered. To complete the economics assessment a preliminary calculation of the operating expense for the LS-DCL process was done based on prior conceptual design studies. This of course is much more significant than the cost contribution of the coal, and results in operating costs of about $450/ton of carbon fiber, however, this is still a very small amount compared to the PAN cost. (b) (4) [redacted]

The capacity of the HTI Process Development Unit (available and operational at the Axens/HTI facility in Lawrenceville, New Jersey) at a rate of about 3~6 short tons of coal per day which is an amount sufficient to produce approximately 500 short tons of carbon fiber production per year. This unit could be operated in the LS-DCL process mode. It estimated that a similar, small-scale commercial LS-DCL facility can be

[redacted]

- **Product Market Potential**

Carbon fiber and carbon fiber reinforced polymers offer weight and performance benefits that are driving demand for them. Market expectations are for increasing demand for these products across several market sectors (wind energy, aerospace, automotive and pressure vessel) by more than 10 % per year. In 2016 carbon fiber production was about 80,000 tons (metric tons in this document unless indicated otherwise). Projecting this market to 2025 assuming that costs and prices remaining at current levels, at a 10 % annual growth rate, will more than double the 2016 production and will require the addition of more than 100,000 tons of annual production capacity. Current market prices for carbon fiber vary according to the specific properties and end-use over a range of \$25/kg to more than \$100/kg, and cost analyses show that carbon fiber costs are most sensitive to utility and precursor prices. Precursor materials used to produce carbon fibers include rayon, pitch (coal-derived and petroleum-derived) and polyacrylonitrile (PAN). PAN has more than 96% of the CF market due to its historical cost-effectiveness and the quality of the fiber produced. Coal is the cheapest and most abundant source of carbon in the US, and it has a very significant and largely unexploited potential to provide the most economic source of carbon fiber precursor. [redacted] Today, carbon fiber is considered to be too expensive to be widely used in [redacted] major areas of application: [redacted] Accordingly, if a significant price drop in carbon fiber could be engineered, it is possible that the historical demand curve for the carbon fiber could shift.

- **Interface/Integration of the Coal Value Chain**

(b) (4) [redacted] Ramaco Resources is a public company which operates large prep plants for metallurgical coal (in West Virginia and Virginia. Ramaco Carbon is dedicated to environmentally sound coal to products technologies and to non-power uses for coal, and it is managed and staffed with experienced industry personnel from the mining and manufacturing industries. Ramaco's principals and related parties have worked with Axens for more than 40 years. Axens and its parent the IFP Group provide a complete range of solutions for the conversion of coal, oil and biomass to cleaner fuels, the production and purification of major petrochemical intermediates as well as all of coal and natural gas treatment and conversion options.

Merit Review Criterion 2: Technical Approach and Understanding (30%)

- **Advantages to past/current practices**

As evidenced above, the proposed technology offers a continuous process for conversion of coal to high quality pitch precursor for carbon fiber production resulting in significant cost savings and higher yields than are currently available. It represents an "On Purpose" process targeted at the production of coal pitch as the best precursor for a range of highly value added carbon products. (b) (4) [redacted]

- **Adequacy/Feasibility of Work Planned**

Please refer to Scope of work contained in Section 3 – Statement of Project Objectives, contained in this Project Narrative.

- **Project Description**

Please refer to Section 7 - Facilities and Other Resources and Section 8 – Equipment contained in this Project Narrative.

- **Feasibility of SOPO**

Please refer to Section 3 - Statement of Project Objectives contained in this Project Narrative.

- **Project Management Plan**

Please refer to PMP.pdf included with this submission.

Merit Review Criterion 3: Team Technical and Management Capabilities (15%)

- **Key Personnel/Partnering Organizations/Experience**

Dr. Matthew J. Targett, is the chief technologist at Ramaco Carbon. (b) (6) [redacted]

Mr. Charlie Atkins is the Head of Research and Development at Ramaco, (b) (6) [redacted]

Mr. John Duddy is currently Director, Heavy Oil and Coal Technology, Axens North America, Inc. (b) (6) [redacted]

(b) (6) [redacted]

Mr. Everett Harris is HTI Director of Operations Engineering. (b) (6) [redacted]

RAMACO will serve as the lead organization and prime recipient for this proposal. RAMACO has made substantial investments in U.S. coal research both directly and through its related entities, and it has ongoing strategic work to support advancement of carbon neutral and negative emissions conversion of coal as well as the development of number of productive and profitable forms of "durable carbon" or carbon sinks. RAMACO plans to create a 100+ acre "coal to products" mine-mouth industrial park called Wyoming iPark near its Brook Mine to manufacture advanced carbon products.

AXENS is a world-class technology solutions business covering the entire value chain with an integrated offer, from feasibility study to unit start-up and follow-up throughout the entire life cycle of the unit. Axens offers a complete range of solutions including: technologies, equipment, furnaces, modular units, adsorbents, catalysts and services. Axens has an extended global network for a better industrial and technical support & advanced commercial services. Axens North America has its main offices in Houston and Princeton, and manufacturing/fabrication in Georgia, West Virginia, Kentucky, Missouri and Oklahoma. **HTI Services** is wholly owned by Axens North America and operates a fully-equipped, full services R&D Center in Lawrenceville, New Jersey.

- **Facilities and Equipment**

Please refer to Section 8 of this Narrative.

- **Business and Financial Commitment**

Both Ramaco and Axens have committed experienced and highly qualified personnel and cost sharing to ensure the success of this project.

Merit Review Criterion 4: Commercialization Potential (15%)

- **TMP/Development Path**

Please refer to TMP.pdf

- **Commercial Assessment/Applicability to specific market segment/Anticipated Commercial Benefits**

This technology is currently needed by many markets. First and foremost, the [redacted] market is desperately seeking a low-cost carbon fiber for reducing weight while maintaining strength. [redacted] The total market for carbon fiber in 2011 was around 45,000 tonnes, having closely doubled in 2018 to just over 90,000 tonnes. [redacted]

- **Support of Commercial Entities**

Both Axens and Ramaco are commercial entities.

- **Roles in Commercialization**

Ramaco is the supplier of coal or coal-based feedstock to the process, owner operator of the process facility and marketer of the products generated. Axens is the licensor of the [redacted] and associated technologies, provides basic engineering design, provides selected process equipment and modules, catalysts and adsorbents and start-up/technical services support.

3. Statement of Project Objectives

Experimental Validation and Continuous Testing of an On-Purpose High-Yield Pitch Synthesis Process for Producing Carbon Fiber from US Domestic Coal

A. OBJECTIVES

The objective of this work "Experimental Validation and Continuous Testing of an On-Purpose High-Yield Pitch Synthesis Process for Producing Carbon Fiber from US Domestic Coal," is to develop technology that converts domestic US raw coal to high quality, high-value and marketable carbon fiber. More specifically, the objective is to significantly improve the selectivity and yield of carbon fiber produced per ton of coal over conventional coal pitch-based production by using low-severity direct coal conversion technology to maximize the yield of pitch from coal, suitable for production of carbon fiber.

B. SCOPE OF WORK

To meet the stated objective developing a technology platform, capable of producing high quality, high-value and marketable carbon fiber from domestic US coal, the proposed scope of work involves testing a of a low-severity direct coal liquefaction process approach and includes the following sequential activities:

- Coal/Conversion Screening – (b) (4) [redacted]
- Feedstock Production – (b) (4) [redacted]
- Carbon Fiber Production – (b) (4) [redacted]

- Commercialization Plan – (b) (4) [redacted]

C. TASKS TO BE PERFORMED

Please refer to Section 5.0 – Roles of the Participants, which identifies the participant responsibility for the tasks to be performed in the following project narrative sections.

Task 1.0 Project Management and Planning

The Recipient shall manage and direct the project in accordance with a Project Management Plan to meet all technical, schedule and budget objectives and requirements. The Recipient will coordinate activities in order to effectively accomplish the work. The Recipient will ensure that project plans, results, and decisions are appropriately documented and project reporting and briefing requirements are satisfied.

The Recipient shall update the Project Management Plan 30 days after award and as necessary throughout the project to accurately reflect the current status of the project. Examples of when it may be appropriate to update the Project Management Plan include: (a) project management policy and procedural changes; (b) changes to the technical, cost, and/or schedule baseline for the project; (c) significant changes in scope, methods, or approaches; or (d) as otherwise required to ensure that the plan is the appropriate governing document for the work required to accomplish the project objectives.

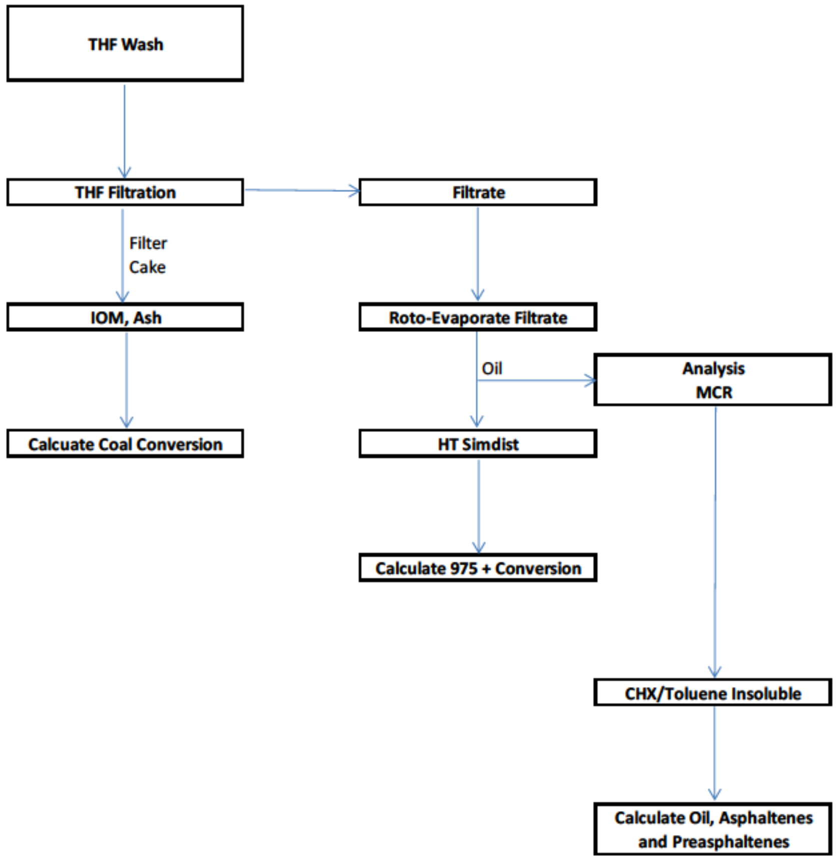
Management of project risks will occur in accordance with the risk management methodology delineated in the Project Management Plan in order to identify, assess, monitor and mitigate technical uncertainties as well as schedule, budgetary and environmental risks associated with all aspects of the project. The results and status of the risk management process will be presented during project reviews and in quarterly progress reports with emphasis placed on the medium- and high-risk items.

Task 2.0 – Coal/Conversion Screening

This task describes the requirements for coal conversion testing in a 20-cc microautoclave test unit. The purpose of this testing is to assess the reactivity of coal at standard and non-standard test conditions. The preliminary test plan shown in Table 1 includes a matrix of microautoclave tests at 3 temperatures (750, 800 and 825 °F) and 3 times (15, 30 and 45 minutes). This is a standard test matrix that has been extensively used previously for coal reactivity characterization. Two additional matrices will be performed, at lower severity on the actual coal reactivity and process performance requirements (15 tests total). The lower severity matrices will study pressure, temperature and time variables. The coal feed will be analyzed for proximate, ultimate and sulfur forms. An inventory of suitable donor solvent to be used is available onsite. The donor solvent was prepared via hydrogenation of coal-derived anthracene oil and 3.5 W% tetralin will be added. Figure 3 shows the microautoclave product work-up/analysis. The microautoclave reactor is thoroughly washed with THF (Tetrahydrofuran) to remove all of the contents of the reactor. The THF wash material is filtered to recover a filter cake. The filter cake is then analyzed to determine ash and IOM (Insoluble Organic Matter) in order to calculate coal conversion. The THF is evaporated from the filtrate to recover the oil product and analyzed by HTSimDist (high-temperature simulated distillation) to determine 400 °C + content in order to calculate the selectivity to carbon fiber presursor. The oil product will be further analyzed for MCR, CHX (cyclohexane) and toluene insoluble contents.

Table 3 - Microautoclave Standard Test Matrix Coal Feed – 2 g/Solvent – 8 g/2,000 psig H2			
Time/Temp	**750 °F**	**800 °F**	**825 °F**
15 minutes		x	
30 minutes	x	x	x
45 minutes		x	

Figure 4 - Work-Up/Analysis of Products



Task 3.0 - Feedstock Production

It is proposed to use an existing HTI pilot plant Unit 245 to produce sample quantities sufficient for laboratory testing of the product to evaluate the yield and mechanical properties of carbon fibers derived from the feedstock. Please refer to Section 8 for a description of Unit 245. The daily product work-up includes batch pressure filtration and batch vacuum distillation. Operating conditions will be based on prior development work and the microautoclave testing results. A single coal feed will be used at a single set of operating conditions for 15 days of operation. The solvent used in the testing will be the same as that used in the microautoclave testing. In order perform material balance, performance and yield calculations daily analysis requirements are shown in Table 4. For a single period of operation true boiling point product fractions will be prepared and analyzed as shown in Table 5.

Table 4 - Daily Analysis Required of Pilot Plant Products				
Detailed Daily Analysis	**Vent Gas**	**SOH**	**PFL**	**PFC**
GC Gas Analysis	x			

Carbon		x	x	x
Hydrogen		x	x	x
Nitrogen		x	x	x
Sulfur		x	x	x
Oxygen		x	x	x
Density		x	x	
Conradson Carbon Residue			x	x
Toluene Insoluble			x	x
Quinoline Insoluble				x
Ash				x
Distillation		x	x	
Reduce Daily Analysis	**Vent Gas**	**SOH**	**PFL**	**PFC**
GC Gas Analysis	x			
Density		x	x	
Conradson Carbon Residue			x	
Toluene Insoluble			x	x
Quinoline Insoluble				x
Ash				x

Table 5- Analysis of TBP Products (1-period)			
	Naphtha (IBP - 180 °C)	**Diesel (180-400 °C)**	**Heavy Oil (400 °C+)**
Density, @15 °C, kg/L	x	x	X (15/20 ˚C)
Carbon, wt%	x	x	x
Hydrogen, wt%	x	x	x
Sulfur, ppmwt	x	x	x
Nitrogen, ppmwt	x	x	x
Distillation	x	x	x
Viscosity, cSt			x (50/100 ˚C)
GC Composition	x		
ICP metals analysis, ppmwt			x
Bromine number, gBr/100g	x	x	
Refractive Index		x	
Distillation	x	x	x
Pour Point			x

Task 4.0 - Carbon Fiber Formation Testing (Ramaco)

(b) (4) [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

(b) (4) [redacted]

Task 5.0 - Commercialization Plan

(b) (4) [redacted]

D. DELIVERABLES

The periodic and final reports shall be submitted in accordance with the Federal Assistance Reporting Checklist and the instructions accompanying the checklist. In addition to the reports specified in the "Federal Assistance Reporting Checklist", the Recipient must provide the following to the NETL Project Manager (identified in Block 15 of the Assistance Agreement as the Program Manager).

(b) (4)
[redacted]

E. BRIEFINGS/TECHNICAL PRESENTATIONS

The Recipient shall prepare detailed briefings for presentation to the NETL Project Manager at their facility located in Pittsburgh, PA, Morgantown, WV, Albany, OR, or via WebEx. The Recipient shall make a presentation to the NETL Project Manager at a project kick-off meeting held within ninety (90) days of the project start date. At a minimum, annual briefings shall also be given by the Recipient to explain the plans, progress, and results of the technical effort and a final project briefing at the close of the project shall also be given.

(b) (4)
[redacted]

4. Relevance and Outcomes/Impacts

This project is the first vision and version of using coal to produce "On-Purpose Pitch Plant" (OPPP) using the fundamental and well-known concepts of direct coal liquefaction technology. All other pitch to carbon fiber facilities use produced pitch which is a by-product (most often an unwanted by-product), of the steel making process, or in earlier days, the production of town gas. The US government has expended the billions of dollars in the US to develop coal to liquid fuels technology since the 1973 oil embargo, and developed technology ready for commercial deployment. In fact many learnings from this highly successful development effort currently deployed and in commercial operation in China today in commercial-scale coal to fuels and chemicals facilities. (b) (4) [redacted] A plant specifically optimized, designed and operated to minimize the cost, maximize the yield and enhance the quality of the pitch produced. (b) (4) [redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]

- [redacted]

5. **Roles of Participants**

The roles of the participants are described below:

Ramaco Carbon, LLC (Ramaco) is a private Wyoming-based company focused on "Coal to Products." Ramaco Carbon is a vertically integrated coal technology company pursuing an integrated resource, technology and manufacturing based approach to new coal uses. Ramaco Carbon owns a 1.1 billion ton coal resource in Wyoming and specifically intends to develop this to commercialize coal-based carbon products. Ramaco Carbon is the applicant and intended award recipient. Ramaco will be responsible for Task 1 – Project Management, Task 4 – Carbon Fiber Production and Task 5 - Commercialization study.

Axens North America, Inc. (Axens NA), a subsidiary of Axens, is an international technology provider in the field of refining, petrochemicals, gas processing and alternative fuels. Activities include technology-licensing, process engineering, sales and manufacturing of catalysts and adsorbents along with the associated services for these activities (technical assistance, supply chain). Axens is the developer of the H-Coal process for direct coal liquefaction and has a recognized world leader in these fields, especially for the production of clean transportation fuels. HTI – HTI is wholly owned by Axens NA and operates a Commercial Support facility located in Lawrenceville, New Jersey comprising [redacted] of laboratories, pilot plant units, and office space. Axens NA will be the principle investigator for the Task 2 – Coal/Conversion Screening and Task 3 – Feedstock Production and direct the experimental activities at HTI and will assist Ramaco in performance of the Task 5 – Commericalization Study.

6. **Multiple Principal Investigators (PI)**

[redacted]

(b) (4) [redacted]

- Carbon Fiber Production and End Use – (b) (4) [redacted]
- Coal Conversion Process Technology - (b) (4) [redacted]
- Publications – Ramaco and Axens will jointly author all publications resulting from this project.
- The PI's will have monthly coordination meetings to ensure any potential technical or logistical issues are identified and quickly resolved.

7. Facilities and Other Resources

Axens North America – Axens North America, Inc. (Axens NA), a subsidiary of Axens, is an international technology provider in the field of refining, petrochemicals, gas processing and alternative fuels in charge of North America (Canada, USA, Mexico) as well as Colombia and the Caribbean. Our activities include technology licensing, process engineering, sales and manufacturing of catalysts and adsorbents along with the associated services for these activities (technical assistance, supply chain). Axens is a recognized world leader in these fields. In the US Axens has two main offices, Princeton, NJ focused on marketing and process engineering for our licensees and support functions and Houston, TX handling marketing, technical services, catalyst sales and supply chain functions. Axens work on this project will be performed in the Princeton, NJ office.

HTI – HTI is a wholly owned subsidiary of Axens NA and operates a Commercial Support in Lawrenceville, New Jersey comprising (b) (4) [redacted] of laboratories, pilot plant units, and office space. (b) (4) [redacted] HTI's laboratories house the latest analytical instruments and perform all the ASTM methods required for complete analysis and characterization of oil and liquid fuel products. Due to the nature of the work done in HTI laboratories and pilot plant units, HTI places the highest possible emphasis on safety and environmental protection. HTI is proud of its 100% employee involvement in maintaining a safe work environment and our compliance with all federal, state, and local regulations.

Ramaco – R&D Lab housed within [redacted] manufacturing facility

8. Equipment

[redacted]

[redacted]

- [redacted]

[redacted]

(b) (4)

[redacted]

Current and Pending Support

Current and Pending Support for Ramaco Carbon includes:

Current:

> Department of Energy, Federal Grant No. DE-EE00082803, Consortium for Production of Affordable Carbon Fibers in the U.S., Ramaco is not receiving any support, but is making a $450,000 in-kind contribution to the project, (10/1/2017 – 12/31/20), Person-Months per year 0.56, PI: Charles A. Atkins

Ramaco Carbon does not have any support pending.

Axens/HTI – no current support, no pending support.

Identification of Potential Conflicts of Interest or Bias in Selection of Reviewers

Ramaco Carbon has an ongoing research program in coal-related research with the Western Research Institute, specifically within the framework of the DOE-NETL sponsored CONSORTIUM FOR PRODUCTION OF AFFORDABLE CARBON FIBERS (CPACF) IN THE U.S.. The CPACF consortium of partners includes ORNL, Advanced Carbon Products, Southern Research Institute, MIT and the University of Wyoming.

In June of 2018, Ramaco Carbon signed a Cooperative Research and Development Agreement (CRADA) with the National Energy Technology Laboratory (NETL) in-house research team. Ramaco Carbon currently has two (2) ongoing CRADA-based collaboration projects in the development of coal-to-products with DOE-NETL through the Carbon Materials Manufacturing Facility (CMMF) led by Dr. Christopher Matranga.

Axens/HTI – None.

Bibliography and References

1. Burke,F. P., Brandes, S. D., McCoy, D. C., Winschel, R. A., Gray, D. and Tomlinson, G., "SUMMARY REPORT OF THE DOE DIRECT LIQUEFACTION PROCESS DEVELOPMENT CAMPAIGN OF THE LATE TWENTIETH CENTURY: TOPICAL REPORT" July 2001, DOE Contract DE-AC22-94PC93054.
2. David Warren. Low Cost Carbon Fiber Overview. LM002, Oak Ridge National Laboratory, May 2011.
3. Das, S.; Warren, J.; West, D.; Schexnayder, S. Global Carbon Fiber Composites Supply Chain Competitiveness Analysis. ORNL/SR-2016/100. Clean Energy Manufacturing Analysis Center. May 2016.