# Large-Scale Biochar Production from Crop Residue: A New Idea and the Biogas-Energy Pyrolysis System

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Biochar is an effective means to withdraw carbon dioxide ($CO_2$) from the atmosphere and consequently influence the trend of global climate change. However, there still are substantial knowledge gaps for this idea to be applicable. One big question is how to produce biochar from biomass on a large scale. Our idea is to use biogas produced from agricultural wastes as thermal energy for biochar production from cheap crop residues. A continuous biogas-energy pyrolysis system has been designed and successfully piloted to utilize crop residues for biochar production.

*Keywords: Biochar; Crop residue; Biogas-energy pyrolysis system; Large-scale production*

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## Idea for Large-scale Biochar Production

Biochar is charred organic matter that is prepared under a limited supply of oxygen. The reason why biochar can efficiently sequester carbon is mainly due to its higher carbon content and longer duration in soils than ordinary biomass. Biochar sequestration is now considered a robust and simple way to withdraw carbon dioxide from the atmosphere. If all plant biomass were completely converted to C-rich and environment-persistent biochar, then the theoretical annual potential of net C withdrawal from the atmosphere would be as high as 24 Gt C per year (88 Gt $CO_2$), 20% of the total C captured through photosynthesis (120 Gt per year). But the big question is how to produce biochar on a large scale. The global C storage in crop residues is as high as 9 to 11 Gt C each year, of which 30% comes from China. These crop residues offer cheap resources for large-scale biochar production. The connotation of our idea is as follows: use agricultural wastes such as human and animal manures together with crop residues to produce biogas, and the biogas will be the source of thermal energy for pyrolysis of the crop residue.

Pyrolysis to convert crop residues into biochar using the energy from biogas production from agricultural wastes can have multiple environmental and economic benefits. It offers not only an attractive solution for reducing air pollution from open burning of crop residues, but also a favorable agriculture sustainable model for reutilizing agricultural wastes. Annually, China produces 2.5 to 3 billion tons of animal manures, 0.8 to 1.2 billion tons of fruit and vegetable wastes, 0.2 to 0.3 billion tons human excrements, 0.5 to 0.7 billion tons of domestic garbage, and 0.17 to 0.3 billion tons of domestic meat wastes. Because these fresh biomasses generally have high moisture content, excessive energy requirement is necessary for baking and pyrolysis if they are directly utilized as sources for biochar production. It is more effective to use them as raw materials for biogas production in a marsh gas tank. A relatively high N concentration in animal manures and domestic refuse in comparison with crop residues can provide a favorable C/N ratio for growth of microorganisms and thus enhance biogas production. Moreover, biogas residue is rich in nutrient elements that can be reutilized as fertilizer.

Different from wood, crop residue usually has distinct characteristics of low density, greater bulk, slender shape, and soft structure. It is thus difficult to feed crop residue into a pyrolysis kiln using a normal spiral conveyor. Greater bulk of crop residue also inevitably requires an excessively large volume of the kiln. Although the traditional method of cutting crop residue could realize feeding by a spiral conveyor, it requires additional labor and energy costs. Moreover, chopped crop residue may be too bulky to be placed into a volume-limited kiln for pyrolysis. There is no existing technology applicable to produce biochar from crop residue on large scale.

## Design of the Biogas-Energy Pyrolysis System

According to the above connotation, we designed a pilot continuous biogas-energy pyrolysis system including a continuous rollaway bed kiln for torrefaction and pyrolysis, a biogas subsystem for thermal energy supply, and auxiliary facilities for cooling biochar and eliminating atmospheric emissions (Fig. 1). Both the torrefaction and pyrolysis processes used thermal energy supplied by the combustion of biogas from the biogas subsystem. Torrefaction was carried out in a temperature range of 200 to 300 $^{o}$C. This thermal pretreatment could remove $H_2O$ from crop biomass to reduce oxygen-to-carbon (O/C) ratio, which would improve the efficiency of pyrolysis. The pyrolysis was carried out in a temperature range of 500 to 700 $^{o}$C, adjustable according to the requirements.

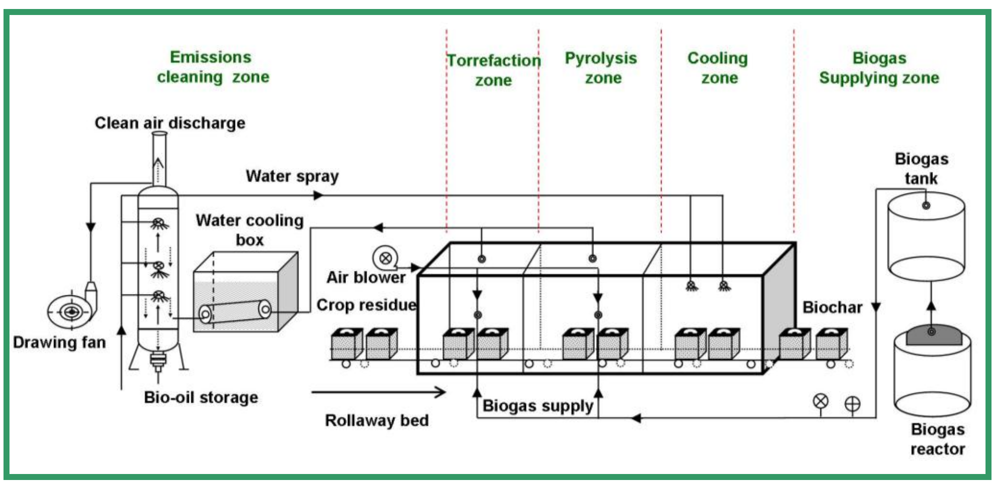


**Fig. 1.** A schematic of the continuous biogas-energy pyrolysis kiln

In addition, the complete sets of auxiliary facilities are considered. Firstly, we used a square pickup baler to automatically bale straw after the crop harvest. The advantages of this approach are that crop residue could be easily placed into high-temperature resistant containers and sequentially fed into the skin for pyrolysis through an automatic rollaway bed; in addition there would be more convenience in transformation and storage. Secondly, we equipped a water spray system and an air-water heater exchange system in the flue from the torrefaction and pyrolysis zones, which can efficiently mitigate atmospheric emissions of volatile organic compounds and particulate matter that may escape during the thermal process. Another water spray system was installed in the cooling zone to cool hot biochar rapidly from the combustion zone, as it facilitated the implementation of a continuous production process and enhanced the rate of biochar production. Moreover, hot water from these cooling systems is then re-circulated into the biogas reactor as heat and water source in favor of biogas production, especially in winter, or reserved for other uses.

This new system was successfully piloted at a private farm in the Taihu lake region, China. The farm mainly produces rice, wheat, mushrooms, and grapes, as well as dairy breeding (Fig. 2). The continuous biogas-energy pyrolysis system improved the efficiency of the inner-circulation of agricultural wastes.

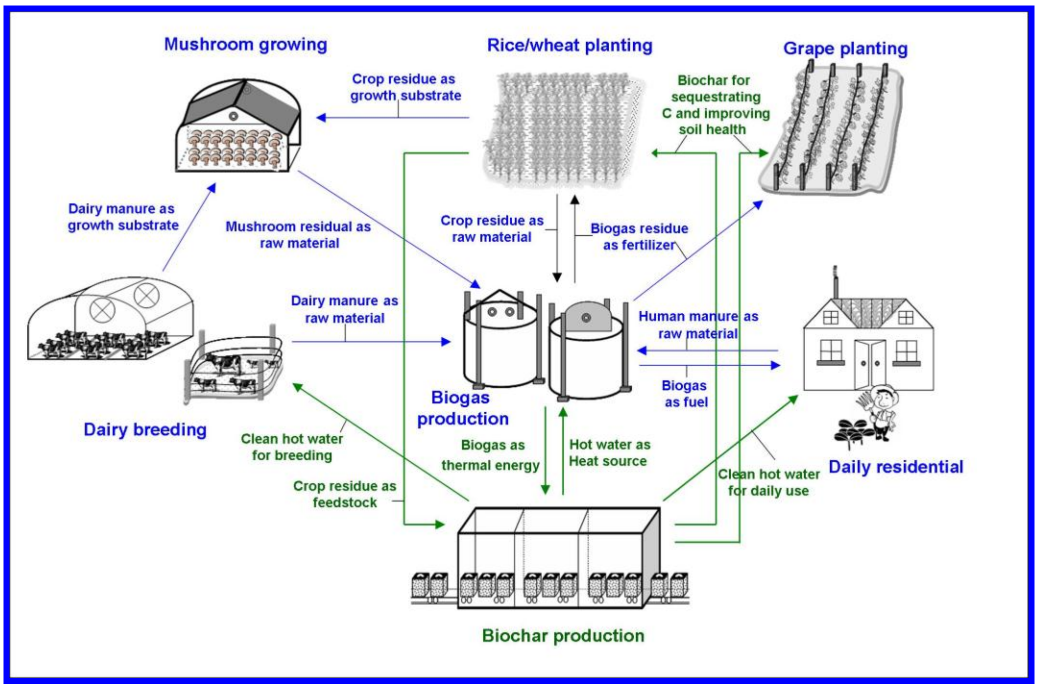


**Fig. 2.** Application of the continuous biogas-energy pyrolysis kiln for biochar production in recycle agriculture

There was enough thermal energy from biogas to provide a relative constant temperature in the continuous rollaway bed kiln for pyrolysis of crop residues, and thus biochars were produced with high quality. The biochar production rate from this system (33%, 35%, and 25% for rice straw, rice husk, and wheat straw under 500 $^{o}$C±10, respectively) was close to that in the laboratory electric furnace (32.6%, 34.6%, and 27% under 500 $^{o}$C±2). As one-time investment on this system declines with the maturity of the technology, we believe that this continuous biogas-energy pyrolysis system can eventually be adaptable for large scale of biochar production.

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