GENERAL PROJECT INFORMATION

Project Type: T - Advance Energy Technology

Project Name: The Forge Project: Rare Earths and Critical Materials Integration

Program Name: Lignite Research Program (LRP)

Grantee Company: Ore Spring Materials, LLC (Ore Spring Materials)

Primary Company Contac: Greg Henthorn

State: North Dakota

Duration of Project (Number of months): 24

Project Description/Abstract: The Forge Project: Rare Earths and Critical Materials Integration is a two-year, $4.6 million research and development program led by Ore Spring Materials, LLC, an affiliate of AmeriCarbon Products, LLC. The project is designed to demonstrate and advance the integration of AmeriCarbon's Eco-Pitch™ carbon manufacturing process with rare earth element (REE) and critical mineral (CM) recovery technologies developed by the University of North Dakota (UND) and Microbeam Technologies, Inc. The program is anchored by the planned AmeriCarbon Forge commercial facility in McLean County, North Dakota, a joint venture between AmeriCarbon and NACCO Natural Resources sited adjacent to the Falkirk Mine. The core objective is to establish the technical, engineering, and economic foundation for a co-located platform that converts North Dakota lignite and process by-products into high-value carbon materials while simultaneously recovering REEs, germanium, gallium, and other critical minerals. AmeriCarbon's Eco-Pitch™ process produces a carbon-rich ash uniquely suited as feedstock for REE and critical mineral recovery — creating a closed-loop system that maximizes resource value and minimizes waste. UND will contribute upgraded lignite carbon ore and humic-based materials as optimized feedstocks for AmeriCarbon's process, while Microbeam Technologies will apply its patented vaporization and selective condensation technology to recover high-purity germanium and gallium from process residues. Worley Group will provide engineering integration support, including process flow diagrams, mass and energy balances, and site layout studies for the planned facility. Project work is organized across seven tasks: project management; preliminary process and site integration assessment; pitch integration and optimization studies; REE process integration studies with UND; Ge/Ga recovery studies with Microbeam; techno-economic assessment; and commercialization planning. Collectively, these tasks are intended to produce a validated process integration framework, empirical performance data across all three technology systems, and an engineering and economic roadmap for commercial-

scale deployment. This proposal also includes an addendum scope to advance Eco-Pitch™ toward commercial qualification as a performance-grade asphalt binder. The Forge Project has received an award of $1.125 million from the North Dakota Clean Sustainable Energy Authority (CSEA), representing the first tranche of committed public funding for the program. This proposal to the Lignite Research Council requests an additional $1.175 million to fully fund the program's public support component, with the balance of the total project budget provided through matching contributions from AmeriCarbon and its industry partners. The proposed project represents an integrated program that advances North Dakota's lignite resources toward high-value carbon and critical materials manufacturing — strengthening domestic supply chains, creating durable economic opportunity in McLean County and the broader region, and positioning North Dakota as a national model for resource-integrated industrial development.

PROJECT ABSTRACT/OVERVIEW

The objective of ***The Forge Project: Rare Earths and Critical Materials Integration*** is to demonstrate and advance the integration of AmeriCarbon's Eco-Pitch™ carbon manufacturing process with rare earth element (REE) and critical mineral (CM) recovery technologies developed by the University of North Dakota (UND) and Microbeam Technologies, Inc. (Microbeam). The project aims to establish a scalable, co-located platform in North Dakota that converts lignite-derived and related feedstocks into engineered carbon materials while simultaneously recovering REEs, germanium (Ge), gallium (Ga), and other critical minerals from process by-products.

This integration will (1) optimize AmeriCarbon's liquefaction process to utilize diverse feedstocks—including upgraded lignite, humins, and humic acid residues from UND's REE processing—tailoring pitch compositions to customer-specific performance requirements; (2) develop a pathway to use AmeriCarbon's carbon process ash as a high-value CM-bearing feedstock for Microbeam's Ge/Ga recovery system; and (3) define the engineering and economic framework for commercial-scale deployment at the Forge site in McLean County, ND.

Through this effort, the project will advance North Dakota's leadership in lignite-based innovation by demonstrating a fully integrated carbon-plus-critical-minerals manufacturing ecosystem—linking clean carbon production, REE-CM extraction, and high-purity metal refining. The outcome will be a validated process model, optimized feedstock strategy, and techno-economic foundation for an industrial complex that strengthens domestic supply chains for both advanced carbon materials and strategic minerals.

The Forge Project will deliver a validated and integrated process framework that unites AmeriCarbon's Eco-Pitch™ manufacturing, UND's rare-earth extraction technologies, and Microbeam's germanium and gallium recovery system into a cohesive, North Dakota–based production platform. The project is expected to:

- Demonstrate feedstock integration and optimization—confirming the technical viability of using upgraded lignite, humins, and humic-acid residues (individually and in blended configurations) as feedstocks for AmeriCarbon's carbon liquefaction process, yielding targeted pitch formulations for downstream customers in energy and materials sectors.
- Quantify and enhance by-product value recovery—producing empirical data on the concentration, separation, recovery, and refinement potential of REEs and critical minerals (Ge, Ga, and Sb) from AmeriCarbon's ash and residue streams using Microbeam's pyrometallurgical and hydrometallurgical processes.
- Validate carbon purity and product performance—through demineralization and purification studies conducted with UND to achieve premium carbon qualities suitable for graphite, anode, and advanced binder applications.
- Develop an integrated process and site design—including mass and energy balances, flow diagrams, and infrastructure layouts defining how REE-CM extraction, ash utilization, and carbon manufacturing can be co-located at AmeriCarbon's commercial plant in McLean County.
- Produce a techno-economic and commercialization analysis—quantifying capital and operating costs, product revenue streams, and economic multipliers for North Dakota, while identifying a practical path to commercial deployment.
- Validate asphalt binder performance and commercialization pathway—demonstrating Eco-Pitch™ as a performance-grade asphalt binder in Phase II testing.

Collectively, these outcomes will advance the technology readiness and economic feasibility of an industrial system that transforms lignite and its by-products into high-value carbon and critical mineral commodities. Successful execution will position North Dakota as a national model for clean-energy resource integration—linking carbon manufacturing, REE-CM recovery, and critical-materials supply-chain development within one regional industrial ecosystem.

The proposed project is being led by Ore Spring Materials, LLC, an AmeriCarbon affiliate formed to coordinate integration of advanced carbon and critical mineral technologies.

AmeriCarbon Forge, LLC—a joint venture between AmeriCarbon Enterprises and NACCO Natural Resources—will serve as the commercial host entity and provide the process and infrastructure platform for pilot validation and future deployment at the Falkirk site in McLean County, North Dakota.

The University of North Dakota (UND) College of Engineering & Mines will participate in the project along with its demonstrated rare earth element (REE) extraction and beneficiation technology, leveraging pilot-scale systems developed under DOE- and NDIC-supported programs to supply upgraded lignite and humins as optimized feedstocks and to conduct purification and demineralization studies. Microbeam Technologies, Inc. (Microbeam) will apply its patented vaporization and selective condensation process to AmeriCarbon's ash residues and UND's mixed rare earth concentrates to recover germanium, gallium, and other critical minerals. As a subcontractor to AmeriCarbon, Worley Group will provide engineering and integration support, developing process flow diagrams and site-level integration studies for co-located operations. South Dakota State University will lead the asphalt binder aspect of the project.

These participants bring a strong combination of industrial capability, engineering depth, and technology readiness. Together, they form a comprehensive team capable of demonstrating a fully integrated carbon and critical materials production ecosystem that aligns with CSEA's mission to advance sustainable, value-added energy and materials manufacturing in North Dakota.

DETAILED PROJECT DESCRIPTION

The overarching objective of *The Forge Project: Rare Earths and Critical Materials Integration* is to develop, demonstrate, and engineer a fully integrated process that combines AmeriCarbon's carbon liquefaction and pitch manufacturing technology with the rare earth and critical mineral recovery systems pioneered by UND and Microbeam. This integrated system will establish the technical and economic basis for a new lignite-based manufacturing industry in North Dakota that simultaneously produces high-value carbon materials and rare earth/critical mineral products from regional resources and process by-products.

Specifically, the proposed project will:

- Integrate and optimize feedstock utilization — Demonstrate the use of upgraded lignite, humins, and humic-acid residues from UND's rare earth extraction process as alternative or blended feedstocks for AmeriCarbon's Eco-Pitch™ process. This

effort will refine process parameters to tailor pitch compositions for distinct industrial applications while maximizing yield and carbon efficiency.

- Develop and evaluate by-product valorization pathways — Characterize and optimize AmeriCarbon's process residues and ashes for use as feedstock in Microbeam's Ge/Ga recovery technology, enabling recovery of high-purity germanium, gallium, and other strategic minerals.
- Advance purification and demineralization techniques — Conduct joint studies with UND, Worley Group, and prospective customers to enhance removal of ash, sulfur, and metallic impurities from carbon and feedstock streams to achieve ultra-high-purity carbon suitable for advanced materials markets.
- Perform process integration and engineering design — Engage Worley Group to develop process flow diagrams (PFDs), material and energy balances, and site-integration studies that define how the carbon manufacturing, REE extraction, and critical mineral recovery systems can be co-located and operated synergistically at AmeriCarbon's Forge site in McLean County, ND.
- Conduct techno-economic assessment and commercialization planning — Quantify the technical performance, cost structure, and economic impacts of the integrated system, including potential product revenues, co-product credits, and state-level economic multipliers.
- Validate asphalt binder performance and commercialization pathway— demonstrating Eco-Pitch™ as a performance-grade asphalt binder in Phase II testing.

The successful completion of these objectives will demonstrate a scalable, North Dakota–based model for the co-production of engineered carbon and critical materials—advancing national supply chain resilience while creating new markets and industrial opportunities within the state's lignite resource base.

The Forge Project will be executed through a structured series of technical and engineering tasks designed to integrate AmeriCarbon's Eco-Pitch™ manufacturing process with the rare earth and critical mineral recovery systems developed by UND and Microbeam Technologies. The following Statement of Work outlines the major work activities, responsible organizations, and corresponding budget allocations that collectively define the technical pathway for the project. This work structure provides the framework for coordination, data sharing, and process optimization across all participants.

The Forge Project will be an industrial manufacturing complex in North Dakota to produce critical materials such as carbon and REE-CM to address national and global vulnerabilities and shortfalls in the United States with severe economic and geopolitical strategic consequences caused by the current offshore supply of these materials. Central to the Forge Project is the planned joint venture (AmeriCarbon Forge, LLC) between AmeriCarbon and NACCO to build a lignite coal-to-carbon pitch/materials plant in McClean County, North Dakota. The establishment of this groundbreaking facility provides the basis for an integrated platform for critical materials manufacturing.

The REE manufacturing/production capability is being initiated by Ore Springs LLC, an AmeriCarbon and NACCO affiliate, to bring production of these critical elements derived from lignite coals and by-product streams from AmeriCarbon's proprietary carbon pitch technology. Integration of these capabilities provide a unique and optimized opportunity that is a key basis of the Forge Project.

Under this proposed work scope being submitted by Ore Spring Materials, LLC, process integration efforts will be undertaken by the key participants to define the necessary optimization between the feedstock inputs and product/by-product outputs of the pitch production (AmeriCarbon) and REE-CM production (Ore Spring / UND / Microbeam).

Project Tasks

Task 1: Project Management:

This task encompasses all project management activities necessary to ensure the successful execution of the project in compliance with CSEA's contractual, technical, and administrative requirements. The Project Management team will provide overall leadership, coordination, and integration of technical, financial, and reporting activities across all project tasks. Responsibilities include tracking schedule and budget performance, managing risk and deliverables, maintaining communication with CSEA program management, and ensuring that project milestones are met in accordance with the approved Work Scope.

The task will also include coordination of subcontractor and partner activities, preparation of project management documentation, and oversight of quality assurance and safety compliance as applicable to R&D operations.

Estimated budget: $100,000

Task 2: Preliminary Process and Site Integration Assessment

Based on the current design basis for each of the critical material technologies, a process integration and site layout study will be conducted. This will provide the starting point for the integration and optimization studies defined for the various technology efforts in Tasks 3-5. Critical parameters such as material mass and energy requirements will be conducted along with site utility, infrastructure process flow and acreage requirements will be defined. Outputs from Tasks 3-5 will be used to update final assessment study.

Estimated budget: $100,000

Task 3: Pitch Integration & Optimization Studies

AmeriCarbon's proprietary Eco-Pitch process produces a unique by-product ash that has favorable characteristics that make separation/purification of REEs and CMs simp

The Forge Project will generate both technical and strategic outcomes that validate the feasibility and economic potential of integrating AmeriCarbon's carbon liquefaction process with UND's and Microbeam's critical-materials recovery technologies. Completion of the project will result in a process integration framework, validated technical data packages, and an engineering and economic foundation to support commercial-scale implementation at the planned Forge manufacturing complex in McLean County, North Dakota.

Key anticipated results include:

Validated Feedstock and Process Integration

- Demonstrated use of upgraded lignite, humins, and humic-acid residues as optimized or blended feedstocks for AmeriCarbon's Eco-Pitch™ process.
- Quantitative data defining yield, composition, and carbon conversion efficiency for each feedstock scenario.
- Confirmed compatibility of these materials with existing pilot operations and projected commercial-scale plant parameters.

Improved Product Quality and Purity

- Demonstrated reduction of ash and mineral impurities through optimized demineralization and purification processes.
- Production of ultra-high-purity carbon materials suitable for advanced applications such as synthetic graphite, carbon anodes, and binder pitches.

By-Product Value Recovery

- Characterization of REE, Ge, Ga, and Sb concentrations in AmeriCarbon's process residues and UND's by-product streams.
- Bench-scale verification of Microbeam's vaporization and selective-condensation process using these materials, achieving target Ge/Ga purities above 90% oxide basis.
- Data supporting downstream refining to 99.999%-purity metals for evaluation by industrial offtakers.

Engineering and Economic Integration Framework

- Development of process flow diagrams, material and energy balances, and preliminary site layouts illustrating how carbon and critical-mineral systems can be co-located.
- Definition of shared utilities, waste management, and by-product handling schemes to enable an integrated commercial facility.
- Completion of a techno-economic assessment (TEA) quantifying capital and operating costs, product revenue potential, and overall economic contribution to North Dakota.

Technology Development and Commercialization Pathway

- Identification of remaining technical gaps and a stepwise plan toward full commercialization, including pilot-to-plant scale-up milestones.
- Defined roles for industrial, academic, and engineering partners in the next development phase.
- Comprehensive dataset and engineering documentation suitable for inclusion in future CSEA and DOE funding applications supporting scale-up.

Asphalt Binder Testing

- Demonstrated validation of Eco-Pitch™ as a performance-grade asphalt binder through Phase II testing and commercial blending trials, generating specification-aligned data to support DOT/FHWA qualification and establishing a near-term infrastructure market that strengthens project economics and accelerates commercialization.

Collectively, these outcomes will establish a first-of-its-kind lignite-based carbon and critical-materials manufacturing model. The project will demonstrate how North Dakota's lignite resources can underpin a new clean-energy and strategic-materials industry—producing value-added carbon, recovering critical minerals, and enabling supply-chain resilience for the nation while diversifying the state's energy economy.

Proposed Commercial Plant Site

AmeriCarbon and its partners have identified a strategic location for the Forge Project site near Underwood, North Dakota. The proposed site is situated near the following:

- *Falkirk Mine*, a significant lignite coal mining operation, and in proximity to key industrial infrastructures;
- *Rainbow Energy Center's Coal Creek Station*. This is North Dakota's largest power plant, known for its efficiency and substantial electricity generation capacity; and
- *Blue Flint Ethanol Plant*. Located just east of the Coal Creek Station, this facility has been operational for over a decade, producing ethanol and contributing to the region's biofuel industry.

The proximity to these facilities offers potential synergies, such as shared infrastructure and services, which can enhance operational efficiency and sustainability.

Pilot Plant: Foundation for Commercial Design

AmeriCarbon operates the only known multi-ton-per-day coal liquefaction and pitch manufacturing pilot facility in the United States. The pilot plant incorporates AmeriCarbon's patented Liquid Carbon Process (Eco-Pitch™), which converts domestic coals—including lignite—into engineered coal tar pitch and advanced carbon materials.

Key systems include:

- A continuous liquefaction reactor train with precision temperature and residence-time control;
- Real-time analytical instrumentation for viscosity, softening point, and product composition;
- Integrated ash-handling and residue collection systems designed for by-product sampling and characterization; and

- Utilities and controls suitable for rapid parameter adjustments during feedstock blending trials.

This facility provides the platform for conducting feedstock and process optimization under Task 3 (Pitch Integration & Optimization Studies), enabling direct scale-up to AmeriCarbon Forge, LLC's planned commercial plant in McLean County, North Dakota. AmeriCarbon's pilot plant is significant for the following reasons:

- *Process Validation*. The pilot plant has been instrumental in validating the technical feasibility of the Eco-Pitch production process, ensuring that each stage operates seamlessly and efficiently.
- *Data Collection for Scale-Up***.** Comprehensive data gathered from pilot operations have been pivotal in informing the scale-up process, facilitating a tenfold increase in production capacity for the commercial plant.
- *Risk Mitigation*. Operating the pilot plant has allowed AmeriCarbon to identify and address potential challenges in a controlled environment, significantly reducing risks associated with scaling up to commercial production.

University of North Dakota – College of Engineering & Mines Research Facilities

UND's College of Engineering & Mines Research Institute houses extensive laboratory and pilot infrastructure dedicated to rare earth element (REE) and critical mineral recovery from lignite and associated materials. These include:

- A fully integrated pilot-scale REE extraction system capable of processing up to 500 kilograms per hour of lignite mine waste feedstock, producing mixed rare earth concentrates (MREC) and upgraded lignite co-products;
- The Advanced Materials Characterization Laboratory (AMCL), equipped with scanning electron microscopy (SEM-EDS), X-ray fluorescence (XRF), X-ray diffraction (XRD), inductively coupled plasma–mass spectrometry (ICP-MS), and thermal analysis instrumentation;
- A bench-scale purification and graphitization laboratory, supporting the develop

The successful execution of *The Forge Project: Rare Earths and Critical Materials Integration* will rely on a coordinated set of technical, analytical, and organizational resources contributed by AmeriCarbon, Ore Spring Materials, the University of North Dakota (UND), Microbeam Technologies, and Worley Group. These resources form the

backbone of the project's ability to execute the technical scope and achieve the anticipated outcomes.

Technical and Engineering Resources

AmeriCarbon Enterprises, LLC / AmeriCarbon Forge, LLC. AmeriCarbon brings the nation's only multi-ton-per-day coal liquefaction pilot facility and a world-class technical team with experience in carbon product manufacturing, feedstock optimization, and process integration. The AmeriCarbon pilot facility will serve as the platform for Task 3 (Pitch Integration and Optimization Studies), providing real-world process data on temperature control, residence time, and yield performance across various feedstock configurations.

AmeriCarbon's engagement of Worley Group provides direct access to multidisciplinary engineering resources for process modeling, mass and energy balance development, and site integration design. Worley's engineering and construction teams have extensive experience in advanced materials, refining, and energy-infrastructure projects in North Dakota and globally.

Academic and Research Resources

University of North Dakota (UND) – College of Engineering & Mines Research Institute. UND contributes a fully operational pilot-scale rare earth element (REE) extraction facility capable of processing up to 500 kilograms per hour of lignite feedstock, producing upgraded lignite and mixed rare earth concentrates. The facility, coupled with UND's Advanced Materials Characterization Laboratory (AMCL), provides comprehensive analytical capabilities (SEM/EDS, XRF, XRD, ICP-MS, and thermal analysis).

UND's team has extensive experience in rare earth and critical mineral recovery, feedstock purification, and techno-economic modeling. Their existing DOE- and NDIC-supported programs provide validated process data and a mature platform for integration with AmeriCarbon's carbon liquefaction technology.

UND's REE extraction process produces several products, including a unique upgraded lignite carbon ore ("upgraded LCO"). REE/CM processing uses lignite that would be otherwise unsuitable for thermal applications (high ash and low heating value) and significantly upgrades it by 1) reducing mineral matter using physical separations and 2) removing the organically associated inorganic elements through dilute mineral acid extraction. UND's prior technology development has identified that our REE/CM process

has promising economic potential; however, a major component (~50%) of projected revenues from a commercial facility is from the upgraded LCO, even under the low-value use as a combustion blending fuel. This highlights the magnitude of the potential economic benefit of, instead, manufacturing value-added carbon products.

South Dakota State University (SDSU) is a public research university with established capabilities in civil engineering and materials testing. The university maintains laboratory facilities equipped to perform standardized asphalt binder and mixture testing, supporting evaluation of performance characteristics in accordance with industry protocols (e.g., AASHTO methods).

Industrial Research and Critical Mineral Recovery Resources

Microbeam Technologies, Inc. Microbeam brings to the project a unique combination of analytical, metallurgical, and process-development capabilities. Its Grand Forks and Minnetonka facilities are equipped with equilibrium thermodynamic

The Forge Project: Rare Earths and Critical Materials Integration will employ a suite of bench, pilot-, and engineering-scale techniques to validate the integrated process for carbon production and critical mineral recovery. All techniques are established and available within the existing facilities of AmeriCarbon, the University of North Dakota (UND), Microbeam Technologies, and Worley Group. Together, these techniques provide the ability to conduct process development, performance optimization, and economic evaluation at a level sufficient to inform commercial-scale design.

1. Feedstock Evaluation and Liquefaction (AmeriCarbon)

AmeriCarbon will utilize its Liquid Carbon Process (Eco-Pitch™) pilot plant and associated laboratory equipment to process and evaluate various feedstocks including run-of-mine lignite, upgraded lignite, humins, and humic acid residues supplied by UND. Techniques include:

- Controlled liquefaction testing. Continuous pilot-scale runs under variable residence time, temperature, and pressure conditions to determine yield and quality of resulting pitches.
- Analytical characterization. Viscosity, softening point, quinoline insolubles, toluene insolubles, elemental analysis, and ash content to assess performance and reproducibility.

- By-product handling and sampling. Automated collection and compositional mapping of ash and carbon residues for mineralogical and REE/CM content analysis.
- Blending and process-optimization matrix. Systematic blending of multiple feedstocks to identify optimal ratios for yield, purity, and pitch specification control.

All techniques are established within AmeriCarbon's operating pilot plant and have been used to generate validated process data for scale-up to commercial operations.

2. Rare Earth Element (REE) and Carbon Co-Product Processing (UND)

The UND College of Engineering & Mines Research Institute will apply a proven set of hydrometallurgical and beneficiation techniques used in its DOE- and NDIC-funded REE extraction programs. These include:

- Mild-acid leaching of lignite-based feedstocks to extract REEs and critical minerals from organically associated matrices while retaining the carbon structure for subsequent use by AmeriCarbon.
- Solid–liquid separation and washing to recover the upgraded carbon material with near-zero sodium and low-ash content.
- Two-stage oxalate precipitation and calcination to generate mixed rare earth concentrates (MREC) with ≥75 wt% REE purity on an oxide basis.
- Advanced purification and demineralization using bench-scale chemical treatment and filtration to produce high-purity carbon suitable for anode and binder applications.
- Bench-scale graphitization and electrochemical testing of resulting carbon materials (coin and 18650-cell evaluations).

All techniques are operational within UND's 500 kg/h pilot-scale REE extraction facility and Advanced Materials Characterization Laboratory (AMCL), which houses full analytical capabilities (SEM/EDS, XRF, XRD, ICP-MS, and TGA). These facilities have already achieved Technology Readiness Level (TRL) 6 for REE extraction from North Dakota lignite.

3. Critical Mineral (Ge/Ga/Sb) Recovery and Refining (Microbeam Technologies)

Microbeam will apply its patented vaporization and selective-condensation process to recover germanium (Ge), gallium (Ga), and antimony (Sb) from AmeriCarbon and UND by-product streams. The process combines pyrometallurgical techniques, including:

- High-temperature vaporization of MREC and ash feedstocks in controlled-atmosphere furna

The proposed project will be executed as a research, development, and engineering program, utilizing existing pilot and laboratory facilities at AmeriCarbon, the University of North Dakota (UND), and Microbeam Technologies. As such, environmental impacts during the project are expected to be minimal, localized, and fully manageable within standard institutional safety and environmental procedures.

Environmental Impacts

Limited Material and Energy Use. Pilot- and bench-scale testing will use small quantities of lignite, upgraded carbon feedstocks, and process residues. No large-scale excavation, construction, or waste disposal is planned. Energy and water use will remain within normal laboratory operations.

Waste and Effluent Management.

- Liquefaction residues, process ash, and small volumes of spent reagents generated at AmeriCarbon and UND will be managed under existing facility permits and standard operating procedures.
- Any acid or solvent streams from UND's REE extraction and purification work will be neutralized and disposed of through UND's hazardous waste program in compliance with state and federal regulations.
- Gaseous emissions from Microbeam's high-temperature testing will be captured through particulate control and ventilation systems; no uncontrolled emissions are expected.

Environmental Health and Safety (EHS) Compliance. All partner facilities maintain active EHS programs that include staff training, chemical hygiene plans, and hazardous waste management protocols. No new permitting actions or environmental assessments are anticipated during this phase of work.

No Adverse Community or Ecological Effects. Work will occur entirely within existing industrial or research facilities in Grand Forks, Morgantown, Minnetonka, and other controlled laboratory environments. No fieldwork or disturbance of natural land, water, or habitat will occur during the project.

Economic Impacts

Direct Employment and Workforce Development. The project will support a skilled multidisciplinary workforce of engineers, scientists, and technicians across AmeriCarbon, UND, and Microbeam. Temporary project-specific employment will include graduate and undergraduate researchers at UND, contract engineers, and technical support personnel.

Local and Regional Spending. Project expenditures will include laboratory supplies, analytical services, and engineering support procured within North Dakota and neighboring states. UND's research operations and the project's overall planned activities will direct a substantial portion of spending to local vendors, utilities, and service providers.

Capacity Building for Future Industry. Beyond the immediate project, this work expands North Dakota's industrial base in high-value carbon and critical-mineral technologies. It strengthens institutional and workforce capacity for future phases involving pilot expansion and commercial deployment at the Forge site.

In summary, during the project's execution period, environmental impacts will be negligible and confined to controlled laboratory activities, while economic impacts will be positive, centered on job creation, technical workforce training, and procurement within North Dakota's research and industrial ecosystem. The project thus aligns with CSEA's mission to support clean and sustainable energy innovation with responsible environmental stewardship.

The Forge Project: Rare Earths and Critical Materials Integration will demonstrate the technical and economic viability of an integrated system that transforms North Dakota lignite and process by-products into high-value carbon materials and critical minerals. The project will validate an entirely new model of resource utilization — one that combines advanced carbon manufacturing, rare earth element (REE) extraction, and critical mineral recovery within a single industrial ecosystem. The long-term impacts extend well beyond this research phase, establishing a foundation for new industries, jobs, and supply chains centered in North Dakota.

Technological Impacts

The project will advance a first-of-its-kind integration of carbon and critical-material technologies, combining three complementary innovations:

1. AmeriCarbon's Eco-Pitch™ Liquefaction Process, which converts lignite, upgraded lignite, and humic-based materials into tailored binder and impregnating pitches for high-value applications in synthetic graphite, battery anodes, and carbon composites;
2. UND's Rare Earth Extraction and Carbon Upgrading Process, which isolates REEs from lignite mine wastes and humic materials, producing upgraded carbon feedstocks with low ash and high purity suitable for conversion into premium carbon products; and
3. Microbeam's Germanium and Gallium Recovery Process, which separates and refines critical minerals from AmeriCarbon and UND process residues using proprietary vaporization and selective-condensation techniques.

Together, these systems create a closed-loop process chain that captures value from every portion of the lignite resource—carbon, rare earths, and trace metals—while minimizing waste.

Technologically, the project will demonstrate:

- Integration at the process-engineering level, enabling simultaneous production of high-purity carbon materials and REE/CM concentrates within a single facility footprint;
- Improved environmental performance, including lower energy consumption and reduced waste generation compared with traditional REE and carbon manufacturing methods;
- Scalability and replicability, with data and designs directly transferable to commercial-scale deployment at AmeriCarbon Forge in McLean County, ND, and to future projects across other lignite-producing regions; and
- Alignment with national strategic goals, including the *2025 Executive Order on Increasing American Mineral Production*, which prioritizes domestic manufacturing of critical materials essential to defense, energy, and advanced manufacturing sectors.

By establishing the technical basis for co-locating carbon, REE, and critical-mineral production, the Forge Project will showcase a new generation of resource-integrated

manufacturing capable of supporting the United States' long-term industrial and supply-chain resilience.

Economic Impacts and Value to North Dakota

The Forge Project's long-term economic impacts will be transformative for North Dakota, positioning the state as a center of excellence for critical-materials and advanced-carbon production.

Key economic impacts include:

- Creation of a New Industrial Platform**.** The integration of carbon manufacturing and REE/CM recovery represents the foundation of a new high-value industry in North Dakota—one that leverages the state's lignite resources not for combustion, but for advanced manufacturing and critical-materials production.
- Expansion of Domestic Supply Chains**.** By enabling U.S.-based production of coal-tar-pitch equivalents, synthetic graphite precursors, an

The Forge Project: Rare Earths and Critical Materials Integration is needed to close a critical gap between research-stage technologies for rare earth element (REE) and critical mineral recovery and the commercial-scale carbon manufacturing system now being advanced in North Dakota through AmeriCarbon Forge, LLC. This project represents the essential integration phase—aligning the technical, engineering, and operational interfaces that will enable these complementary processes to function as one unified manufacturing platform.

For decades, the United States has been almost entirely dependent on foreign sources for two strategic material streams—coal-tar pitch (used for graphite, anodes, and carbon composites) and rare earth elements and critical minerals (used in electronics, defense, and clean-energy technologies). China currently dominates both supply chains. This dependence poses serious risks to national security, economic competitiveness, and the resilience of U.S. manufacturing.

The Forge Project directly addresses these vulnerabilities by creating a North Dakota–based integrated production system that converts lignite and process by-products into high-value carbon materials and co-recovered critical minerals such as germanium, gallium, and REEs. Through coordinated development by AmeriCarbon, UND, and

Microbeam Technologies, the proposed project will establish the technical and engineering basis for co-locating these processes at the AmeriCarbon Forge site in McLean County.

Germanium (Ge) and Gallium (Ga) are essential materials for advancing energy efficiency and sustainability across a wide range of technologies, including quantum processors, photonic circuits, and high-speed electronic devices. Ge enables low-power, high-speed transistors, single-photon detectors, and quantum dots for integrated sensing and computing, while Ga—especially in the form of gallium nitride (GaN)—powers efficient LEDs, RF amplifiers, and power electronics that reduce energy consumption in data centers, electric vehicles, and renewable energy systems. The lack of readily available Ge and Ga is limiting the US ability to produce high efficiency electronic products for infrared optics, thermal imaging systems, satellite solar panels, emerging quantum computing, and photonics platforms.

Addressing National and State Priorities

1. Energy and Materials Security. The project will strengthen domestic supply chains by enabling U.S. production of two categories of critical inputs: (i) advanced carbon materials and (ii) REEs and associated critical minerals. Integration of AmeriCarbon's Eco-Pitch™ process with UND's REE extraction and Microbeam's Ge/Ga recovery technologies directly supports the U.S. Department of Energy's Critical Materials Initiative and the *2025 Executive Order on Increasing American Mineral Production*.

2. Environmental Performance and Resource Optimization. The integration of these processes creates a closed-loop system that minimizes waste and maximizes value from North Dakota lignite. AmeriCarbon's low-temperature, non-combustion carbon process reduces greenhouse-gas emissions by more than 90% compared with conventional pitch manufacturing. UND's extraction process converts lignite mine waste into upgraded carbon feedstock, while Microbeam's technologies recover high-purity metals from process residues. Together, they form an environmentally responsible pathway to critical-materials production with minimal incremental footprint.

3. Economic Diversification and Industrial Development in North Dakota. The proposed project will accelerate North Dakota's transition from traditional coal utilization toward advanced materials manufacturing. It will position McLean County and the broader lignite region as a national hub.

STANDARDS OF SUCCESS

The success of *The Forge Project: Rare Earths and Critical Materials Integration* will be measured by its ability to demonstrate, document, and de-risk the technical, economic, and environmental viability of integrating AmeriCarbon's carbon manufacturing process with the rare earth and critical mineral recovery technologies developed by UND and Microbeam Technologies.

The project will define and validate the framework for a fully integrated carbon and critical-materials manufacturing platform in North Dakota—one that enhances the value of lignite, strengthens domestic supply chains, and positions the state as a leader in sustainable energy and materials innovation.

Key Metrics for Success

1. Technical Integration and Performance

- Successful completion of pilot- and bench-scale testing demonstrating compatibility among AmeriCarbon, UND, and Microbeam process streams.
- Verified ability to process multiple feedstocks—lignite, upgraded lignite, humins, and humic-acid residues—within AmeriCarbon's Eco-Pitch™ system to produce high-quality carbon pitches with defined customer specifications.
- Demonstrated recovery of germanium, gallium, and other critical minerals from AmeriCarbon and UND process residues, achieving purity levels suitable for downstream refining and potential commercial use.
- Delivery of a comprehensive **process integration model** including mass and energy balances, process flow diagrams (PFDs), and site-integration layouts validated by Worley Group.
- Completion of a **Techno-Economic Assessment (TEA)** showing clear economic potential for integrated production and co-location at the AmeriCarbon Forge site.

2. Environmental and Sustainability Outcomes

- Quantified reduction in process waste and greenhouse-gas intensity relative to conventional carbon and mineral processing.

- Documented lifecycle environmental benefits through data from the integrated process, emphasizing closed-loop material use and minimized waste generation.
- Establishment of an operational baseline to support future environmental permitting and sustainability certification for the commercial Forge facility.

3. Economic and Workforce Development Value

- Demonstrated economic viability and readiness for scale-up, providing the technical and economic foundation for subsequent CSEA and private-sector investment.
- Support of North Dakota-based engineering, research, and laboratory employment throughout the project period, including workforce participation by UND graduate and undergraduate students.
- Creation of an actionable roadmap for commercial deployment, enabling future job creation and local manufacturing investment in McLean County and across the state.

4. Advancement of Research, Development, and Technology Commercialization

- Advancement of three distinct technology families—carbon liquefaction, REE extraction, and Ge/Ga recovery—to a higher level of integration readiness.
- Development of a replicable model for industrial symbiosis that can be applied to other lignite regions or industrial sites in North Dakota.
- Generation of publishable, transferable technical data that can be leveraged by the public and private sectors to support future innovation and commercialization.

Alignment with CSEA Mission and Program Objectives

The Forge Project directly advances the mission of the Clean Sustainable Energy Authority by:

- Enhancing the **sustainability and value** of North Dakota's lignite res

BACKGROUND/QUALIFICATIONS

The Forge Project builds on more than a decade of development in lignite-based carbon manufacturing, rare earth element (REE) extraction, and critical mineral recovery technologies that have been pioneered independently by AmeriCarbon Enterprises, the University of North Dakota (UND), and Microbeam Technologies, Inc. This project represents the convergence of those technology paths into a unified industrial platform for the State of North Dakota.

Project Origins and Context

Ore Spring Materials, LLC was established to manage and coordinate the integration of AmeriCarbon's coal-to-carbon pitch manufacturing process with emerging REE and critical-mineral recovery technologies developed by UND and Microbeam. The combined system—referred to as *The Forge Project: Rare Earths and Critical Materials Integration*—advances a vision of full-resource utilization: converting lignite and related by-products into high-value carbon materials, rare earth elements, and critical minerals, while minimizing waste and environmental impact.

This integration builds on a series of NDIC- and DOE-funded projects that have demonstrated both the technical feasibility and economic promise of these constituent technologies. The current project, submitted to the Clean Sustainable Energy Authority (CSEA), focuses on the next step—process integration, optimization, and engineering design—to prepare for commercial-scale deployment at the AmeriCarbon Forge site in McLean County.

Background of Key Project Participants

<u>AmeriCarbon Enterprises, LLC / AmeriCarbon Forge, LLC</u>

AmeriCarbon has developed the patented Liquid Carbon Process (LCP), a proprietary technology that converts coal, including lignite, into high-performance binder and impregnating pitches (Eco-Pitch™). The process eliminates dependence on imported coal-tar pitch and reduces greenhouse-gas emissions by over 90% compared to conventional coking-oven processes.

University of North Dakota (UND) – College of Engineering & Mines Research Institute

UND has spent the past decade pioneering rare earth and critical mineral recovery from lignite and related materials, with support from both the U.S. Department of Energy (DOE) and the North Dakota Industrial Commission (NDIC). The university's patented REE extraction process uses mild acid leaching and selective precipitation to produce Mixed Rare Earth Concentrates (MREC) while generating a valuable upgraded carbon by-product suitable for further conversion into high-value pitch products.

UND's technologies form the front-end beneficiation and purification component of The Forge Project, providing high-purity carbon feedstocks and process data essential to optimizing AmeriCarbon's Eco-Pitch™ system.

Microbeam Technologies, Inc.

Microbeam Technologies, based in Grand Forks, North Dakota, and Minnetonka, Minnesota, is an applied research and development firm specializing in fuel characterization, ash behavior, and critical-mineral recovery from coal and carbonaceous feedstocks.

Microbeam's role in The Forge Project is to lead the critical-mineral recovery and refinement tasks, evaluating AmeriCarbon's ash by-products as feedstocks for Ge/Ga separation and contributing process data to the integrated economic model.

Worley Group

Worley is a global engineering, procurement, and construction (EPC) firm with decades of experience in front-end engineering design (FEED) and industrial process integration. Through previous collaborations with AmeriCarbon and UND, Worley has developed process flow diagrams (PFDs), piping and instrumentation diagrams (P&IDs), and mass/energy balances for lignite-based carbon and REE facilities in North Dakota.

South Dakota State Uni

MANAGEMENT

Management Approach and Oversight

The Forge Project will be managed through a collaborative project management framework led by Ore Spring Materials, LLC, with technical execution carried out by AmeriCarbon Enterprises, LLC, the University of North Dakota (UND), Microbeam Technologies, Inc., and Worley Group. Ore Spring will serve as the project integrator and administrative lead, responsible for coordination, schedule adherence, and reporting to the Clean Sustainable Energy Authority (CSEA). Governance will be provided by a Project Steering Committee comprising representatives from Ore Spring, AmeriCarbon, UND, Microbeam, and Worley. The Steering Committee will convene monthly to review progress, technical results, budget performance, and risk management. Day-to-day authority resides with the Project Director (Dave Berry, AmeriCarbon) and designated technical leads from each partner organization. Project management will follow established best practices for research program execution, including structured work breakdown, milestone tracking, and risk-based decision gating.

Organization and Responsibilities

Ore Spring Materials, LLC (Project Lead)

- Owns project scope, schedule, and budget.
- Manages partner coordination, reporting, and communications with CSEA and NDIC.
- Oversees compliance, risk management, and quality assurance.
- Maintains the Project Management Plan (PMP), change control procedures, and reporting cadence.

AmeriCarbon (Carbon Manufacturing Lead)

- Leads Task 3 (Pitch Integration & Optimization Studies) and contributes to overall integration design.
- Provides pilot plant operations, data collection, and process optimization for feedstock blending.
- Supplies process performance and material balance data to inform Worley's engineering integration models.

University of North Dakota (REE Integration Lead)

- Leads Task 4 (REE Process Integration & Optimization Studies) and contributes to feedstock and purification research.

· Provides upgraded lignite, humins, and humic-acid residues as test feedstocks.

· Conducts bench- and pilot-scale validation of demineralization, purification, and carbon-quality improvements.

Microbeam Technologies, Inc. (Critical Mineral Recovery Lead)

· Leads Task 5 (Ge/Ga Process Integration & Optimization Studies).

· Conducts bench-scale vaporization, condensation, and refining trials on AmeriCarbon and UND by-product streams.

· Provides mineralogical and compositional analysis to support the techno-economic assessment.

Worley Group (Engineering and Integration Lead, subcontractor to AmeriCarbon)

· Leads Task 2 (Preliminary Process and Site Integration Assessment) and contributes to system modeling, process flow diagrams (PFDs), and mass/energy balance integration.

· Supports development of the Techno-Economic Assessment (Task 6) and future FEL-3 readiness.

Execution Controls and Reporting Cadence

The Project Management Office (PMO), under Ore Spring, will implement an integrated control and reporting system that emphasizes technical performance, schedule adherence, and accountability. Monthly Progress Reports will summarize technical milestones, budget-to-actual performance, safety metrics, and partner activities. Quarterly Steering Committee Reviews will validate milestone completion and address corrective actions where required. Change Control (MOC) procedures will govern scope and budget modifications, ensuring transparent communication and documented decision-making. A shared risk register will be maintained and reviewed.

TIMETABLE

The Forge Project: Rare Earths and Critical Materials Integration is planned as a 24-month project commencing upon award authorization. The schedule below outlines the target timing, activities, and key deliverables.

Project Initiation and Management Setup
Description: Execute partner subcontracts, finalize Project Management Plan (PMP), and convene kickoff meeting.
Timing: Month 1 to Month 2
Deliverable / Reporting Milestone: Project Kickoff Meeting.

Task 1 – Project Management (Ongoing)
Description: Continuous coordination, reporting, and oversight throughout all project phases.
Timing: Month 1 to Month 24
Deliverable / Reporting Milestone: Monthly progress reports; quarterly steering committee reviews; risk register updates.

Task 2 – Preliminary Process and Site Integration Assessment
Description: Worley conducts initial process integration, baseline data review, and site layout study.
Timing: Month 2 to Month 6
Deliverable / Reporting Milestone: Preliminary Process Integration Summary; included in Q2 Report.

Task 3 – Pitch Integration & Optimization Studies (AmeriCarbon)
Description: Pilot-scale testing using lignite, upgraded lignite, humins, and blended feedstocks; generation of process data on yields, ash content, and pitch composition.
Timing: Month 3 to Month 14
Deliverable / Reporting Milestone: Interim Technical Report #1 (Month 9); Pilot Test Data Package #1 (Month 14).

Task 4 – REE Process Integration & Optimization Studies (UND)
Description: Production of upgraded carbon by-products and REE-rich residues; purification and demineralization testing; validation of product quality.
Timing: Month 4 to Month 15
Deliverable / Reporting Milestone: Interim Technical Report #2 (Month 12); Data Summary for Integration Model (Month 15).

Task 5 – Ge/Ga Process Integration & Optimization (Microbeam)
Description: Bench-scale testing of AmeriCarbon and UND residues; validation of selective vaporization and condensation for Ge/Ga recovery.

Timing: Month 6 to Month 18
Deliverable / Reporting Milestone: Interim Technical Report #3 (Month 18); Analytical Results Package.

Task 6 – Techno-Economic Assessment (TEA)
Description: Integration of process data into a unified engineering and economic model; evaluation of commercial potential for Forge site co-location.
Timing: Month 16 to Month 21
Deliverable / Reporting Milestone: Draft TEA and Integration Report (Month 21).

Task 7 – Technology Development and Commercialization Pathway
Description: Identification of remaining technical gaps and development of a roadmap for pilot-to-commercial transition and follow-on funding.
Timing: Month 20 to Month 23
Deliverable / Reporting Milestone: Final Technical Report (Month 23) summarizing integration readiness.

Task 8 – Eco-Pitch™ Asphalt Binder Validation and Commercial Integration Studies
Description: Production of Eco-Pitch™ for asphalt applications and execution of Phase II testing in collaboration with SDSU and industry partners, including formulation optimization, AASHTO-based binder grading, mix-level performance validation, and commercial blending trials to assess constructability and plant compatibility.
Timing: Month 6 to Month 20
Deliverable / Reporting Milestone: Asphalt Performance Data Package (Month 16); Commercial Blending Trial Report (Month 20).

Project Closeout
Description: Submission of final reports and documentation; conduct of project review with CSEA and partners.
Timing: Month 24
Deliverable / Reporting Milestone: Final Report and Presentation.

BUDGET

Total project budget:

Task 1: $100,000

Task 2: $100,000

Task 3: $2,975,000

Task 4: $800,000

Task 5: $300,000

Task 6: $150,000

Task 7: $75,000

Task 8: $100,000

Total: $4,600,000

$1,175,000 is requested from the Lignite Research Council under this application

An additional $1,125,000 has been approved by NDIC for award from Clean Sustainable Energy Council.

The remaining $2,300,000 will be provided in the form of cost share.

PATENTS/RIGHTS TO TECHNICAL DATA

Any patents or rights that the applicant wishes to reserve must be identified in the application.

All background IP, including any and all pre-existing patents, inventions, know-how, research results, and proprietary methods, will remain the sole property of the originating organization. Any new data, methods, or intellectual property developed during the course of this project will be governed by mutually agreed terms among the parties.

STATUS OF ONGOING PROJECTS (IF ANY)

Contract No. FY22-XCVII-241
Title: North Dakota Lignite Coal-Based Pitch for Production of High Value Carbon Product
Term of Contract: January 2022 through June 2023
NDIC Share: $550,000.00

Contract No. FY23-102-251
Title: Engineering Design and Feasibility Analysis for Commercial Graphite and Asphalt Manufacturing from Lignite Derived Carbon Pitch
Term of Contract: July 2023 through June 2025
NDIC Share: $700,000.00

Contract No. FY24-104-258
Title: Lignite Conversion Reactor Optimization for Commercial Carbon Pitch Manufacturing
Term of Contract: July 2024 through January 2026
NDIC Share: $743,800.00

Contract No. FY25-107-264
Title: Commercial Plant Design Optimization: Lignite to Critical Carbon Materials
Term of Contract: May 2025 through July 2026
NDIC Share: $1,499,653

OTHER STATE PROGRAMS AND INCENTIVES

The NDIC has voted to award a grant to Ore Spring Materials, LLC, and contracting is pending.