"Field-scale Pyrolyzer" (FSP) Project: Introduction Notes

ALL aspects of this document are provisional, temporary, and can be changed.

Prepared by Paul Anderson, January 12 - 15, 2015.

As I prepared this document, I realized that I am in contact with at least six different and separate people and entities that have interest in Field-scale pyrolysis (FSP). So, I have written ONE introductory document that I can send to all six. But I am not introducing you to the others for two reasons. One is that each of you has different special interest that might not be of interest to the others. The second reason is that YOU might not want others into our (you and me) discussions because of something unique to you, including IP rights, etc. I believe that all of you could get along with each other, but it is not my role to bring others into what you want to accomplish regarding FSP.

By the way, the six of you are spread over three continents, have vastly different feedstocks, have widely different resources, and some favor inexpensive-with-much-labor while others favor high-priced solutions with automation. Also, for some the 100 kg/hr of biomass input is only a token amount; sizes for 1 ton/hr inputs are certainly of interest. But for those, the amount of heat released justifies additional expenditures to utilize that heat. I will work with each of you to accomplish your goals, which we are still in the process of defining.

When appropriate, I will gladly introduce you to the others. But for now, we are just talking the generalities and broad strokes. And with each of you, depending on your schedules and resources, I will start immediately to advance your "flavor" of the FSP projects.

Paul

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Starting points: a few key aspects:

** Input of 100 kg/hr of low-value biomass residue, with prospects for 200 to 500 kg/hr.
** Seeking char produced at 500 to 700 deg C. I suspect that 550 C would be fine, but less than 500 C might not be acceptable char.
** Use of forced air (blowers or fans) is acceptable in the process, if beneficial.
** Of a size that could be pulled by a tractor to the fields and even across the fields.

Additional aspects:
** Plentiful manual labor is available if needed for some approaches. But others will include much automation and mechanical processing.
** NO requirement to utilize the heat from the device.
** Char that is created can be stored and saved or it can be deposited in the same field where it is produced.
** The risks of a fire in the field are to be kept minimal because of operator caution and prevention. Fire risks can relate to many factors including dryness, winds, sparks, char that is not completely extinguished, etc.

** Cost of the unit should be kept low, but no numbers are yet discussed. Cost of US$2000 (INR 120,000) might be acceptable in India, but $5000 can be justified if some extras are included to reduce the labor costs. (All to be discussed in the near future).
** Initial efforts are NOT to give much attention to appearance nor to longevity of the component parts. Such issues will be addressed after a properly functioning unit has been tested.

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Principles for making char:

1. There are **five (5) main stages** in the conversion of biomass refuse to char. Size preparation, drying, torrification, pyrolysis, and char separation. There are many "tasks" such as collection of biomass, loading, fire tending, etc, etc. But only 5 **main** stages. We must be able to dominate each main stage. And then put them together into our desired system.

A. **Size preparation:** The other main stages are seriously impacted by the size of the pieces of the raw biomass. Issues include thickness, length, uniformity (or not) in the materials (such as leaves, stems, and branches mixed together), etc. This also relates to getting sufficiently close together the biomass and the processing unit. A whole tree one kilometer up a ravine presents numerous challenges before any of the other stages can be functional. Size preparation produces "pieces."

B. **Drying:** Excessive moisture inside the pieces of fuel is a major obstacle to producing char. Optimal drying would be with a few days of sunshine on the biomass. That is usually easier said than done. Moisture content (MC) below 10% is wonderful. Above 20% MC causes limitations. Above 30% should be avoided. Thickness is the biggest obstacle for drying to reach the center of the pieces. Dry external surfaces can be hiding internal liquids. Temperatures between 105 and 150 deg C are desired for extended time periods.

C. **Torrification:** This endothermic state requires heat to drive off the final water, the interstitial water, and low temperature volatiles. Browning and blackening can be obvious and acceptable. Off-gases are marginally flammable or even inflammable. Temperatures between 120 and 350 C are expected.

D. **Pyrolysis:** High heat is needed to bring the biomass above 350 C so that the dual processes of carbonization (making char) and pyrolysis (making gases) can occur. For better biochar we desire temperatures of 550 C and higher. The physical structure of the biomass breaks down, allowing pieces of char to fall from the non-carbonized biomass.

E. **Char separation:** Unless protected from oxygen and high heat, char is vulnerable to being consumed (char oxidized or char-gasified), yielding more heat and less char. Water quenching is generally not appropriate with larger quantities of char. Oxygen starvation requires time for cooling. Insufficiently contained char is known to spontaneously combust.

All of the above is widely known, as are the other principles regarding char making.

2. Time, temperature and turbulence can be balanced for different solutions.

3. Biomass variability can be an advantage as well as a disadvantage.

4. Consider BOTH batch processing and continuous processing. A batch is mainly based on time with relatively static physical conditions, and with most of the biomass at similarly increasing temperatures. Continuous processing is mainly based on the length of the unit and the duration of time from entry to exit, with the temperature of the feedstock associated with the position within the unit, cooler at the entrance and hotter at the exit.

5. 6. 7. Can be added.
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A proposed approach:

1. **Define our biomass** (or several that are quite similar). By being too general or generic we would greatly complicate our tasks. Consider the issues of size preparation and drying for the specific biomass. Once a feedstock is sufficiently dry and within appropriate sizes, the later stages can become quite similar.

2. Obtain access to **sufficient quantities of the biomass** as it is expected to be encountered in normal field conditions. Define the size specifications and develop the physical means to obtain the desired size range. For some biomass, the harvesting can result in appropriate sizes, requiring minimal size preparation. If the size preparation is not feasible physically or economically, choose a different feedstock. Be successful with the "low hanging fruit" that can easily be obtained. Later we can tackle the difficult feedstocks.

3. Study the **moisture content** of the feedstock. Determine how the feedstock can be dried with the least inconvenience or costs BY USING THE NATURAL CONDITIONS. If artificial conditions are required, analyze the alternatives. Remember that the full process of char making will have abundant heat that could be utilized, but with costs of the structures and devices and labor to have the heat into the desired locations. Because the objective of drying is to drive off excess moisture, drying should be sufficiently remote from the other stages so that moisture should NOT be directed into the other stages of the process. When sufficiently dry, the biomass can be stored for later, delayed usage, but it must be protected from precipitation and even from excessive humidity.

4. The sufficiently dry and appropriately sized biomass is placed into a **torrification unit** that is externally heated either through the unit's walls or by passing hot dry gases through the biomass, or both. As with drying (and later with pyrolysis), the variable of "distance from the hot wall" or "thickness of the individual pieces" must be considered so that the heat reaches to the most insulated feedstock. The biomass can be mixed (such as being stirred or tumbled) to facilitate the heat reaching all of the biomass within a reasonable time. The gases coming from the feedstock are "low grade" and contain non-combustible moisture. This stage can be adjusted (with additional construction and costs) to draw off some or much of these gases with possibilities to condense them (along with the water) and perhaps having a flare for some that are combustible. Release of the gases to the atmosphere would be considered pollution. Keeping the gases inside and entrained into the pyrolysis processes is a lower-cost alternative. The torrefied feedstock could be cooled and sold (limited demand) or saved for later pyrolysis, but that would mean that it would again need to be heated to the highest torrification temperature before pyrolysis could begin.

5. The **pyrolysis / carbonization stage** is a natural continuation after torrification. What is different is that the pyrolytic gases are quite combustible, so any oxygen in the feedstock bed can have a mini flame when it combines with hydrogen, methane, carbon monoxide, or combustible hydrocarbons. The key is

to control the amount and location of the entry of any outside air, and that is what we must learn to do in the implementation stages of our project. Assuming we gain that control, we are able to create heat INSIDE the pyrolysis unit to bring the temperature of the feedstock to the desired temperature, tentatively set to be 550 deg C. That temperature will cause a great release of combustible gases which will be either pushed (by increased gas pressures) or pulled (by chimneys or induction blowers/fans). As those combustible gases exit the zone of pyrolysis, they can be channeled where we want them to go. As explained in the section about building the device, we will have those gases go back in a gap between the outside of the units for pyrolysis, torrification and drying, but inside of another wall. By controlling the entry of secondary air in that gap, we can maintain flames of combusting gases, thereby providing the heat for the pyrolysis, torrification and drying.

6. **Char separation** begins inside the pyrolysis unit. Created char is friable, easily broken, and fragile. Small pieces are formed from very thin pieces such as leaves, and they can break into powder. Slightly large pieces hold their shape well, but are reduced in size. Thicker pieces develop cracks because the non-yet-pyrolyzed central part is still large compared to the shrinking char on the surface of the piece, and cracks lead to broken pieces, especially if disturbed against other pieces. In a batch processor, the char just sits there, accumulating slowly. In a continuous feed operation, all of the created char moves toward the exit. There is still no or very limited air in the device. The exit has a set of horizontal bars as a grate at an appropriate size for the feedstock. Pieces of char that are small enough will fall though the grate and enter a collection box. Pieces that are larger remain on the grate until pyrolysis is completed. A mechanical means, such as a shacking grate or slowly moving grate, can assist to have the char fall through. The collection box is totally without oxygen (anoxic), so the hot char is not consumed. It is collected until emptied by the operators.

As stated before, all of the above is well known, and might have been more eloquently written elsewhere before this. By utilizing the above we will be able to create the appropriate devices for our char-making objectives. And we will do it for the commonly called “field size” char makers that are not sufficiently defined and operationalized to fulfill the objectives.