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Purpose of evaluation and assessment criteria

The purpose of this evaluation is to verify the environmental and climate performance of the equipment, in terms of emissions of air pollutants, management of solid and liquid wastes, and emissions of greenhouse gases. In addition, the aim is to evaluate the capability of the equipment to produce high quality biochar. This evaluation follows the requirements set out in the Puro Standard for Biochar (Edition 2022, Version 2).

Puro's evaluation of pyrolysis equipment is built around the following 7 assessment criteria:

Criteria 1: Methods to ensure complete combustion

Criteria 2: Methods to ensure low emissions of air pollutants

Criteria 3: Methods to ensure safe disposal of any waste stream

Criteria 4: Emission testing of air pollutants

Criteria 5: Emission testing of greenhouse gases

Criteria 6: Testing of biochar quality

Criteria 7: Material choices and expected equipment lifetime

Endorsed technology partner, equipment models and configurations

Technology Partner Information	
Name of the manufacturer	Beston Group Co., Ltd.
Country where manufacturer is registered	China
Website	www.bestongroup.com
Name and contact details of representative, date of submission	Contact: Mr. Zoe Zhang Email: zoezhang@bestongroup.com Tel: +8618569981780 Date of submission: 18-10-2023

Equipment model and configurations applicable

Name of the model: **BST-50S**

Configuration and meaning of components:

1. **Dryer** (pre-dryer): for drying of the input biomass
2. **Pyrolysis system**: rotary carbonization reactor
3. **Pyrolysis gas recovery system**: pyrolysis gas combustion chamber, connected to the pyrolysis system (together forming the **carbonization reactor**)
4. **Cyclone de-duster**: cyclone system to filter large particles from the syngas prior to its combustion
5. **Excess Pyrolysis Gas Combustion Chamber**: a second combustion chamber where both excess syngas, alongside flue gas from the carbonization reactor, and primary air are combusted.
6. **High-end flue gas treatment system**: flue gas cleaning system made of an air-to-air heat exchange, a pulse bag filter, a desulfurization tower, an activated carbon filter, and a chimney. It also includes devices for monitoring air pollutants and operating conditions.
7. **Heat exchanger and refrigeration systems**: various components to cool down biochar and process water, or heat combustion air and syngas, at different stages of the process.

Puro's evaluation is limited to the unique model and configuration described above, i.e. BST-50S without pyrolysis oil condensation, two flows of syngas and combustion systems, recirculation of flue gas, and equipped with an advanced flue gas treatment system.

Assessed criteria and summary of observations

Note – the summary of observations in this public version have been redacted to not disclose any confidential information, and the redaction has been approved by the Technology Partner. Interested buyers may request additional information directly from the Technology Partner.

Criteria 1: Methods to ensure complete combustion of pyrolysis gases and oils
☒ Criteria is met, in full. ☐ Criteria is met partially. ☐ Criteria is not met.
Observations: Criteria 1 is met, thanks to the design measures listed above, evidenced with some pictures, technical drawings, and written declarations. It is noted that the system has two combustion chambers, one for excess pyrolysis gas combustion (four burners) and one for sustaining the reactor (equipped with four burners). Both chambers are closed, have forced injection of pre-heated air, fuel-air mixing burners, some degree of insulation, and reach sufficient combustion temperature and residence time. Flue gas is also partly recirculated. It is noted that the operation of the equipment relies at least partly on manual adjustments, with some limited degree of automation, requiring important training of operators.

Criteria 2: Methods to ensure low emissions of air pollutants
☒ Criteria is met, in full. ☐ Criteria is met partially. ☐ Criteria is not met.
Observations: Criteria 2 is met, thanks to the design measures (such as flue gas recirculation in combustion chambers) and the flue gas treatment system installed (including flue-gas cooling, bag filters, desulfurization, activated carbon filter). It is noted that this flue gas treatment system was tested for a clean biomass feedstock (woodchips) for which it is usually not necessary to have an advanced flue gas treatment system. The model evaluated here was not tested without the treatment system and it is therefore expected to be installed by projects using this equipment. For other more complex feedstocks (e.g. sewage sludge, manure), an advanced flue gas treatment system is usually necessary (especially for SO2 removal); however, the equipment model evaluated here was not tested for such feedstock. This said, it will be verified on a project basis that equipment installed meets the regulation applicable locally.

Criteria 3: Methods to ensure safe disposal of any waste stream
☒ Criteria is met, in full. ☐ Criteria is met partially. ☐ Criteria is not met.
Observations: Criteria 3 is met, as the information provided identifies all waste streams and quantifies the amounts generated during normal operations. The model assessed, equipped with a complete flue gas treatment system, generates under normal operations both solid (about 700 kg/week of ash, charcoal fine and tars, spent desulfurization agent, dust, filter) and liquid waste (about 125 L/week of wastewater excluding washing and cleaning). This is an important aspect to be considered designing a project using this equipment, as it will

then be verified during regular facility and output audits of projects that waste streams are disposed adequately.

Criteria 4: Emission testing of air pollutants

☒ Criteria is met, in full.
☐ Criteria is met partially.
☐ Criteria is not met.

Observations:
Criteria 4 is met, thanks to the data provided for at least one biomass feedstock (a clean feedstock, eucalyptus wood chips) showing compliance with some regulation (Singapore). However, it should be noted that at this stage, it was not shown that environmental permits have been obtained for this equipment in other jurisdictions. In addition, emission testing was conducted on a prototype device model (BST-03), which is stated to operate with the same carbonization process and flue gas treatment systems as the BST-50S. More thorough analyses could have been conducted by the equipment provider to include comparison with legislations from multiple jurisdictions. This said, it will then be verified during regular facility and output audits of projects that equipment installed meets the regulation applicable locally.

Criteria 5: Emissions testing of greenhouse gases

☒ Criteria is met, in full.
☐ Criteria is met partially.
☐ Criteria is not met.

Observations:
Criteria 5 is met, meaning that GHG emissions have been quantified and can be used for determining the carbon footprint of biochar produced with this equipment, at least one biomass feedstock (eucalyptus wood chips). Emission testing was conducted on a prototype device model (BST-03), which is stated to operate with the same carbonization process and flue gas treatment systems as the BST-50S. Puro notes that CH4 emissions are low, representing < 0.1% the carbon stored in the biochar, which seems in line with the combustion system deployed. Puro notes that N2O emissions are low, representing <1% of the carbon stored in the biochar, likely due to recirculation of flue gas in the combustion systems.

Criteria 6: Testing of biochar quality

☒ Criteria is met, in full.
☐ Criteria is met partially.
☐ Criteria is not met.

Observations:
Criteria 6 is met, meaning that it has been demonstrated that the equipment can be operated with certain biomass feedstocks (eucalyptus woodchips) in a way that leads to biochar of sufficient persistence (H/Corg < 0.7) and sufficient environmental quality for at least some applications, e.g. soil applications (using limit values from the EBC). For certain application types (e.g. EBC AgroOrganic), the detection limits were not sufficient to determine compliance. This said, it will then be verified during regular facility and output audits of projects that biochar produced is of sufficient persistence and sufficient environmental quality.

Criteria 7: Material choices and expected equipment lifetime

☒ Criteria is met, in full.
☐ Criteria is met partially.
☐ Criteria is not met.

Observations:
Criteria 7 is met, meaning that sufficient information was disclosed to enable calculations by projects. In such calculations, the expected lifetime included in carbon footprint accounting may be conservatively reduced to 5 years. As for any other endorsed technology provider, Puro will make adequate disclaimers, ensuring that biochar projects do perform their own due diligence with respect to equipment material quality, expected lifetime, availability of spare parts, support from manufacturer and warranty.

Other comments

None.

Decision

☒ The applicable equipment by the Technology Provider have successfully passed the Puro.earth evaluation against the requirements set out in the Technology Provider Evaluation Criteria.
☐ The submission requires revisions before the evaluation of the applicable equipment by the Technology Provider can be finished.
☐ The applicable equipment by the Technology Provider have not passed the Puro.earth evaluation against the requirements set out in the Technology Provider Evaluation Criteria.

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