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INTERPROFESSIONAL PROJECTS PROGRAM

Small Town Sustainable Economic Development Feasibility of a Biochar System for Orange, Massachusetts

Final Report
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Executive Summary

The purpose of this project is to perform analysis of a sustainable system for managing solid organic waste in rural areas using biochar systems and alternative technologies. This pilot project was conducted in order to help the town of Orange; Massachusetts manage their solid organic waste whilst simultaneously providing economic stimulation. A useful way to manage solid organic waste is by using waste-to-energy technologies, such as pyrolyzers. These systems range in size (small-scale to large-scale), and have the potential to be used to manage local waste or waste generated in smaller-scale farms. This report examines the pros and cons of a small-scale decentralized system and a large-scale centralized system for managing local waste. Analysis also includes identified alternative technologies for organic waste management in this study.

The resultant strategy is built around a two-pronged approach of both centralized and decentralized systems. A larger, centralized system would have the capability to manage large amounts of waste, provide energy, and produce larger amounts of biochar that can be used to fertilize soil, increase its yield, and reduce the need for water and use of fertilizers, recover energy from the synthetic gas, and produce bio-oil. A smaller scale, (decentralized model) would turn farm waste into a useful product that can be used for soil amendment at local farms.

Purpose and Objectives

<u>Statement of Problem:</u>

Small towns like Orange are severely affected by the increasing urbanization of the service sector and the outsourcing of manufacturing jobs to other countries. Forced to seek opportunity elsewhere, young people have moved out, leaving towns with aging populations, struggling economies, and crumbling infrastructures. Emerging entrepreneurs in the area hope to create jobs and stimulate the local economy by making use of the area's resources.

The current waste disposal method for the town of Orange, Massachusetts comes at a cost to the citizens of the town and requires shipping sewage waste a long distance. A waste management facility in or near Orange could reduce or eliminate this expense for residents and provide useful byproducts that could be sold commercially and subsequently stimulate the local economy. We seek to foster the economic attractiveness and vitality of the town by designing a better and more sustainable way to manage the town's waste.

<u>Project Goal</u>

The purpose of the project is to design a model of a sustainable waste management system for the town of Orange, Massachusetts. We seek to foster the economic attractiveness and vitality of the town by designing a more effective and sustainable way to manage the town's waste.

<u>Strategic Alignment:</u>

(Sustainable Managing Strategy for Organic Waste in Rural Areas) This project intended to investigate both the design specifications and end-product characteristics of biochar systems for the town of Orange Massachusetts in order to produce a feasibility study and primary business plan. The following sections discuss the project under consideration (centralized and decentralized biochar systems). As presented, a centralized system would be a large-scale plant that would have higher capacity with the high capability of recovering energy and producing biochar. The costs associated with running a centralized system are also high, both capital and operational costs. A small-scale decentralized project would allow farms and households to manage their own solid organic waste, cutting down on personal costs of transportation of waste.

<u>Team Objectives</u>

- Gather information and characterize the type, quality and quantity of organic solid waste generated in Orange, MA.
- Examine and compare biochar to other technologies to determine if it is a sustainable and economically feasible solution for managing and converting organic waste generated in rural areas into marketable byproducts while also encouraging economic development and job creation in those areas; specifically, the team will focus on the town of Orange, MA and its socio-economic characteristics.
- Develop a business case for the proposed technology, including costs, benefits, risks, potential market, and likelihood for economic growth in Orange.
- Examine and select the most promising technology identified based on our investigation mentioned above; develop a working prototype or acquire a pilot-scale technology for the following purposes:
    - Test and perform qualitative and quantitative analysis of the system.
    - Research the potential products and byproducts that can result from the process and their possible uses
    - Determine the commercial viability of the products and byproducts.

Organization and Approach

The team had been divided into two major sub-teams: The design team and the business/ marketing team. Design team members will be responsible for ultimately designing and testing a sustainable waste management system for the town of Orange. The business/ marketing team will perform a commercial viability analysis for the products and develop a marketing strategy.

The aim of waste management is to prevent or reduce the impact of waste materials on human health or local amenity. Waste management can involve solid, liquid and/or gaseous wastes, and the methods involved for each are disparate. Waste management practices are often very different between urban and rural areas, and residential and industrial/commercial producers, even within the same local region.

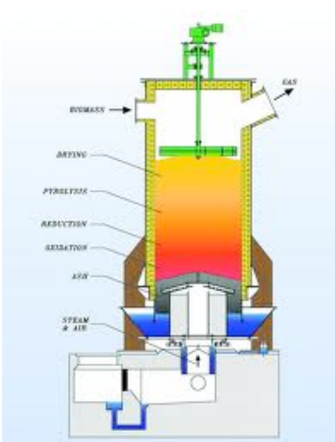
There are several technologies available for converting waste into useful products. Mostly commonly used are discussed below:

- **Recycling**: This is the reuse of a material that would otherwise be considered waste. The most common recycled material includes aluminum and steel cans, PET and glass bottles, paperboards, newspapers and magazines. The process of recycling requires significantly less energy, water and other resources to recycle materials than to produce new materials. Recycled or used materials have to compete in the marketplace with new materials. The cost of collecting and sorting the materials sometimes make it equally or more expensive than virgin materials.

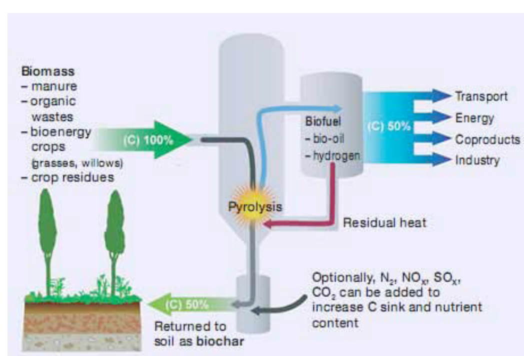
- **Incineration:** This method destroys waste material by burning it. The process is often used to produce electrical energy by burning the waste material and producing steam to drive an electric generator. Incinerations as a waste management process is very controversial as the gases and the ash residue produced are often toxic to human health and the environment.
- **Pyrolysis and Gasification:** These are related processes of thermal treatment where materials are incinerated with limited oxygen. The process typically occurs in a sealed vessel, under high temperature and pressure; Converting waste material to energy. This way is more efficient than direct incineration, with more energy recovered and used, making the process more environmentally friendly.

Biochar Technology

The main technology that the team will explore is biochar technology. Biochar is char derived from the thermal conversion of biomass that is used for non-energy purposes. Biochar is a fine-grained, porous charcoal substance that, when used as a soil amendment in combination with sustainable production of the biomass feedstock, effectively removes net carbon dioxide from the atmosphere. Thermal decomposition involves baking biomass in the absence of air to drive off volatile gases, leaving carbon behind. There are three main processes to achieve this: Pyrolysis, gasification and hydrothermal carbonization. These methods can produce clean energy in the form of gas or oil along with the biochar. This energy may be recoverable for another use, or it may simply be burned and released as heat. It is one of the few technologies that are relatively inexpensive, widely applicable and quickly scalable.



Gasification



Pyrolysis

It is important to note biochar technology encompasses more than just the equipment needed to produce biochar. It necessarily includes entire integrated systems containing various components that may or may not be part of any particular system.

In general, biochar systems include the following elements:

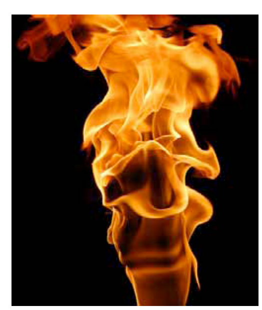
- Collection, transport and processing of biomass feedstock
- Production and testing of biochar
- Production and utilization of energy co-products: gas, oil or heat
- Biochar transport and handling for soil application
- Monitoring of biochar applications for carbon accounting or other purposes.

<u>Benefits of Biochar Systems</u>

- The char is an excellent soil amendment, useful for avoiding and reversing soil degradation, and also for preventing nutrient run-off and erosion thereby creating sustainable food and fuel production in areas with severely depleted soils.
- Biochar is the only 'Carbon Negative' process of waste management known until now. Biochar restores carbon back into the soil, rather than releasing carbon into the environment.
- The process of making biochar also produces a biofuel and a synthesis gas ("syngas"). The bio-fuel can be refined and sold on the market, and the syngas can usually be burned on-site; alternatively, both fuels can be burned on-site. Bio-energy can also be used for cooking, drying and grinding grain, producing electricity and thermal energy.
- Low-cost, small-scale biochar production units can produce biochar to build garden, agricultural, and forest productivity.
- Biochar gets rid of organic wastes like cornhusks, manure and sewage sludge; the last two of which are significant sources of water and land pollution.
- Since Pyrolysis does not allow for the creation of carbon dioxide, biochar sequesters carbon effectively when it is applied on the ground as a soil amendment.

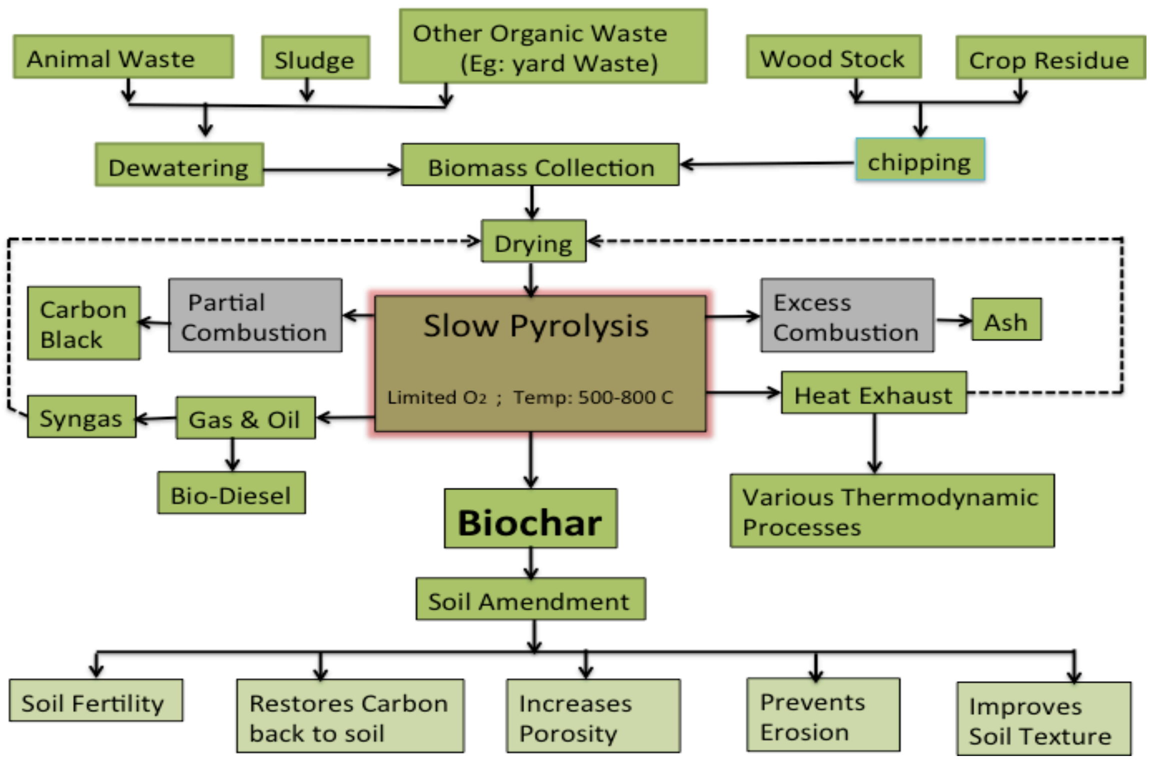

Biochar


Biofuel


Energy (Heat)

Process Flow Diagram

A process flow diagram describes all of the inputs and outputs of a given system. Flow diagram helps in a better understanding of the system and gives an overview of how the process works. The diagram in the below illustrates the process flow categories of the biochar production process from acquisition of the biomass to the application of biochar to soil. This is only indicative and not definitive for all pyrolysis processes.



	% liquid	% char	% gas
Fast Pyrolysis	75	12	13
Moderate Pyrolysis	50	20	30
Slow Pyrolysis	30	35	35
Gasification	5	10	85

Analysis and findings

There are two main design options for a biochar system namely centralized and decentralized operation systems.

Decentralized system

In this system, one can privately produce biochar 'grills'. This system combines a grill and a pyrolyzer into a single operation (see Appendix for design example). Like other pyrolyzers, a small amount of fuel (usually propane) is needed to start the reaction and to a large extent, with enough biomass, the system can sustain the pyrolysis for several hours. One can create dinner for the family or friends while producing biochar for their personal gardens or farms.

One of the major strengths of a decentralized biochar system is its simplicity. Little training and education is needed to teach farmers to use the pyrolysis grills, and the biochar produced just needs to be tilled and buried into the soil. Transportation costs can largely be ignored as a small-scale on-site pyrolyzer can easily be moved by hand. There are no legal concerns to deal with in terms of permits when using a pyrolyzer to produce biochar at the scale of a family farm.

A small-scale pyrolyzer is relatively inexpensive, but not free. Farmers would most likely have to purchase their own pyrolyzers, making a $200-500 investment that would eventually pay for itself in gas, fertilizer, and waste disposal costs. More expensive models may have the ability to be more efficient, but require more starting fuel and very dry solid biomass.

Depending on the amount of use the grill sees, the average small pyrolyzer may have a lifespan of 5 years. Because it is assumed that all biochar produced would be used on-site for the farm at which it was produced, there is no saleable product in the decentralized system.

Farmers would have to account for their own labor, as well when pyrolyzing waste materials. This would not create extra time for tilling and planting, and the pyrolyzer can be fed and left to burn for several hours, but the labor costs to build, operate, and maintain a pyrolyzer or grill should be noted.

Centralized System

The centralized system is where a facility or plant will convert most, if not all, of the biomass collected from the outlying area around and within Orange, MA. These biomass materials do not just need to consist of solid waste from water treatment plants. They can also consist of “dry” organic waste such as the following: corn husks, hay, glass clippings, manure, food waste, etc. This facility will not only produce biochar, but also recover all other products from pyrolysis. The components are as follows: heat, syngas, and bio-oil. These components can be converted and refined. The heat can be transferred into electricity with steam and turbines. The bio-oil can be refined into bio-diesel or used as fuels in furnaces. Lastly, the biochar can be used as fertilizer or be sold commercially for other uses (water filters, etc.). One can also recover some of the financial costs such as facility overhead, etc.

The most beneficial factor of having a plant or facility is for its size. “Economy of Scale” is the concept of reduction of costs per unit through bigger facilities and higher output levels. By having a large pyrolyzer, one can produce mass quantities of biochar all at once. Keeping to the theme of sustainability and being green, the hauling of waste can be substantially reduced. The location of the facility will be close to Orange.

Another possibility with having a centralized system is government funding. The government may fund or give grants to this project. Other than grants and government funding, the ‘company’ can sell carbon credits. The credits are still a free market, but should soon be organized and regulated.

Business Case

The developed business case for the use of biochar systems when managing organic waste in rural areas is focused on applicability and conditions under which biochar system could be used in town of Orange, Massachusetts. As such, we also investigated applicable rules and regulations associated with organic waste disposal in Massachusetts. The business strategy is built around two operational models, namely, a centralized approach and a decentralized approach (Fig. 1.1).

Centralized operation

A larger, centralized system would have the capability to manage large amounts of waste, recover energy from the syngas and bio-oils, and produce larger amounts of biochar. The biochar can be used to fertilize soil, increase its yield, and reduce the need for water and use of fertilizers

Decentralized operation

The small scale (decentralized model) that can be used by homes and farms would turn waste into a useful product that can be used for soil amendment at local farm. This report was also produced to respond to the task that required the IPRO team to discuss the benefits and the costs associated with both business models, centralized and decentralized biochar units. The advantages and disadvantages, associated with using biochar system and alternatives were also evaluated and are presented in this report.

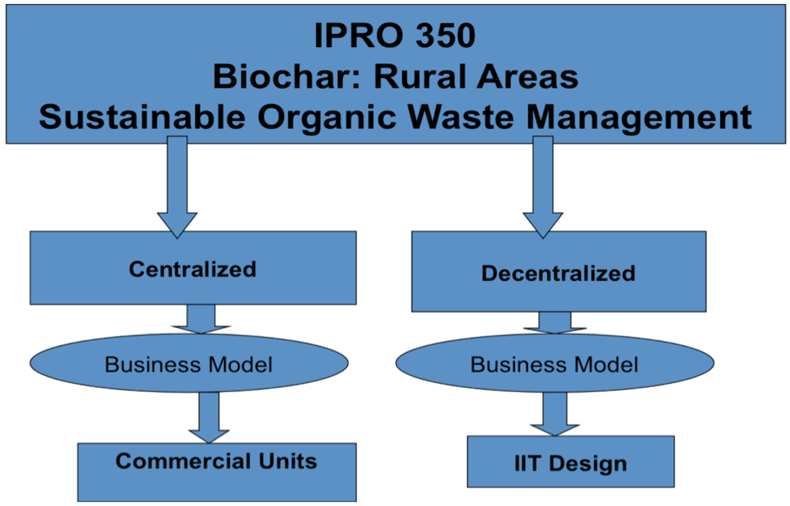


Figure 1.1

List and specification of alternative projects

1) Incinerator

- Carbon Positive

- Heat can be used to generate electricity

- Byproducts made are not as useful as biochar

- Gases and the ash residue produced may be toxic in nature.

-Requires air pollution control devices which produces other waste streams

2) Landfill

- Requires the purchase of a large amount of land (large land footprint)

- Potentially most expensive in terms of transportation

- Generally expensive and unpopular

-Problems with GHG emissions and leachate (contaminated water) formation, potentials for groundwater contaminant

3) Composting

- Can be scaled

- Carbon neutral

- Byproduct useful as a soil amendment, maybe as animal feed, depending on the inputs

-Requires maintenance, needs to be closed system

-Potentials for energy recovery

<u>Proposed Business Models</u>

Summarized in the table below is an overview of the cost parameters, benefits, business and operational impacts, and the constraints associated with biochar systems.

Centralized System:

Cost Parameters	**Benefit**	**Business and Operational Impact**	**Constraint**
Capital costs (Pyrolyzer, Land, Building, Generator/Turbine)	Sale of biochar	Jobs	Government regulations
Transportation costs	Sale of electricity from burning bio-oil	Waste Management	Safety issues
Installation Labor	Tipping fees	Sustainable energy	Cost of carbon credits
Operational costs (Dewatering sludge, packaging biochar, marketing costs)	Reduced energy costs	Income generation for Orange	Market size
Insurance, Taxes, Accountant, legal fees, labor, cost of training, interest payments, depreciation	Carbon dioxide offsets	Carbon sequestration	Competition from where they currently send wastes

Decentralized System:

Cost Parameters	**Benefit**	**Business and Operational Impact**	**Constraint**
Capital cost	Reduced transportation cost	Waste management	Safety issues
Cost of fuel	No tipping fees		

Conclusions and recommendations

Through our analysis we have decided the best option for a successful business in sustainable solid organic waste management would be to either run a large centralized system as a side project of another business, or some form of a combination of both centralized and decentralized.

If it were run as a side project of another business it would be more likely to be profitable. These systems do not require much labor to run and maintain. Therefore, if another business were in place we could use its labor force to run the pyrolyzer, cutting down costs and making better use out of resources.

A combination of centralized and decentralized would ideally be run the same way as a centralized plant, but would be producing and selling small biochar units to farmers in the area. This would again make better use out of our labor costs, and would bring in additional income for the business.

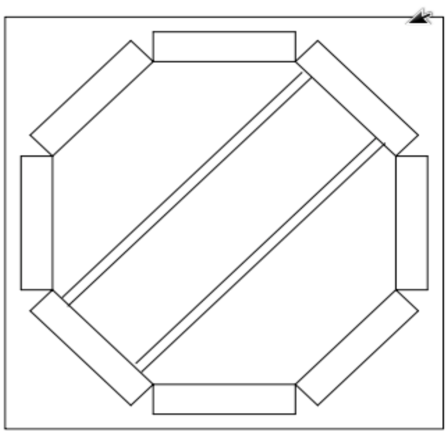
Future studies

In order for biochar to become a business that can run on its own, further studies need to be conducted on specific small towns that might be interested in implementing this technology. A more detailed cost benefit analysis will need to be done to determine if biochar business will be profitable for a small town. Specific data will have to be collected from the town of Orange including types and characteristics of waste and their amount; the feed into a pyrolyzer determines the quantity and quality of biochar that will be produced. Research needs to done on different kinds of feed and their respective product quality.

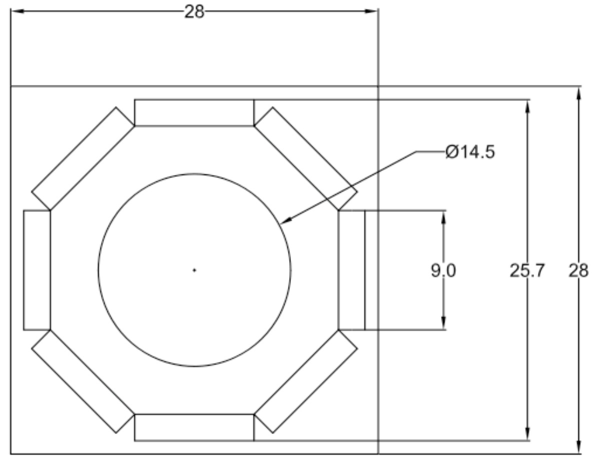
Appendix

Design Example:

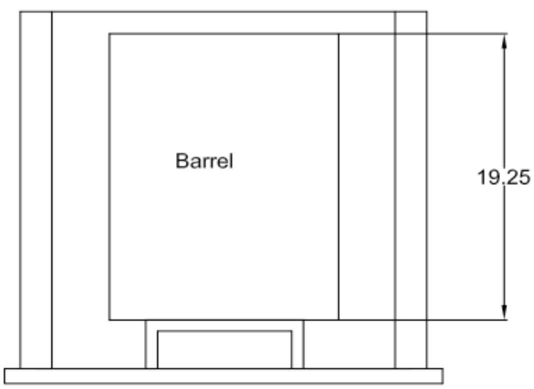
Top view - Without Barrel



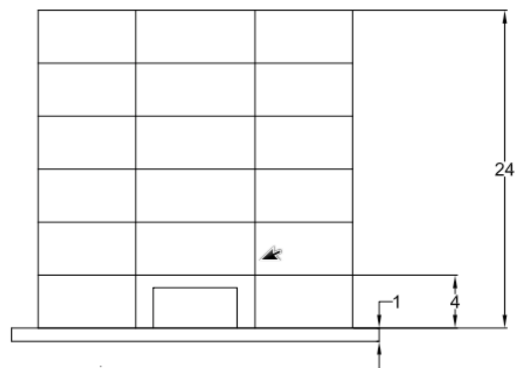
Top view - With Barrel



Side view cross section



Side view



Double retort kiln built by IPRO 350

Team members

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*Indicates team leader

**Indicates sub team leader

Project Budget

IPRO 350 expenses	
Items	Cost
Biochar grill	$612
Prototype	$500
Trip	$234
Material and supply for testing	$180
Presentation and manual	$200
Total	**$1726**

Financial Cash Flow of Large Stationary System (Cost & Benefit of Stationary plant) Centralized and Decentralized system combination

ITEM	NUMBER	COST	BENEFIT	MEMO
Capital cost of Pyrolyzer system	**1**	**$150,000**	/	Market Average Price
Capital cost of generator	**2**	**$45,500**	/	Market Average Price
Capital cost of computer & software		**$10,000**	/	Market Average Price/unit * Quantity
Operational cost:		**$77,500**	/	**Transportation of system +Installation labor cost +maintenance cost + etc.**
Cost of office supply and stationary		**$5,000**	/	/
Capital cost of building		**$200,000**	/	May changed based on real-estate market situation and local price in certain time
Raw material transportation & supply		**$40,000**	/	Transportation cost + labor cost (local price)
Insurance/yr		**$25,000**	/	Current price of environmental project, may change, getting from local insurance company of Massahchusett
Accountant fee		**$8,000**	/	Current price from Pwc
Legal fee		**$12,000 start-up $5,000 following year**	/	Current price provided by environmental lawyor
Sale of unique biochar system		/	**$30,000/yr growing**	$300/unit *100
Sale of by-product (heat /electricity)		/	**Gas/Heat price*capacity**	Depends on the capacity of energy generation and local situation,may change

Tipping fee	/	**$20/month each family *100*12= $24,000**	
Carbon-dioxide offset	/	**N/A**	Depends on the local policy and partnership with local companies, need to negotiate with local environmental department
Reduced energy cost of burning syngas	/	**N/A**	
Tax	/		**Depends on gov tax policy; during the 1.5yrs, the whole cost will be more than the revenue, which means there will be no tax outlay;**

(Sale of unit biochar system and decentralized system + sale of by-product + income of tipping fee –Carbon dioxide offset – reduced energy cost of burning syngas – tax beneficiary by local motivation policy)*24 months - all kinds of cost * 24 months=0

All initial fixed cost can be covered by income generation in 2 years.

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