TITLE PAGE

1. PROJECT TITLE:

Renewable Liquid Hydrocarbon Fuels from Industrial Processes

2. APPLICANT CONTACT INFORMATION:

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2. PARTNER:

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4. TOTAL PROJECT COST: $500,000
Grant funds requested: $375,000
Match committed: $125,000 (25%)

5. PREVIOUS PROJECT TITLE(S) AND/OR APPLICATION NUMBER(S) FOR GRANTS FROM THE RENEWABLE ENERGY FUND OR DENALI COMMISSION EMERGING ENERGY TECHNOLOGY GRANT PROGRAM:

NONE

6. PREVIOUS PROJECT TITLE(S) FOR ABSTRACTS SUBMITTED TO THE EMERGING ENERGY TECHNOLOGY FUND:

NONE

ABSTRACT

1. Project Summary

a. Project Description: The *Renewable Liquid Hydrocarbon Fuels Project* will demonstrate the feasibility and cost-effectiveness of converting carbon dioxide (CO_2) and water directly into renewable liquid hydrocarbons using solar energy (or other sources of renewable energy) and the same thermodynamic principles (but not the same bio-chemical process-steps) as in biological photosynthesis (the product being carbohydrates, not hydrocarbons, in the biological world). The proposed nanotechnology concepts provide opportunities and methods for fabricating nano-reactors that can convert CO_2 into long-chain hydrocarbons. Proposed objectives will confirm the commercial potential of the technology for targeted markets and sustain high tech R&D programs in Alaska. This project will be an extension to the existing R&D collaboration effort between University of Alaska Fairbanks (UAF) and M3 Consulting Services, Inc. under a U.S. Air Force funded Small Business Innovative Research (SBIR) grant. The project team will consist of M3 Consulting, and its technology partner, the Advanced Materials Group, AMG (Alaska's only Nanotechnology and Microelectronics research center) at the Institute of Northern Engineering, University of Alaska Fairbanks (UAF).

b. Project Eligibility: The project will further develop and test an emerging energy technology that has been initiated under a funded SBIR grant by the U.S. Air Force. The project is designed to demonstrate how available industrial technologies can be integrated through nano-technology to create renewable liquid hydrocarbon fuels and will focus on generating these fuels in rural residential and commercial locations in Alaska. Funding will be used to implement a three-phase project to advance the nano-reactor system to TRL 6 over a three-year project period and meets AEA's priorities to promote the expansion of energy sources available to Alaskans through demonstration projects of technologies that have a reasonable expectation to be commercially viable in the next five years. M3 Consulting Services, Inc. is an eligible business holding Alaska Business License #970267, *(attached)*, and its partner for the project is the University of Alaska Fairbanks, an Alaska postsecondary institution.

c. Project Innovation and Scientific Concept: The U.S. economy is highly dependent on foreign sources of oil while at the same time it is struggling to reduce the level of greenhouse gasses, especially CO_2. A novel approach is needed to take advantage of our domestic renewable energy resources, prominently including solar energy, to convert, and thus reuse, CO_2 available from conventional energy conversion processes, to produce renewable liquid hydrocarbon transportation fuels. This project will integrate the most important aspect of fuel-cell technology, namely conduction of ions, with advanced chemical-reaction engineering, including imbedded electronic reaction control, under conditions of confinement, by employing nano-fabrication technology. The net result of using this innovative approach is that chemical reactions such as the direct reduction of CO_2 to long-chain, liquid hydrocarbon fuel molecules can be accomplished. The detailed configuration of the array of nano-scale chemical reactors, and their interfaces with the other macro-scale components of the overall system, are proprietary, but this information will be provided to AEA on a confidential basis.

The artificial photosynthesis process to be implemented is a photo-electrochemical process for producing liquid hydrocarbon fuels from sunlight, wind, or other renewable energy source(s); CO_2; and water. It can operate most effectively in synergy with, and recycle the CO_2 from, other more conventional energy conversion processes such as the gasification of coal and biomass. The carbon dioxide stream from gasification becomes a valuable and ideal resource for recycling, by artificial photosynthesis, into renewable liquid hydrocarbon transportation fuel of the highest quality, rather than merely a byproduct that must be sequestered.

The net result of combining artificial photosynthesis with a more conventional gasification process (focused on Fischer-Tropsch fuel production, for example) can be that, with the input of additional renewable energy, virtually all the input carbon, whether it comes from fossil or renewable energy sources, can end up as part of an extremely high-value, hydrogen-saturated, liquid hydrocarbon fuel. This approach can reduce overall carbon footprint, even when using fossil carbon sources exclusively, to about half that attributable to current conventional energy conversion processes. There is also the potential for even further reductions by incorporating renewable carbon resources such as biomass into the gasification process.

d. Priority: This project will be conducted by an entity with an Alaska business license (M3 Consulting), in partnership with the University of Alaska Fairbanks. By producing renewable liquid hydrocarbon fuels that are a drop-in blending component or replacement for current petroleum-derived middle-distillate type fuels (i.e. diesel fuel), the project has the potential for widespread deployment in the state. The project will provide in-kind matching funds in partnership with the State of Alaska.

2. Technology Validation and Research Methodology

Technology Readiness: Basic and applied research in nano-materials and advanced electronics is being avidly pursued in government, industry, and academic laboratories for efficient nano-fabrication of various structures. Nano-fabrication of structures to be used as chemical reactors is an emerging technology, but it has indeed been demonstrated previously. This project will focus on efficient fabrication of not only the array of nano-scale chemical reactors, but also on the interfaces between the reactor array and the other macro-scale components of the overall system. Recent work has encouraged participation of project partner, Advanced Materials Group (AMG), UAF students and researchers in nanotechnology activities. These ongoing efforts of materials development provide opportunities for leveraging the core competence of AMG. Funding will be used to advance the technology from TRL 4 to implement activities in TRL 5-6 over the three-year project. An additional 1-2 years is estimated to be needed for testing the nano-reactor prototype in its final form and to complete TRL 8 and TRL 9 under actual deployment conditions. Funding is budgeted for M3 and UAF to file with the U.S. Patent and Trademark office for provisional and final patents during the course of the project.

Objectives and Methodology: Proposed research will demonstrate the nano-reactor device configuration, material suitability, and synthesis methods to incorporate organic and inorganic active materials, and address fidelity of device configuration for testing. **Objective #1** will optimize the process types and their associated capabilities in terms of device dimensions, conductivities of ions and electrons, and layer-to-layer registration. The project team will measure the performance of both the individual components and the overall integrated subsystem. **Objective #2** will determine the path forward for future R&D to TRL 8 and TRL9. **Objective #3** will provide a means to sustain high tech R&D programs in Alaska through active collaboration with students and faculty of engineering with UAF. As part of the technology validation and research component, data collection is included in the scope and budget for the project. The specific parameters that will be gathered and reported will be technology and project specific. Quarterly reports will be submitted as required for the project and will include all information outlined in the grant agreement.

3. **Summary of Project Schedule and Summary of Project Budget.** The project will follow Phases I through III over the three year period, as follows:

PHASE/ TRL	TIME-LINE	ACTIVITIES	MILESTONES
Phase I: Pre-Development TRL 5	MONTHS 1-12	Completion of research plan; preliminary Commercialization plans; Project financing finalized; Activities will optimize processes and capabilities in terms of device dimensions, conductivities of ions and electrons, and layer to layer registration.	a) Project scoping completed; b) Final design completed; c) Financial plan finalized; d) Research plan finalized; e) Preliminary Commercialization Plan completed; f) Required reporting completed.
Phase II: Deployment Activities TRL 6	MONTHS 12-24	Pilot project, less than full scale demonstration of nano-reactor device in relevant environment; validation of sub-system operational parameters and efficiencies, research plan put into effect; monthly reports; update financial plan.	a) Project deployment; b) Project monitoring activities; c) Project improvement activities; d) Financing Plan updated; e) Commercialization Plan updated with current project costs; f) Reporting through 2014.
Phase III: Post Deployment TRL 6	MONTHS 24-36	Analyze and report on technology validation and research plan results; update commercialization plan to reflect study results; decommission project, as needed.	a) Commercialization Plan complete; b) Continued performance monitoring; c) Final performance report; d) Analysis and recommendations

The total project budget is $500,000. M3 and UAF will collectively provide $125,000 of in-kind and cash match for the project. The total grant funding requested is $375,000.

4. Project Team Qualifications

M3 staff is experienced in grant administration and business management, and has established processes for engineering, research, data management, and record keeping procedures. M3 will engage AMG for the proposed technical research, nano-reactor device fabrication, and testing. AMG employs professionals for running the facility, R&D, and pilot production. Multiple opportunities for interdepartmental collaboration will offer graduate students participation in the project. The project team includes staff from M3 and AMG**.**

- Project Manager, *Steve Bergin, PhD, P.E., Director of Research at M3,* has worked closely with AMG for the past 15 years to develop, expand, and commercialize the business model for synthetic fuels. He will maintain the overall supervision of the project, direct all phases of the effort, coordinate budget management, submit required reports and manage development of the commercialization plan. Dr. Bergin will work closely with AMG to develop questions that need to be answered to move from lab/pilot-level work to pre-production work, and will maintain continuous oversight of the market demand for the technology.
- Principal Investigator for Technology Validation and Research: *Shiva Hullavarad, Ph.D., Assistant Professor, Advanced Materials Group, INE – UAF,* presently heads Microelectronics and Photonics DARPA funded program at AMG, UAF. As Principal Investigator for the technology, he will be responsible for ensuring valid scientific and economic data and other technology validation and research activities; providing the aforementioned information in the format reasonably specified by the Authority for all phases of the Project: Ph. 907-455-2017 Email: shiva.h@alaska.edu
- Co-Principal Investigator for Technology Validation and Research: *Nilima Hullavarad, Ph.D. Research Assistant Professor, Advanced Materials Group, INE - UAF,* is leading a nano-fabrication DARPA funded program to synthesize semiconductor-metal nanoparticles, nanowires and composite materials for advanced device miniaturization technology applications. As Co-Principal Investigator, she will work

closely with the Principal Investigator to ensure valid scientific and economic data and other technology validation and research activities from the Project; Ph. 907-455-2017 Email: nilima.h@alaska.edu

5. Discussion of Commercialization of Funded Technology

The development of a system for producing liquid hydrocarbons using artificial photosynthesis has broad application across all facets of the global economy. This technology stands to replace some, if not all, traditional petroleum-based refinery production of transportation fuels. In addition to the use of such a system for production of transportation fuels for niche applications, this technology will also be marketed to both traditional and non-traditional energy suppliers in the private sector. Licensing arrangements will be pursued with large energy providers such as ExxonMobil, BP, and other traditional fuel suppliers. Below is a summary of the key milestones, estimated additional investment, and commercialization results expected as part of this commercialization strategy. It also depicts how this project will advance the commercialization of the proposed energy technology.

Commercialization Milestone	Date	Financing Method	Approx. Investment
Start-up	2011	Sweat Equity	$500,000
Concept Development	2012	US Air Force SBIR	$100,000
IP Protection	2012	Retained Earnings	$50,000
Nano-reactor Deployment	***2015***	***AEA EETF Grant Funding***	***$500,000***
Full-Scale Production Scale-up	2016	Equity Investor	$5,000,000
Licensing	2017	Strategic Partners	$10,000,000
Marketing / Sales	2017	Strategic Partners	$1,000,000

A key advantage offered by this project team is they have worked together on similar projects for over 10 years with a history of successful transition of technology from research to commercialization. A prime example of this proven commercialization track record is the synthetic fuels program that was managed by M3 Consulting with UAF serving as its research subcontractor. Under this program, sponsored by the National Energy Technology Laboratory of the Department of Energy, M3 and UAF successfully developed, demonstrated, tested, deployed, and produced synthetic fuels based on the Fischer-Tropsch (FT) process. The fuel produced under this program was subsequently used by the U.S. Air Force and U.S. Army to certify the use of these fuels in military equipment. At this point, there are several commercial suppliers preparing to service the military need for these FT fuels. This program serves as a prime example of how the principals involved in this proposed project can and will transition synthetic fuels solutions to commercialization.

6. Signed Applicant Certification

By signature on this application, I certify that we are complying and will comply with the amount of matching funds being offered.

Kevin Mulrenin
President
M3 Consulting Services, Inc.