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*Comment Received From: Frank H. Shu*
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## Astron Solutions Corporation

*Additional submitted attachment is included below.*

CALIFORNIA ENERGY COMMISSION
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The Energy Commission is currently soliciting ideas and stakeholder input for the 2018 – 2020 EPIC Triennial Investment Plan. For those that would like to submit an idea for consideration in the 2018-2020 EPIC Triennial Plan, we ask that you complete the form below. Submittals are due by **5:00 p.m. on February 10, 2017.**

**Part 1. Initiative Description and Purpose:**

1. Please provide a brief description of the proposed initiative:

Astron Solutions Corporation proposes to scale up for commercial application a patent-protected supertorrefaction (STR) technology that immerses any form of biomass under molten salt at a temperature of 450 Celsius to convert the organic matter into char and volatile organic compounds (VOCs). If an oxidant is added to the salt to perform charcoal fines oxidation (CFO), the char and VOCs can be oxidized inside the salt, with carbon dioxide and water vapor ideally as the only emissions. In practice, recovering the oxidant requires sparging in air, and there will be slight amounts of NOx and SOx mixed with air, CO2, and H2O. The NOx and SOx can be scrubbed out by standard methods. The oxidation of the char and VOCs adds heat to the molten salt at essentially 100% efficiency. If tubes carrying supercritical carbon dioxide thread the container of the molten salt, the added heat can be converted to electricity by a Brayton cycle turbine at greater than 40% efficiency. If the biomass is chopped sufficiently fine (with the char automatically becoming charcoal fines) so that the biomass can be blown into the container of molten salt, the STR/CFO process can occur in a continuous manner in equipment of arbitrarily scalable size and power.

2. What technical and/or market barriers would the proposed initiative help overcome? For scientific analysis and tools, what knowledge gaps would the proposed initiative help fill?

The combustion of biomass for electricity generation traditionally faces two problems: (a) the creation of tars that gum up moving parts (e.g., pistons of internal combustion engines), and (b) equipment sizes so large that they are not easily transportable to remote sites where California has considerable waste biomass (e.g., beetle-infested pine trees in High Hazard Zones for forest fires.) Our solution can be implemented in two stages. In the first stage, we will build STR/CFO equipment that can transform biomass into biochar. The biochar can be used as a superior fuel to power existing electricity plants that combust biomass in traditional boilers. In the second stage, we will partner with other companies that are developing prototype turbines driven by supercritical carbon dioxide (sCO2) to generate electricity in the few MWe power range (e.g., General Electric after 2019). We can couple the small turbines to the molten salt heated by directly oxidizing finely chopped biomass, thereby foregoing the intermediate step of making biochar. The powerful combination of STR/CFO technology and sCO2 turbines solves the two traditional problems because (a) tars are oxidized inside the molten salt before they can escape as vapors to foul the rest of the system, and (b) the combined system is so compact that equipment capable to generating a few MWe can easily be transported on trucks that can go wherever there are paved roads (not necessarily superhighways).

**Part 2. Benefits and Impacts**

3. If this initiative is successful, either fully or partially, what would be the expected impact? Who are the primary users and/or beneficiaries?

A primary difficulty with existing renewables to generate electricity (except for hydroelectric and geothermal) is that they have to be backed up either (1) with thermal power plants (e.g., gas-fired, coal-fired, or nuclear), or (2) by large banks of batteries. Agricultural residues, yard trimmings, and forestry wastes are under-utilized resources in California, and if they could be used as fuel for STR/CFO/sCO2 machines, they could provide the needed carbon-neutral back-up to the intermittent renewables. In California, we envision the primary users to be the independently owned utilities and their rate-payers, particularly in under-served rural communities that have ample access to waste biomass. Transportability of the equipment brings electricity to communities not hooked to the grid, as well provides a vital dispatachable component to microgrids. Unlike the direct combustion of biomass in air, the oxidation of biomass under molten salt by STR/CFO emits no soot, and cleaner air would be enjoyed by all California citizens, urban and rural.

4. Describe what quantitative or qualitative metrics or indicators would be used to evaluate the impacts of the proposed initiative:

Improved efficiency for electricity generation in terms of net kWh of electricity output per MJ of heating value of biomass inputted.

Shorter mean transportation distance of biomass feedstock to processing facility.

Lower amortized capital equipment and operations/maintenance costs to generate a kWh of electricity.

Higher capacity factor = (electrical energy generated in a year)/(nameplate power x 1 year)

Smaller annual costs of repair, maintenance, and replacement of facility equipment.

Longer projected service life of equipment from annual inspections of the mechanical wear and chemical corrosion rate of the equipment.

5. Please provide a list of peer-reviewed references that support the responses for questions 3 and 4. Proposed initiatives that include peer-reviewed references will be given stronger consideration.

1. Frank H. Shu, Michael J. Cai, Fen-Tair Luo, Supertorrefaction of Biomass into Biocoal, United States Patent 9,096,800

2. Frank H. Shu, Fen-Tair Luo, Michael J. Cai, Supertorrefaction by Batch Process, United States Patent granted but yet to be given a serial number

3. YouTube video on Reversing Climate Change: Biochar in Ten Minutes (with change of salt and higher temperatures, it takes one minute or less for batch processing of biomass) https://www.youtube.com/watch?v=xx2LLCuxdH4

6. (For technologies only) What competitive advantages does the proposed technology solution have over current benchmark technologies? If the technology is beyond the prototype stage, what strategies do you suggest to bring to scale?

A. Improvement in speed: traditional batch-process torrefaction that uses flue gas as the heat-transfer medium takes several hours to days to complete the conversion of wood chips or wood pellets to charcoal; we can do it in a minute or less.
B. Improvement in equipment size: for machines that can process 10,000 tonne of biomass a year or more into charcoal (none existing in the US), traditional torrefaction equipment occupies the floor space of a large factory. Because molten salt has volumetric heat capacities 2000 times larger than flue gas, we can achieve the same results with equipment the size of a household water heater.
C. Improvement of cleanliness: relative to existing pyrolytic methods of processing of biomass, our thermochemical approach is cleaner in producing no emissions of tar or soot (esp. PM2.5 particulates).
D. The prototype equipment that we have built in Hsinchu, Taiwan demonstrates scientific feasibility. We are now in discussions with the Hsinchu County government to build a commercial-scale production facility in 2017 that will process more than 10,000 tonne/year of pruned citrus wood branches into biochar. The same STR/CFO coupled to a sCO2 turbine can generate an average electric power of more than 2.3 MWe. When a mature industry develops around this technology, we anticipate that such machines could have capacity factors rivaling those of modern nuclear power plants, i.e., in excess of 0.9.

**Part 3. Connection to Energy Commission's EPIC Framework**

Energy Commission staff have developed a draft strategic framework to guide the CEC's planning and implementation of EPIC across triennial investment cycles. One of the objectives of the draft strategic framework is to communicate a consistent set of priorities for organizing current and future EPIC investments.

7. Please indicate which of the following strategic framework themes you feel the proposed initiative best fits within:
    - Advance Technology Solutions for Deep Energy Savings in Building and Facilities
    - Accelerate Widespread Customer Adoption of Distributed Energy Resources
    - Increase System Flexibility from Low-Carbon Resources
    - Increase the Cost-Competiveness of Renewable Generation
    - Create a Statewide Ecosystem for Incubating New Energy Innovations
    - Maximize Synergies in the Water-Energy-Food Nexus
    - Develop Tools and Analysis to Inform Energy Policy and Planning Decisions
    - Catalyze Clean Energy Investments in California's Underrepresented and Disadvantaged Communities

(Select One)

If Other, Please Specify