University of Minnesota Duluth
Natural Resources Research Institute

# Visit to Mauritania to Explore NRRI-Developed Option for Conversion of *Typha australis* to Biocoal

## Notes and Discussion Points


**Dr. Donald R. Fosnacht (NRRI)**
**Peter P. Strzok (AFGRO)**

Edited D.A. Ward


## About the Natural Resources Research Institute

The Natural Resources Research Institute (NRRI) of the University of Minnesota - Duluth is a research institute dedicated to the fostering economic development of Minnesota's natural resources in an environmentally sound manner to promote private sector employment.

Back in the early 1980s, Minnesota's economy—largely dependent on natural resources—was taking a beating. The state was reeling from a domestic steel crisis that left about 13,000 workers unemployed on the Iron Range, and global competition was threatening the state's logging, pulp, and paper industries. To counteract the blow—and avoid a similar occurrence in the future— a group of researchers, legislators, and community members envisioned building a center that would study the economic impact and sustainability of Minnesota's minerals, forest products, peat, biomass, and water-related industries.

This vision became a reality. In 1985, the Natural Resources Research Institute opened its doors in an abandoned Air Force building. The 20-foot ceilings and cavernous concrete spaces were filled with science laboratories and industrial-sized equipment.

Over the past 20-plus years, NRRI has earned the respect of industry leaders, the academic community, and environmental watchdogs. Its reach is felt throughout the state and beyond. NRRI operates a minerals research laboratory in Coleraine on Minnesota's Iron Range providing research for mining industries, a diatoms research lab in Ely, Minn., that focuses on water quality issues, and a Fens Research Facility in Zim, Minn., to study peatland restoration and the development of torrefied biomass.

## About CSR's White Paper Program

Working in conjunction with the University of Minnesota (U of M), the Porta Family Foundation, and other not-for-profit rail and biomass research organizations, CSR's White Paper Program is bringing scholarly works pertinent to biofuel, modern steam locomotive and transportation research into the public discourse.


## Acknowledgements

CSR would like to thank Dr. Don Fosnacht, NRRI and AFGRO for sharing its exciting research developments in Mauritania with it and allowing them to be published under the CSR White Paper Program. CSR looks forward to continuing to provide mechanical and energy generation design support to NRRI and its partners.


**Cover Photo -** *A country of beauty and contrast, this shot of the mountainous Adrar Region of the country provides a glimpse into the beauty it has to offer. NRRI and AFGRO are working to find ways to transform a pest into a clean, renewable energy source. - Wikimedia Commons Photo, User: Manu25*

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## Foreword

Dear Reader:

Engineers and researchers have an obligation to take the technologies they pioneer to solve some of the most pressing issues facing humanity, and as benign as "cattails," or more specifically, *Typha australis*, may seem, it is an invasive pest to the people of Mauritania that impedes free water flow and agricultural development. The Natural Resources Research Institute (NRRI), a research partner of the Coalition for Sustainable Rail, has been working with the Agency to Facilitate the Growth of Rural Organizations (AFGRO) to tailor its torrefaction technologies to convert pest species into clean fuel stocks.

In late June 2013, Peter P. Strzok of AFGRO and I traveled to Mauritania to meet with government officials and witness the impact of *Typha* directly. In July, 2012 the undersigned, aided by Mr. Cheiguer and the Ministry of Rural Development project manager for the control of *Typha*, Mr. Ismaila Kane, shipped roughly 100 kilograms of dried *Typha* stalks from a Senegal River village to NRRI at its Duluth, MN office. This sample was converted into a biocoal product. In October-November, 2012, samples of this product were presented to interested Mauritanian officials as noted above.

So, how does this link into modern steam trains and the Coalition for Sustainable Rail? To begin, the electricity generation technologies the Coalition for Sustainable Rail is promoting, based upon the modern steam mechanical engineering of S.T. McMahon and L.D. Porta, is a perfect pair for *Typha* in generating electricity in places like Mauritania. Further, the ability to take an invasive species, such as Kudzu, or waste commodity, like railroad ties, and turn them into a clean fuel is of key importance domestically.

This document provides a day-by-day synopsis of the work we undertook overseas and is followed by the detailed presentation on *Typha* I gave to senior officials in Mauritania.

As with any of the documents produced in conjunction with CSR, feel free to reach out to the organization if you have any questions via its email: info@csrail.org. The ability to meet the needs of our ever-expanding global population will only be met through innovation; the kind of work that is championed by NRRI and its partners.

Sincerely,

Dr. Donald R. Fosnacht
Director, Center for Applied Research and Technological Development, NRRI
Member, CSR Board of Directors

## Log of Visits

Principal Participants: Donald Fosnacht, University of Minnesota Duluth; Peter Strzok, AFGRO; Ismaila Kane, Mauritanian Ministry of Rural Development

CID International Participants:

Mr. Sidi Mohamed Cheiguer, President Director General.
Mr. Issa Ba, Adminustratif.

## Figure 1: Map of Mauritania and Sites Visited


Basemap: Wikimedia Commons

## Visit to Ministry of Rural Development

**June 23, 2013**

The meeting began with Ismaila Khan giving a brief history of his work for controlling *Typha* along Senegal River, and then Don Fosnacht presented our concept on the use of hydrothermal carbonization to produce energy products. The minister, Brahim Ould Mohamed El Moctar Ould M'Bareck, was very impressed what we were doing and actively encouraged us to continue the work. He welcomed us, speaking in English, and described the serious problems that *Typha a*., by its promiscuous growth, was creating for villages all along the lower delta of the Senegal River, in both Mauritania and Senegal, as well as how the two national parks, Diawling and Djoudj, established to safeguard migratory birds and other wildlife. He asked if it could be brought to greater scale and we indicated that it would be possible after the prototype plant was constructed, commissioned and fully proven in operation. He also indicated that the President was going to Rosso on June 30 and asked if we could talk with the President about the concept. We declined the offer due to our departure on the 29th.

The Minister of Rural Development specifically asked about using the biocoal, on a large scale, as an energy source to produce electricity, which is in short supply, especially for industrial users and urban centers that continue to expand rapidly, as rural people migrate to urban centers. We then met with MinRD staff and examined in detail the issues now confronting Mauritania, in its efforts to control *Typha a*. What became clear is that despite 8 years of efforts, funded largely by the African Development Bank, to find uses and control methods for this aquatic pest, these control measures to-date are insignificant relative to the gravity of the problem.

In that regard, a new coordinator for this project was recently appointed, namely Cheikh Ahmed Ould Sidi Abdella. He requested our assistance in combatting this serious threat. It should be noted that Mr. Ismaila Kane will continue in an important role in working with the villages along the Senegal River, with whom he established excellent working relationships and credibility over the past 8 years.

From these meetings, we returned to CID offices. Mr. Cheiguer encouraged us to begin developing a work plan that would take the process through village acceptance tests of the biocoal as a household energy source and proceeding to a scale sufficient to establish that the product has value in the energy marketplace.

He promised (and provided) elements of a business plan. CID partner, Abdulla Babou, developed the specific elements to use as a guide in the Business Plan development. This document is being translated into English and will be provided to CARTD, NRRI, on an expedited basis.We then adjourned and had a detailed discussion with the staff of the ministry.

Similar information was reviewed with the staff and then a discussion ensued. One researcher on the staff asked if the volatile matter in the pucks would cause any issue. We discussed this in some detail about how they were likely to be used and thought that this would not be an issue. I think we need to follow-up and understand the possible emissions in more detail to confirm this. Overall, the group was very supportive of the potential of the conversion technique. We left samples of the product with the Ministry of Rural Development.

*Figure 2: Discussion Group - Ministry of Development Staff and Visitors.*

## Visit with the Ministry of the Environment
**June 24, 2013**

Our team met with the Minister of Environment and Durable Development, Mr. Amedi Camara and two of his directors: 1.) Mr. Sidi Mohamed Ould Lehlou, in charge of the protected areas (parks and environmentally fragile areas) and coastline, including the Senegal River and 2.) Mr. Boubacar DIOP, in charge of stabilizing sand dunes and protecting vulnerable areas. Minister Camara showed us a map (March 2013) delineating the extent of the *Typha* infestation (approximately 12,000 hectares) and showed photos of a serious fire that swept through the *Typha* infestation, in November 2012. It caused major damage to villages, wildlife and Diawling Park, a protected area for migratory birds and other wildlife. He encouraged us to move quickly to scale up to a level that would have an impact on the magnitude of infestation. Again Ismaila began the meeting, Pete Strzok then explained the partnership of organizations involved in developing solutions and Don presented the work on the hydrothermal carbonization concept.

Amedi Camara, the Minister of Environment (ABOVE), participated actively as the presentation and discussion ensued. (Originally the meeting was to be 20 minutes and we stayed for an hour-and-a-half). We showed our samples to the all present and it became clear that they felt this had real potential to them.

Mr. Camara indicated that 5 ministries are implicated in this threat (*Typha*). These are Rural Development, Environment, Fish, Hydraulics, and Health. Given the importance of the problem, he envisioned an inter-ministerial committee to manage the measures taken to control/manage the threat. Comment: Whether such a structure would facilitate or slow down urgently required solutions should be considered.

The Minister then obtained a large map and illustrated the magnitude of the problem not only for the villages, but also for two large National Parks and said that the problem is a catastrophe for Mauritania. He then brought out photographs which were taken in November 2012 where the villagers had taken action into their own hands and tried to burn away the *Typha*. It led to a catastrophic fire that caused massive smoke and destruction to villages along the river and to animals in the area. He showed that the fires could be seen from long distances and also showed a captured snake and crocodile that were driven from the impacted area. The situation is so important that the President will visit the Rosso area to talk with the people along the river on June 30. He indicated he would speak with the President and show our materials to him as one means to help address the problem.

Our second meeting was with Mr. Fadal, Mauritanian representative of OMVS (Organization pour la Mise en Valeur du fleuve Senegal). This is a four country organization (Guinea, Mali, Mauritania and Senegal) that is responsible for efforts to improve the functioning of the Senegal River and its tributaries. Thus, it has oversight over the two major dams on the Senegal River, located at Manantali, Mali, and Diama (near the ocean delta of the Senegal River). The Manantali Dam, on the Bafing River (a major tributary of the Senegal River), is designed to provide year-round water control and hydro-electric power to its member states; the Diama is designed to prevent salt water intrusion into the Senegal River at low water levels, produce electricity and provide a road crossing between Senegal and Mauritania. Mr. Fadal encouraged us to find a solution of scale to the *Typha* infestation, indicating that "what has been done to date is insignificant." Accordingly, he strongly supports our project and goals to move to commercial level production.


***Figure 3:*** *Compacted HTC Typha Fuel shown to Government Officials.*

## Visit to the Rosso Area
**June 25, 2013**

CID International arranged for a car and driver to take the Team to the River areas, and this was quite a trip!

We obtained an excellent view of the desert and countryside and experienced the typical road conditions of the people. We came across herds of goats, camels, and donkeys and various small villages, and we crossed at least five checkpoints where we were stopped and asked what we were doing. CID had prepared paperwork to give to the police to explain our mission. Along the way, we passed the major water treatment and pumping facility for Nouakchott which obtained water from the Senegal River about 200 km away. We also passed two major power lines coming from different directions that supplied the city with power. The dams along the River were used to produce hydroelectric power. One can begin to see the importance of this River system to Mauritania for supporting general living conditions for over 1 million residents as both water and power are supplied from this source. In addition as we were starting the journey, we passed a 28 MW diesel fuel-based power plant in the city itself. This is an expensive means for power generation. It took roughly three hours to get to the impacted area. During the drive, many topics were discussed and we estimated that the cost of electricity was roughly $0.20/kWhr (as compared to roughly $.07/kWhr in much of Minnesota, or nearly three times the cost).

We passed through Rosso to visit a village along a tributary of the River. On the way to the village, we stopped along a side of the road to take some pictures of the *Typha* infestation near the bridge crossing the tributary.

One could clearly hear the chirping of the Quelea-Quelea birds that nest in the dense *Typha* plants. One area near the bridge had been cleared of the plants, but the stalks had been left in a large pile at the River edge.

***Figure 4:*** *Varous views of Typha australis infestation on a tributary of the Senegal River.*

***Figure 5:*** *Villagers Greeting Ismaila Khan, Peter Strzok, and Donald Fosnacht at Chgaara.*

### Visit to Chgaara

We entered the village and were warmly greeted by the Chief, the men and women of the village and their children. The chief gave a welcoming address and then the President of the Women's Co-operative also addressed us.

She started by saying in English: "I am fine!" We took some pictures of the area which showed the area cleared by the villagers over one year ago and also of some cattle that appeared to be eating the bottom of the *Typha* plants.

We observed areas that had been cleared of *Typha*; we adjourned to the meeting room in the home of the village chief to discuss our plans for next steps. We informed him of our meetings with the ministers of RD and ENV. He indicated that President Abel Aziz was expected to visit the area on Sunday, 30 June, and said he would discuss our technology with him (President AA), given the opportunity.

We then adjourned from the river and met in the chief's residence in a very nice room that had rugs on the floor and cushions all along the walls. We discussed our approach to converting the *Typha* into an energy fuel for their use and presented the Chief and President with samples of their converted *Typha* product. They were very happy in seeing the materials and the Chief said he would show the President the material when he visited on June 30. Key observations at the village: animals eating bottom of plant, area still was open to water, and initial acceptance of the product on viewing. The key next step will be to produce enough material for villagers to try the biocoal as a substitute for charcoal. When we were leaving they encouraged us to bring back more materials.

***Figure 6:*** *Views of River area Cleared by villagers and Cattle eating Typha roots.*

After the visit to Chgaara, we went to the River and on the way we passed rice farms and also transported the Chief to one of the farms he owned. He left us at the farm and it was notable that he had both a tractor and large harvester in use during the harvesting operation. I noted that this equipment needed to be routinely maintained and it is obvious that they have the ability to do this since they are vital to the operation.

At the river, we entered another small village and talked with the local policeman who checked people leaving and entering the river. Small channels were cut into the *Typha* to allow passage of pirogues to the river for hauling people and goods between Senegal and Mauritania and for fishing on the river. The density of the *Typha* is amazing. It is very thick and tall. One could see how the tops of the plants act as a desiccant during the time of the desert winds. This leads to significant water loss from the river. We also saw a woman washing clothes directly in the river. Peter indicated that the stagnant nature of the water promoted the creation of small flukes which can cause bilharzia by entering through skin exposed to water. It was pretty evident that this could be the case in using the water to clean clothes or to bath. Bilharzia causes a malaise to occur as the disease impacts the liver and makes people tired. They have to take medicine to treat the condition.

After visiting the River, we visited a French NGO called Gret. We spoke with Benjamin Trouilleux, Assistant Technique, Project Typha (BELOW)

He explained his work with the villagers in the area and outlined the program. They start by qualifying the village that will be involved through a series of meetings that lasts six months. They use this to identify the people who will participate in the harvesting of the *Typha*, the drying of the material, the baking of the material to charcoal, the grinding of the material to a powder, the mixing of the powder to a paste, the formation of pieces of charcoal from the paste, and the final air drying of the material. During the formation of the charcoal from the paste, a small extrusion type of machine is used with a rod around a cylinder to create pieces of roughly 38 mm in diameter with a 6 mm hole in the near center (this aids in combustion of the charcoal during cooking).

The pieces can be varying lengths, but the pieces we were shown ranged in approximate length from 100 to 150 mm. The process takes roughly 3 months to produce 1.5 tons from 10 tons of starting materials. The technique of baking seems reminiscent of something that would have been done a millennium ago in that the materials are simply put in a metal cylinder approximately 2.5 m across by 1.3 m high. The dried *Typha* is placed in the cylinder, it is started on fire and dampers at the bottom are adjusted to control the degree of burning to produce the charcoal.

***Figure 7:*** *View of Chgaara village.*

***Figure 8:*** *Rice fields near Chgaara.*

***Figure 9:*** *At a small village on the Senegal River.*

After forming the charcoal, women wearing gas masks open the top of the furnace and remove the processed materials for the grinding step to reduce the material to a fine powder. The powder is mixed with water to form the paste and then formed into the shapes noted above. Key takeaways: Labor intensive, low productivity, environmental processing issues abound, poor physical quality of product (they do sell it below the cost of the available charcoal (20% less expensive to buy)), hard work needed at each stage, women are exposed to fumes from the furnace, dust during grinding, nasty bugs and other critters during *Typha* manual cutting, and the materials need many steps to reach a final product.

Technique makes only a small dent in the *Typha* issue; a more industrial process is needed both in harvesting and processing the *Typha* materials. This process does involve the villagers in the problem and solution, but other involvement scenarios must be considered to make major progress in reducing the *Typha* infestation and in making use of the *Typha* as an energy product and potentially as a food source.

We also explained our potential approach to Benjamin and he thought it was a strong potential solution. He knows that the method they are currently using will not have a great impact on removing all the *Typha* that exists along the banks of the River. Ismaila also brought out the need to have cooperation between Mauritania and Senegal so that the sources of new contamination are controlled. We wished Benjamin well in his work and left to return to Nouakchott.

We stopped at Tiguent for lunch and arrived back at our hotel around 6 pm. The travel back and forth with the visits took about 12 hours.

***Figure 10:*** *Views at Tiguent (about halfway between Nouakchott and Rosso)*

# Visit with Various Agencies
**June 26, 2013**

**World Bank --**

Ismaila and Don presented what has been done and what we are proposing to do with the new approaches and Don also showed the products that were made. Pete then explained the multi-party partnership that already exists between government, NGO, CID International, and University. Mr. Sall thought it was most important to approach future funding as a Public Private partnership in order to obtain funding and was glad to see that we were already working in that regard. He also mentioned that the World Bank is allocating close to $460 million for rural development in Mauritania and that our potential proposal would fit into the areas targeted for this funding.

**Glencore-Xstrata-SNIM --**

Pete Strzok and Don participated with Mr. Fettah at the office in Nouakchott.

**Spanish Embassy --**

While the others went to talk about iron ore, Ismaila went to see the representatives of Spain who provide development funds. He had a fruitful discussion with the Spanish representatives who indicated that they were very favorably impressed with the proposed program.

**UNDP --**

All involved then traveled to the UN agency focused on rural development and like the other visits. We explained our program to Alain Olive, Charge de programme environment, Point focal affairs humanitaires.  A good discussion then ensued and we discussed the program in detail and answered Alain's technical and business questions. He indicated that what we are advocating had merit and he would welcome review of a formal proposal for implementing the vision once it is developed. Ismaila also explained the various meetings we had already had with Mauritanian officials and the positive reaction from the Ministers we have visited.

**European Union --**

The final meeting of the day was at the headquarters for the European Union's development agency in Mauritania. We met with Audrey Maillot, attaché, Section "Development Rural Decentralization et Environment". Similar to the other discussions of the day, we gave our presentation of the approach that we are advocating regarding the *Typha* threat. She then mentioned that the EU is already supplying some monies in dealing with the issue and that she had participated in various review meetings regarding that effort and thought it was being received well. She cited the NGO Gret and their work with the villagers. She did not know if the villagers could maintain some of the more complicated aspects of the approach we are advocating.

Ismaila then indicated that the current approach has not involved his agency in its implementation and that the successes that they are having were facilitated by his previous work with the villagers over the last eight years. Don mentioned that he witnessed farmers operating harvesters and tractors and indicated that the anticipated equipment would be no more complicated than this equipment. Ms. Maillot indicated that every two years, the EU has a call for new projects (RFP) and she indicated when the new call comes out we should apply if our program meets their desired funding areas. She also indicated that the EU was putting significant new monies into West Africa, but that unfortunately Mauritania is not qualified to receive any of the monies based on their current level of development. She also indicated that there will be an audit of the effectiveness of the currently funded approach in the near future. We thanked her for meeting us and ended the day of discussions.

## Briefing at the U.S. Embassy
**June 27, 2013**

The team met various embassy officials including Consular & Commercial Officer, Stacy Ba, the Deputy Chief of Mission, David Reimer; Hamet Ly, Economic and Commercial Assistant, and Scott Clayton, Political and Economic Officer

The presentation was begun by Peter asking for the Embassy's view on the current focus for Mauritania and did not get guidance. Pete then explained that we are attempting to put together a partnership along the lines explained to the World Bank. Don then reviewed his thoughts on what he had seen and heard during his visit to the various meetings in Mauritania and the visit to the Rosso area. He outlined our approach to converting to a biocoal and that mechanization of the collection system was also necessary.

We indicated that we had the support for the concept from USAID based in Senegal and that we would bring our finished proposal to USAID for potential future funding. Pete also asked if any funds might be able to support our immediate next steps, but DCM Reimer indicated they had no funds.

### Components to a Solution to Typha Issue

- More modern material harvesting that reduces health and safety risks to personnel involved
- Sound logistical methods to bring harvested materials to conversion process
- Determination of the food value of the rhizomes and roots of the *Typha* plant and how this might be factored into the harvesting program
- Demonstrated industrial methods for converting materials to useful fuel products for household and/or industrial applications
- Acceptance trials for anticipated conversion products with intended end users
- Agreed to policies by governments on how they want the *Typha* issues addressed including timetables, prioritized locations for *Typha* removal
- Pending prototype acceptance, scale-up of commercial implementation
- Since this new fuel could disrupt current fuel supply sectors, considerations should be given on how to address various issues of resistance that likely will arise from the current supply base
- Development of overall environmental remediation strategy that meets the sustainability and practical needs of the area
- Funding sources for program implementation both private, governmental, and public

***Figure 11:*** *View of Bareina, a small desert village in Mauritania - F. Reus Photo | Wikimedia Commons*

## Stay Up-to-Date on the Coalition for Sustainable Rail


**Email List |** Join our email list at the top of any of our web pages: www.csrail.org

**Facebook |** www.facebook.com/csrail

**Mail |** Coalition for Sustainable Rail | P.O. Box 120361 | New Brighton, MN 55112

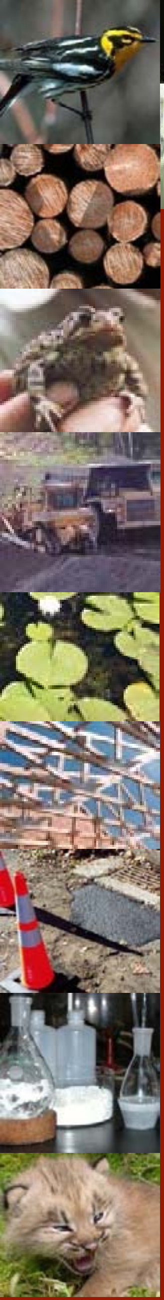
# Conversion of *Typha australis and other biomass* to a Biocoal for Local Use in Heating and Cooking

Donald R. Fosnacht, Ph.D.
Peter Strzok, AFGRO

UMD
Natural Resources Research Institute
University of Minnesota Duluth
Driven to Discover

# Project Vision

- **Provide positive economic, health, and social benefits to regions of Mauritania by creating a new fuel for use in heating and cooking while enhancing the manageability of *Typha australis* (Typha), a prominent plant pest and other aquatic weeds.**
- **Team with local villagers and Mauritanian scientists to implement conversion technology at rural locations**



# Project Team

- **University of Minnesota Duluth's Natural Resources Research Institute**
- **Mauritania Ministry of Rural Development**
- **Agency to Facilitate the Growth of Rural Organizations**
- **Cid International**

UMD Natural Resources Research Institute
University of Minnesota Duluth

# Challenges Presented by Typha

**Over 30 million people adversely affected by Typha-infested waterways**

**Typha covers >346,000 acres of water in the Senegal River**

# Challenges Presented by Typha and Aquatic Weeds

- **Disruption and clogging of irrigation channels**[1]
- **Reduction of fishing productivity (the livelihood for many villagers)**[1]
- **Sheltering of agricultural pests**[1]
- **Increased levels of water-borne diseases (e.g., malaria)**[1]
- **Reduction in water quality, villagers' access to water, and livestock access to water**[1]
- **Reduction in rice crop productivity**[2]

Sources: (1) Elberson, W. 2005. Typha for Bioenergy. Report on BUS ticket no. B1. (2) Owsianowski, R. P. and Nickel, E. 2007. Cattail (*Typha australis*) as an innovative insulation and construction material for industrial and developing countries. GTZ-PERACOD, Dakar.

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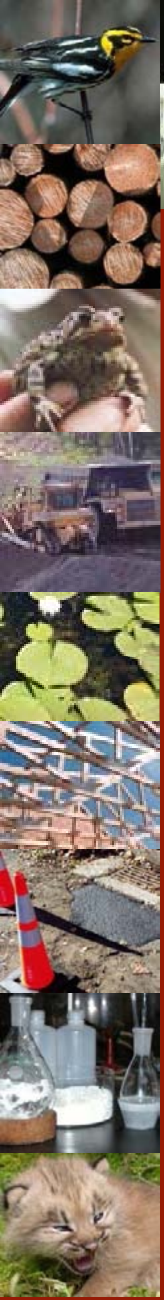
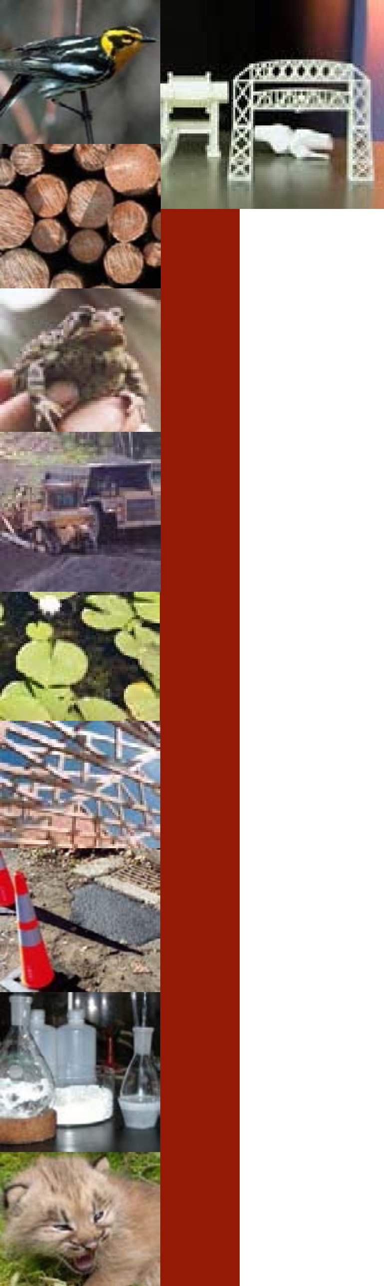




# Hydrothermal Carbonization of Biomass for Biocoal Production.

- **Hydrothermal Carbonization (HTC) – processing the carbonaceous material in water at elevated temperature and pressure, that keeps water as a liquid rather than steam.**
- **Unlike Supercritical processing (SCW, HTL, "Hydrofaction" etc.), the HTC-procedure converts the biomass materials to <u>solid products</u>, commonly named as "Biocoal" or "Biochar".**
- **The Biocoal is similar to the common coal brands by combustion properties, and can be combusted as a coal substitutes or in co-firing mode.**



# Convert Pest to a Value added resource

- **Take advantage of energy content of biomass**
- **Reduce volume of plant material near site of removal**
- **Create jobs in plant collection and in production of biocoal for rural workers**
- **Meet fuel needs of rural villages**

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# HTC Basics. Material Versatility:

City Biomass

A variety of biomass samples have been tested at NRRI in HTC Biocoal processing (2010 – 2013). All materials demonstrate good conversion factors at mostly uniform process conditions.

Energy Crops

Food Industry by-Products

## HTC-Biocoal:

*Yield by weight - (55 – 60)%;*
*Carbon Recovery - ~ 80 %;*
*HHV Recovery – (80 – 85)%;*
*Options: Molding, briquetting*

Farm and Garden Wastes

Roadside plants, Cattails

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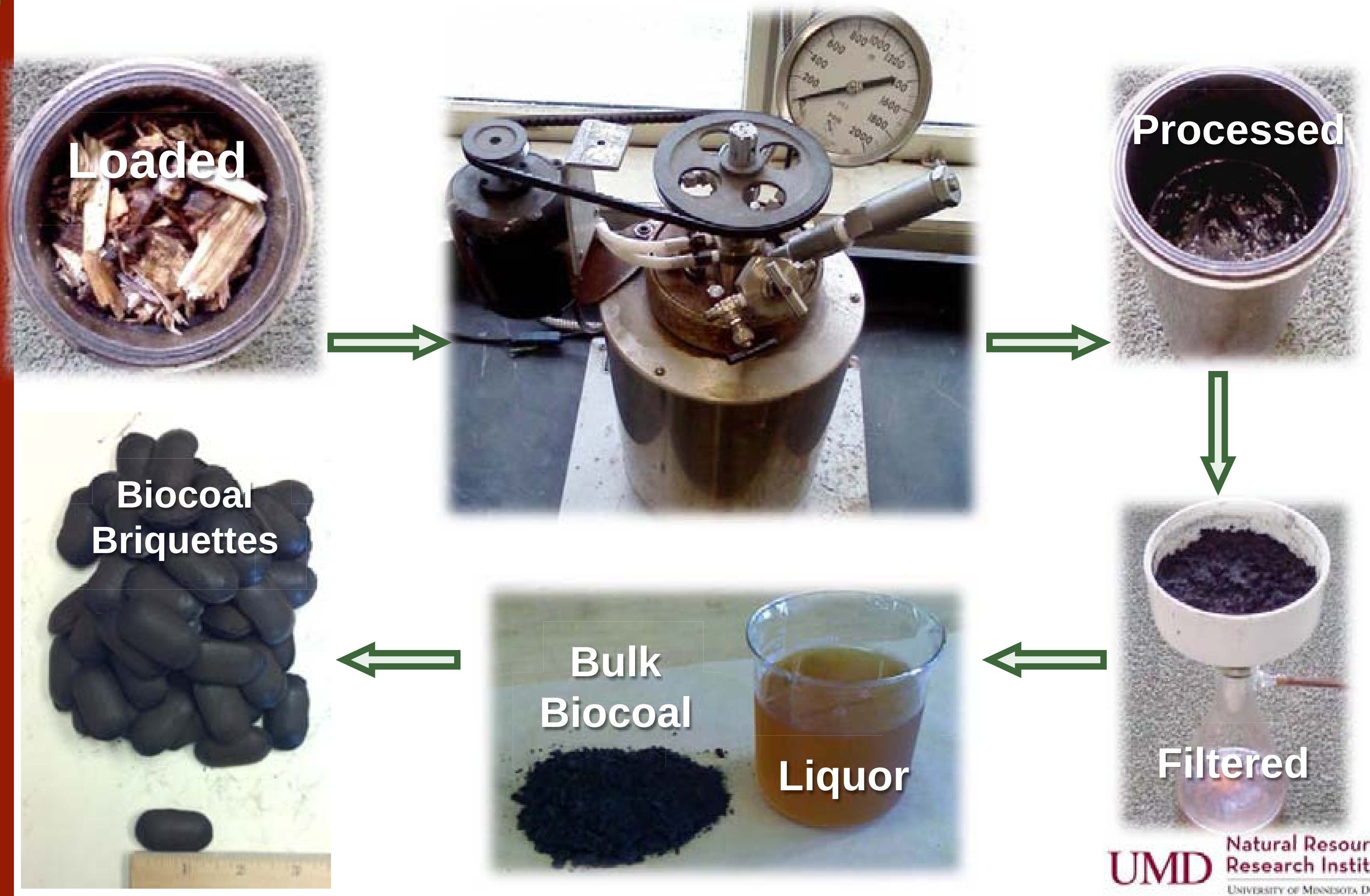
# HTC-Procedure (Lab scale, Mix Wood Chips):

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# Chemistry of the HTC-Process:

**Carbonaceous compounds:**

**Cellulose (fiber)** – remains mostly stable in the process;
**Hemicellulose** – totally decomposes (hydrolysis and decarboxylation);
**Lignin** – partly decomposes (hydrolysis, probably no thermal degradation).

| Raw Biomass (DW, AF): | |
|---|---|
| C – | (50.5 – 54.5)% |
| H – | (5.2 – 6.2)% |
| O – | (39 – 44)% |
| HHV - | ~ 18 MJ/kg |

| HTC-Biocoal (DW, AF): | |
|---|---|
| C – | (61.5 – 65.2)% |
| H – | (5.5 – 5.8)% |
| O – | ≤ 33 % |
| HHV - | ≥ 24 MJ/kg |

**Inorganic components:**

**Na, K** – fully extracted to the liquid phase;
**Ca, Mg** – partly extracted to the liquid phase (the liquors are acidic);
**$Al_2O_3$, $SiO_2$** – remain intact in the solid Biocoal;
**Minors (Fe, Mn, heavy metals)** – mostly extracted to the liquor*.

**M.T.Resa et al., Biomass and Bioenergy, 49 (2013), p.86-94.*

# *Typha A.* Cattails to Biocoal:

The lab research (2012) comprise HTC-processing of original *Typha A.* Cattails from Senegal river basin, Rosso region.
Total of 100 lbs of material converted to Biocoal at variable process conditions (temperature, process time, load ratios).

**Cattails *(Typha A.)* Biocoal:**

| | |
|---|---|
| Yield (by dry weight basis), % - | 58.3 |
| Process Temperature (optimal), °C – | 240 |
| Top Pressure (observed), bar - | 45 |
| Higher Heating Value (HHV), MJ/kg - | **25.9** |
| HHV Recovery, % – | **82.5** |
| Total Ash, % - | 4.4 |

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# Cattails Biocoal – Firing Tests:

Left: Cattails Biocoal Briquettes (made on site).

Right: Kingsford™ Commercial Charcoal Briquettes.





# More Biocoal sources - Waste wood:

Most kinds of wood can be converted to Biocoal using HTC-technology.
Pre-sizing of the materials not that important, the processed Biocoal appears as a loose material, easy for further briquetting, molding or pelletizing.

**Wood Biocoal:**
(NRRI-UMD, 2012 – 13)

| | |
|---|---|
| Yield (by dry weight basis), % - | 54 - 58 |
| Process Temperature (optimal), °C – | 245 |
| Top Pressure (observed), bar - | 45 |
| Higher Heating Value (HHV), MJ/kg - | **25.3 – 26.8** |
| Total Ash, % - | 0.05 (sap) – 1.2 (bark) |

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# More Biocoal sources - Switchgrass:

Switchgrass – a candidate for biocoal in various countries responds well.
The HTC-technology allows processing switchgrass to Biocoal in “as harvested” condition, no matter of the moisture content. The final Biocoal appears as a loose material, good for briquetting, pelletizing, or any other densification procedure.

**Switchgrass Biocoal:**
(NRRI-UMD, 2013)

Yield (by dry weight basis), % - 54.5
Process Temperature (optimal), °C – 230
Top Pressure (observed), bar - 40
Higher Heating Value (HHV), MJ/kg - **23.5**
Total Ash, % - 4.3

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# More Biocoal sources – Crop residues:

The common corn residues - stovers and cobs – have been tested in the HTC-Process at variable conditions. No matter of the raw material sizing, the processed Biocoal appears as a loose material, easy for further briquetting, molding or pelletizing.

**Corn Stover Biocoal:**
(NRRI-UMD, 2013)

| | |
|---|---|
| Yield (by dry weight basis), % - | 62.5 |
| Process Temperature (optimal), °C – | 235 |
| Top Pressure (observed), bar - | 40 |
| Higher Heating Value (HHV), MJ/kg - | **24.8** |
| Total Ash, % - | 7.1 |

# More Biocoal sources – Animal wastes:

Cow manure converts to the HTC-Biocoal with typical yield (50 – 55 % depending on temperature).
Like others, this Biocoal appears as a uniform loose material, good for compacting. The relatively high ash content (15.6%) in this Biocoal is due to the significant ash content in the starting material, but is affordable for commercial and residential firing.

**Cow Manure Biocoal:**
(NRRI-UMD, 2012)

| | |
|---|---|
| Yield (by dry weight basis), % - | 53.5 |
| Process Temperature (optimal), °C – | 250 |
| Top Pressure (observed), bar - | 45 |
| Higher Heating Value (HHV), MJ/kg - | **23.7** |
| Total Ash, % - | 15.6 |

# More Biocoal sources – Food Industry:

Sugar beet pulp and potato peelings can be converted to HTC-Biocoal even with no addition of any water/liquors to the process mixture.
After the process, the solid Biocoal easily separates from the mixture. The bulk HTC-product could be fired directly on the food processing facility as a replacement fuel.

**Sugar Beet Pulp Biocoal:**
(NRRI-UMD, 2012 – 13)

| | |
|---|---|
| Yield (by dry weight basis), % - | 44.5 |
| Process Temperature (optimal), °C – | 240 |
| Top Pressure (observed), bar - | 48 |
| Higher Heating Value (HHV), MJ/kg - | **25.2** |
| Total Ash, % - | 4.9 |

# HTC Macro: Bulk Biocoal Values.

***One Truckload*:**
***8 ton DW;***

***HHV: 150 GJ;***
***LHV: 109 GJ.***

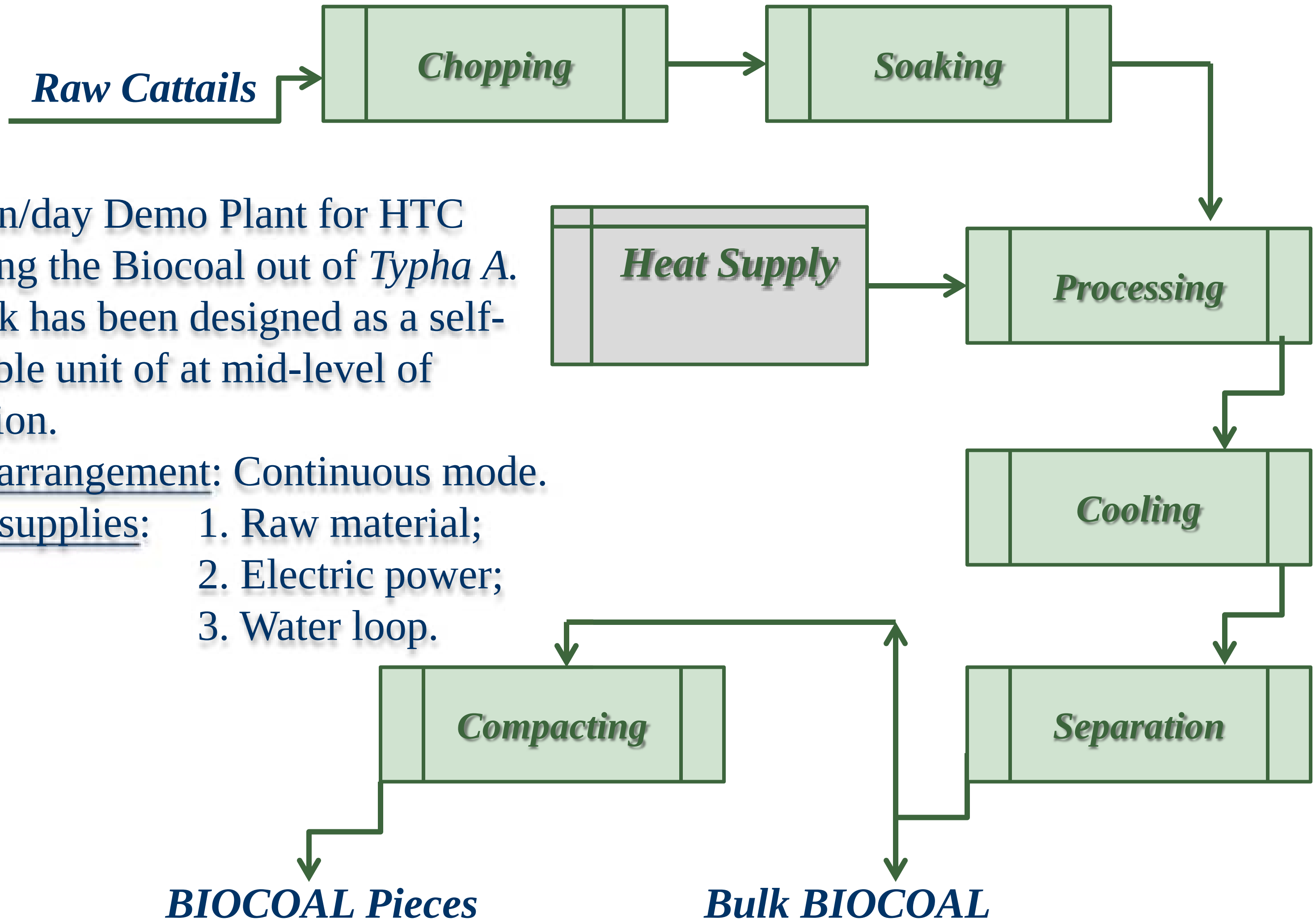
→

***Biocoal*:**
***4.7 ton DW;***

***HHV: 125 GJ;***
***LHV: 102 GJ.***

| Competitive Price estimation: | Gas Oil | Wood Charcoal | Biocoal |
|---|---|---|---|
| **Commercial/FOB Price (2012), USD/ton** | **1,060** | **450** | **370 - 600** |
| **Same, MRO/ton** | **320,000** | **136,000** | **112,500 – 181,500** |
| **Heating Value (HHV), GJ/ton** | **43.2** | **29.6** | **24.5** |
| **Price per 1 GJ, MRO** | **7,400** | **4,600** | **4,559 to 7,396** |

# HTC 2 ton/day: Block Diagram.




The 2 ton/day Demo Plant for HTC processing the Biocoal out of *Typha A.* feedstock has been designed as a self-sustainable unit of at mid-level of automation.

Process arrangement: Continuous mode.

Outside supplies:
1. Raw material;
2. Electric power;
3. Water loop.

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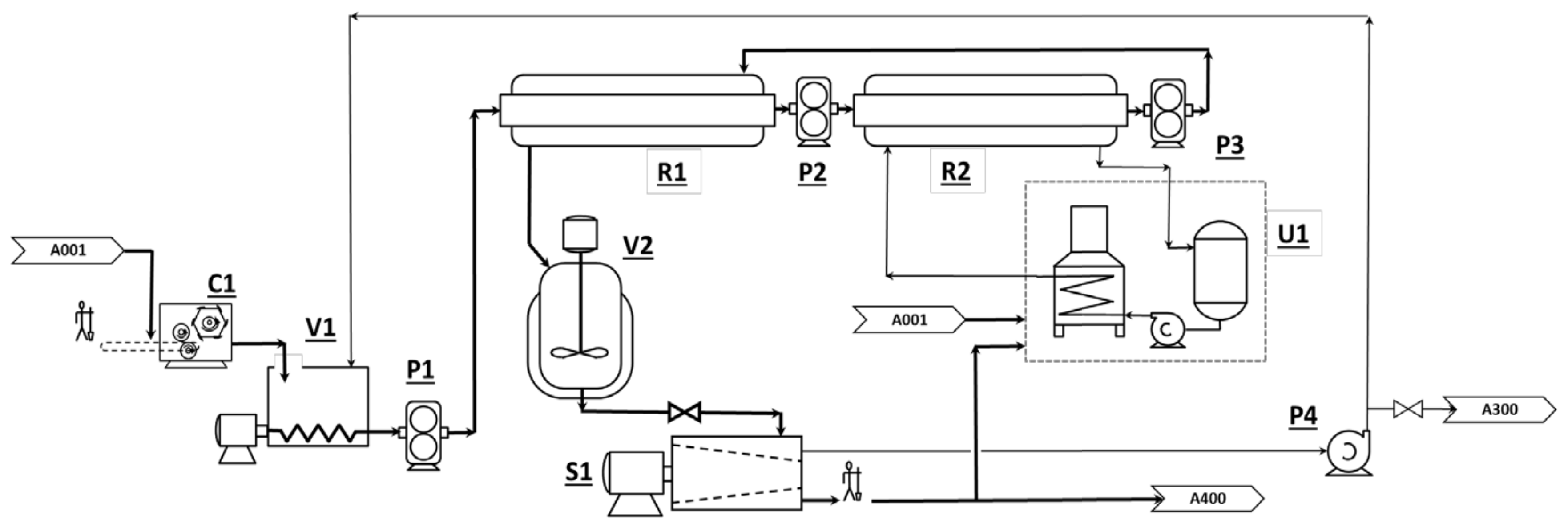
# HTC 2 ton/day : Process Flow Diagram.

HTC-2.0DEMO. Rev.2




| | C1 | V1 | P1 | R1 | V2 | P2 | S1 | R2 | P3 | P4 | U1 | A001 | A300 | A400 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Denomination** | Biomass Chopper | Soaker Tank | Feeder Pump | Recuperator | Recovery Vessel | Hi-P Pump | Centrifuge | Reactor | Discharge Pump | Liquor Pump | Hot Oil Assembly | Raw Biomass | Extra Liquor | Biocoal |
| **Pressure, psig** | ambient | ambient | 150 rated | 100 | ambient | 1000 rated | ambient | 1000 rated | 900 (on inlet) | 80 | 0 - 80 | 0 | 0 - 30 | 0 |
| **Temperature, °C** | ambient | 85 max. | 85 max. | 160 | 100 max. | 160 | 85 max. | 250 | 250 | 60 - 85 | 300 max. | 30 | 80 | 70 |
| **Volume/Flow Rate** | 1000 kg/hr | 6.3 m3 | 20 l/min | 0.4 m3 | 1.0 m3 | 20 l/min | 60 l/min | 0.4 m3 | 20 l/min | 0.05 m3/min | | 170 kg/hr (DW)* | 0.3 m3/hr max. | 90 kg/hr |
| **Technical Data / Remarks:** | Feima 93ZP-1600 Straw Chopper, 3 kW power. | Steel, bottom auger outlet | Gear pump | DN 12 * 6 m; Steel, Double-pipe | Carbon steel, standard design | Carbon steel, standard design | 20" Peeler Centrifuge, manual discharge drive. | DN 12 * 6 m; Steel, Double-pipe | Gear pump, operating in reverse with a speed controller | SS Centrifugal pump, general use. | Sigma Thermal /HESECO; 0.6 MMBTU inst., solid fuel-fired. | 350 – 700 kg/hr, depending on moisture of material. | Flow rate depends on moisture content in the raw material. | 0.13 – 0.15 tn/hr as a bulk material of 30% moisture. |

| | Name | Sign. | Date |
|---|---|---|---|
| Design | | ABK | 02.25.13 |
| PI | | DRF | |
| Dept. | NRRI-CARTD | | |

| Rev. # | Sheet # | Ref. | Sign. | Date |
|---|---|---|---|---|
| 2 | 01 | | ABK | 02.25.13 |
| 1 | 01 | Initial design. | ABK | 11.15.12 |

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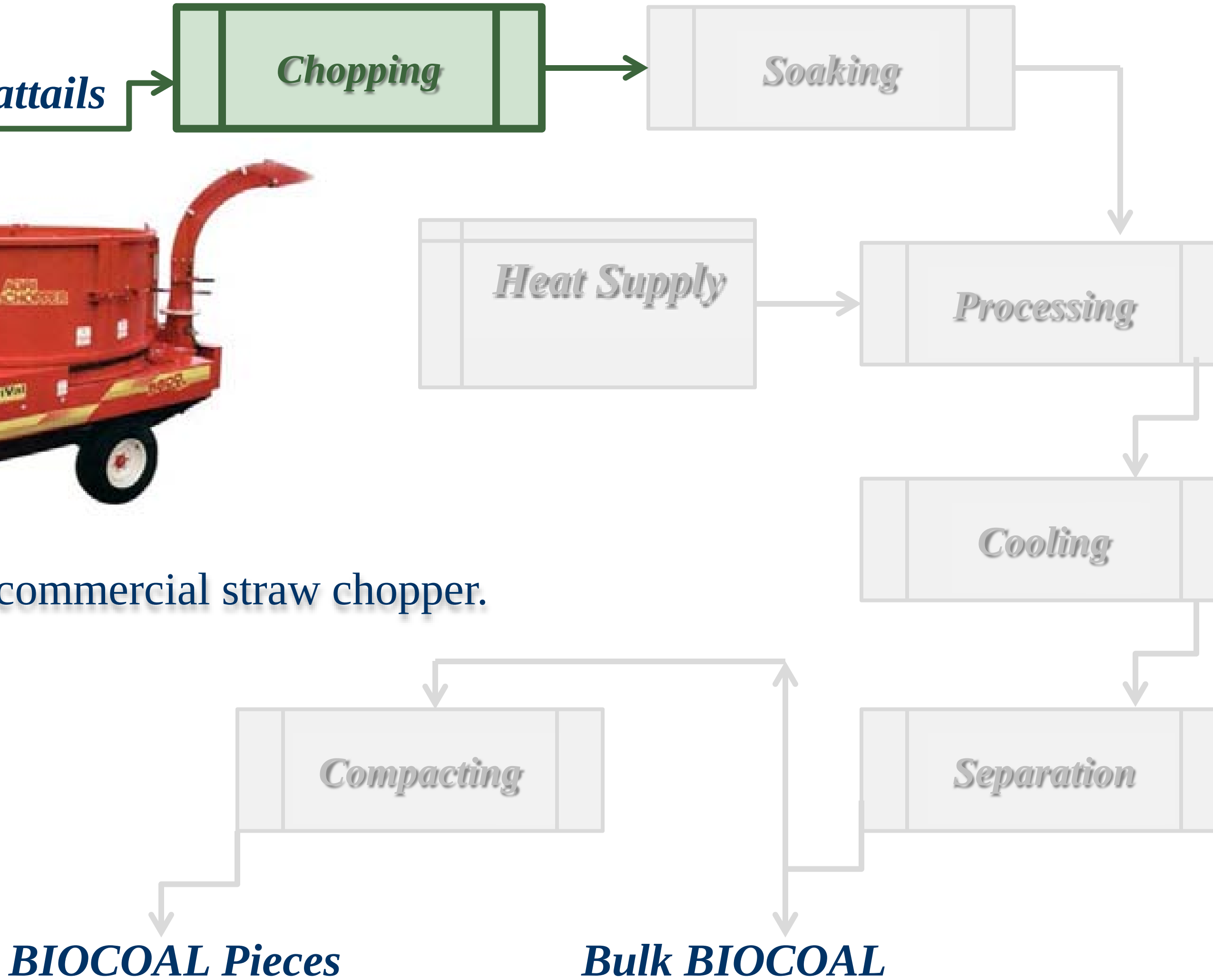
NRRI-UMD

**Hydrothermal Biocoal Demo Plant**
**Continuous Process Flow Diagram**

Scale: N/A | Sheet # 01 | Sheets total

# HTC 2 ton/day : Process Equipment.




1000 kg/hr commercial straw chopper.

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# HTC 2 ton/day : Process Equipment.

*Raw Cattails*

*Chopping*

*Soaking*

*Heat Supply*

*Processing*

*Cooling*

*Separation*

*Compacting*


6.3 $m^3$ Soaking Tank, equipped with the bottom screw conveyor.

***BIOCOAL Pieces***

***Bulk BIOCOAL***

# HTC 2 ton/day : Process Equipment.

*Raw Cattails*

*Chopping*

*Soaking*

*Heat Supply*

**Processing**

*Cooling*

*Separation*

*Compacting*

Double Pipe Assembly, Diameter 300 mm * 6 m equivalent length.

***BIOCOAL Pieces***

***Bulk BIOCOAL***

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# HTC 2 ton/day : Process Equipment.

*Raw Cattails* → *Chopping* → *Soaking* → *Processing*

*Heat Supply* → *Processing* → *Cooling* → *Separation*

*Separation* → *Bulk BIOCOAL*

*Separation* → *Compacting* → *BIOCOAL Pieces*


1.5 $m^3$ standard jacketed reactor.

***BIOCOAL Pieces*** ***Bulk BIOCOAL***

# HTC 2 ton/day : Process Equipment.

*Raw Cattails*

Chopping

Soaking

Heat Supply

Processing

Cooling

**Separation**

Compacting

Peeler Centrifuge, 500 mm basket diameter.

***BIOCOAL Pieces***

***Bulk BIOCOAL***

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# HTC 2 ton/day : Process Equipment.

*Raw Cattails*

*Chopping*

*Soaking*

*Heat Supply*

*Processing*

Biomass Fired Hot Oil Loop Assembly, 0.6 GJ/hr.

*Cooling*

*Compacting*

*Separation*

***BIOCOAL Pieces***

***Bulk BIOCOAL***

# HTC 2 ton/day : Process Equipment.

*Raw Cattails* → *Chopping* → *Soaking* → *Processing* (← *Heat Supply*) → *Cooling* → *Separation* → *Compacting* → ***BIOCOAL Pieces*** / ***Bulk BIOCOAL***

500 kg/hr. Commercial Charcoal Briquette Press Machine.

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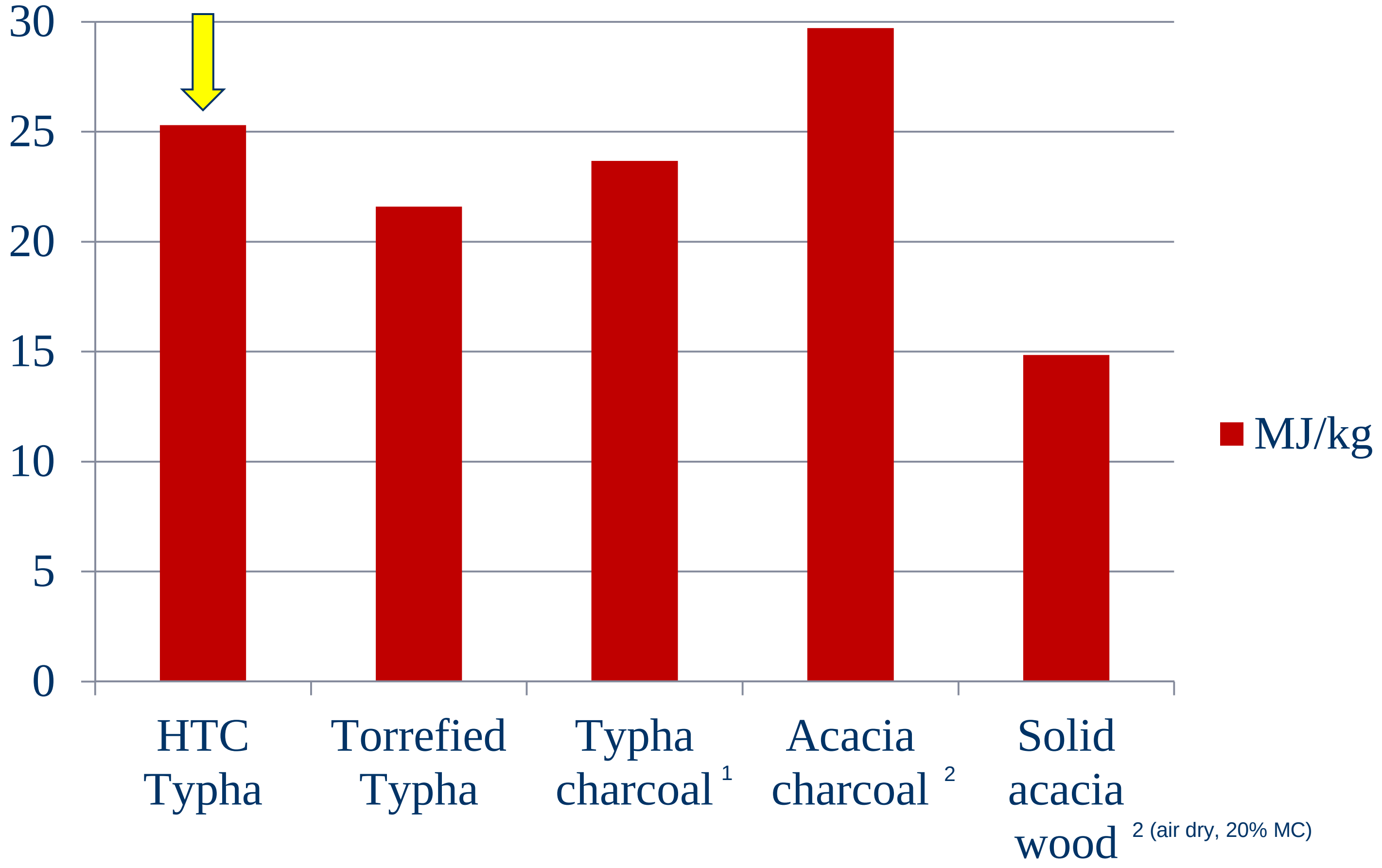
# PRODUCT ATTRIBUTES AND IMPACT

# Competing Fuels

- HTC Typha biocoal
- Torrefied Typha biocoal
- Typha charcoal (using traditional charcoal-making techniques)
- Acacia wood charcoal (using traditional charcoal-making techniques)
- Solid acacia wood

# Energy Content




Sources: (1) Caro, R., de Frutos, H., Nassor Kitwana, A., and Shen, A. 2011. Typha Charcoal in Senegal, Changing a National Threat into Durable Wealth. 15.915, Laboratory for Sustainable Business. (2) http://www.ocean.washington.edu/courses/envir215/energynumbers.pdf.

# HTC vs. Torrefaction

| | "Dry Side" Torrefied Typha Biocoal (300°C/30% dry solids loss) | Hydrothermally Treated Typha Biocoal (260°C/50% dry solids loss) |
|---|---|---|
| **Proximate Parameters (% dry basis)** | | |
| Ash | 12.17 | 10.34 |
| Volatile matter | 58.3 | 53.56 |
| Fixed carbon | 29.53 | 36.10 |
| Sulfur | 0.162 | 0.246 |
| HHV | 8491 | 9966 |
| Mass yield | 70% | 65% |
| Energy densification ratio (EDR) | $(HHV_{final}/HHV_{initial}) = 1.03$ | $(HHV_{final}/HHV_{initial}) = 1.21$ |
| Energy yield | (mass yield x EDR) = 0.72 | (mass yield x EDR) = 0.79 |
| **Ultimate Parameters (% dry basis)** | | |
| Carbon | 49.46 | 58.85 |
| Hydrogen | 4.96 | 5.43 |
| Nitrogen | 0.64 | 0.83 |
| Oxygen | 32.61 | 24.3 |

**HTC Typha biocoal shows a deeper conversion of the carbon (with lower temperature) and a higher heating value**

# HTC vs. Torrefaction

| Treatment Method | Moisture | Compaction Pressure (Bar) | Briquette Thickness (in) | Survives Accelerated Aging? | Briquette Density (lb/$ft^3$) |
|---|---|---|---|---|---|
| HTC Typha biocoal, 260°C/50% dry solids loss | 31 | 321 | 0.54 | yes | 62.5 |
| HTC Typha biocoal, 260°C/50% dry solids loss | 21 | 214 | 0.53 | yes | 67.5 |
| Torrefied Typha, 300°C/30% dry solids loss | 12 | 214 | >1.0 | Unable to form a viable briquette | |

**HTC Typha biocoal requires nearly 10 times less pressure to densify into a viable briquette, even at high moisture content**

# Drop-Shatter (Durability) Test

HTC Typha biocoal

Commercial torrefied biocoal

***HTC Typha biocoal exhibits greater durability**

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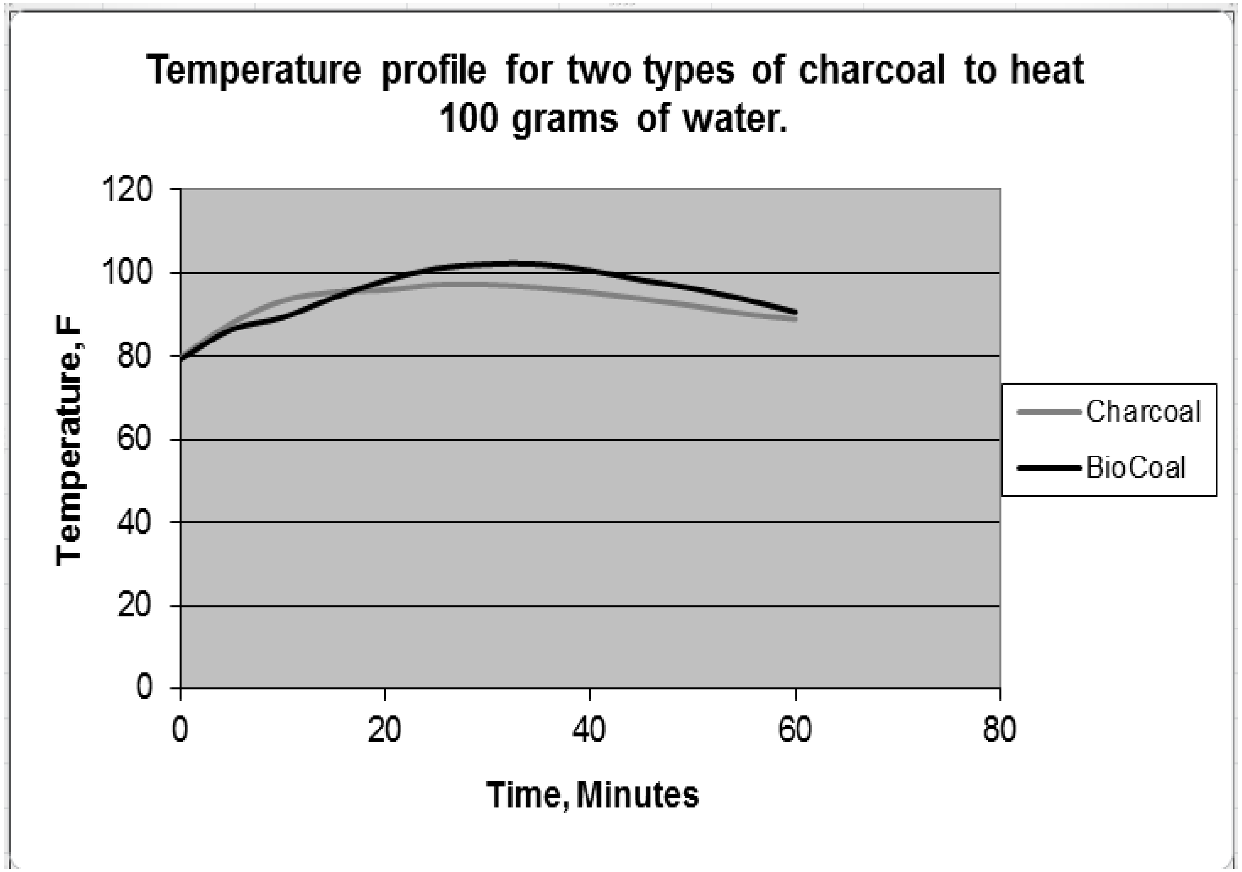
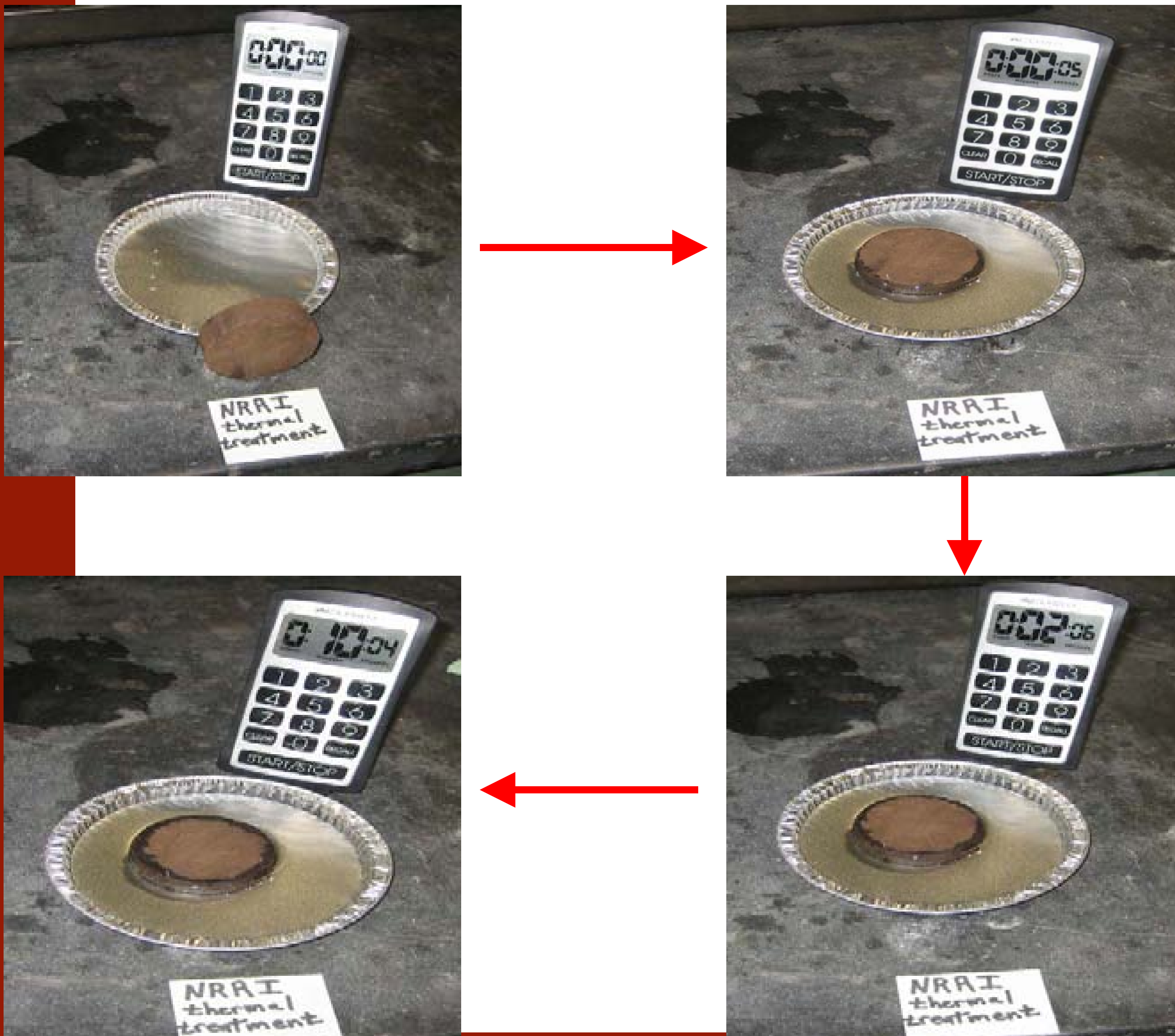
# Heating Ability

**HTC Typha biocoal heats water similarly to commercial charcoal briquettes**



# Moisture Resistance




**HTC Typha biocoal retains integrity, even when submerged in water**

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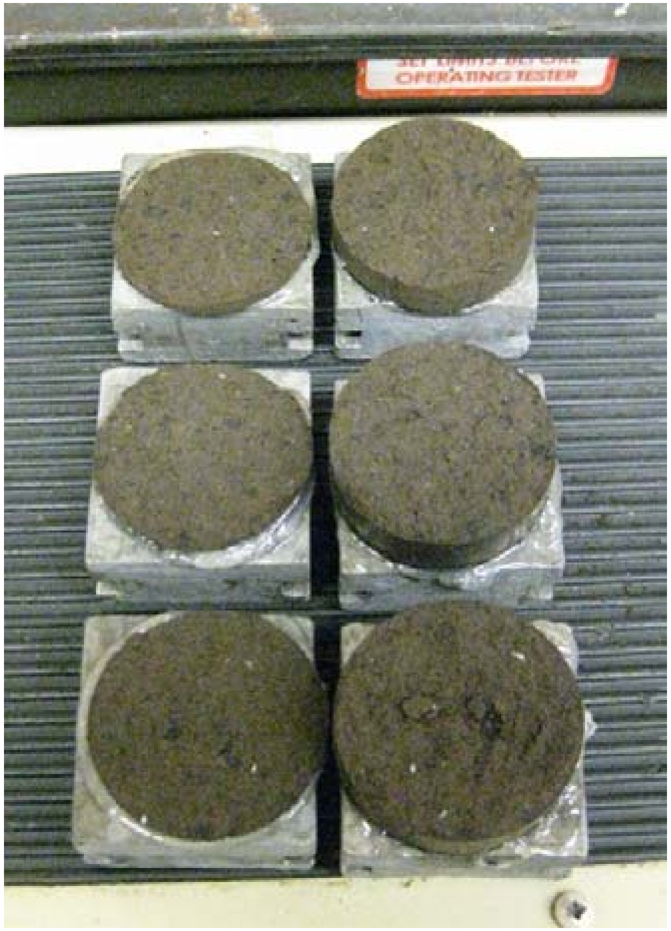
# Wetting/Drying

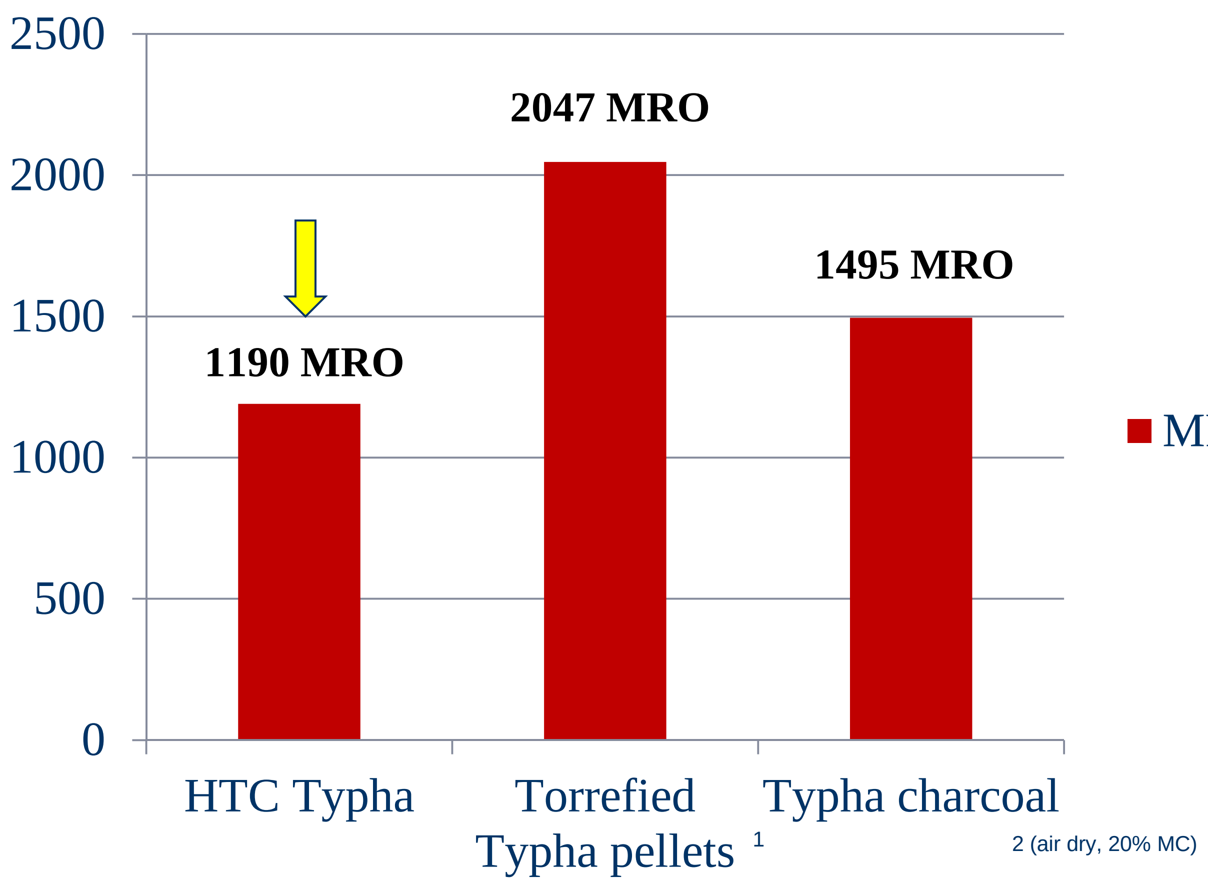
**HTC Typha biocoal retains integrity, even after repeated wetting/heating cycles**

# Internal Bond Strength




**HTC Typha biocoal has internal bond strength that approaches that of wood-based structural construction panels**

# Cost Estimate (MRO/GJ)




Sources: (1) Topell Energy. (2) Caro, R., de Frutos, H., Nassor Kitwana, A., and Shen, A. 2011. Typha Charcoal in Senegal, Changing a National Threat into Durable Wealth. 15.915, Laboratory for Sustainable Business.

# Environmental Benefits

- Reduced ash generation compared to traditional biomass[1]
- Improved water quality for villagers and livestock
- Improved livestock access to drinking water
- Reduced clogging of irrigation channels
- Reduced shelter options for agricultural pests
- Reduced air pollution caused by villagers burning above-water portion of Typha plant
- Allows processing of other wet, invasive plants

Sources: (1) Yu, Y., Lou, X., and Wu, H. W. 2008. *Energy & Fuels*. 22,46.

# Economic Benefits

- Development of a new, affordable household cooking and heating fuel
- New source of sustainable income/employment for villagers
- Increased economic growth rate based on sustainable management of Typha and labor savings due to increased access to clean water
- Typha does not require drying, thus saving sizable drying costs
- Reduced fuel transportation costs due to greater energy density
- Improved fishing productivity for villagers
- Increased rice yield due to fewer Typha seeds in rice fields
- Process liquor may have herbicidal effects (study underway)

# Social Benefits

- Reduced poverty and improved standards of living
- Transfer of valuable skills and knowledge to local producers and those along the supply chain
- Reduced water-borne diseases (e.g., malaria)
- Improved access to water for villagers
- Potential improvement in household health
- Empowerment of local women (consumer acceptance trials and other key aspects of project involve transfer of knowledge and responsibilities to women)
- Processing plants and households are cleaner due to much less charcoal dust/residue