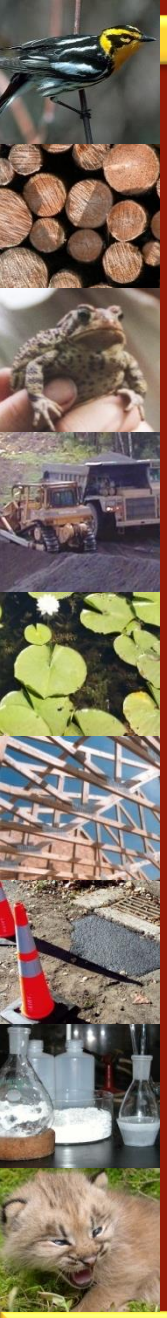

# Biomass Pretreatment at the Natural Resources Research Institute

8/23//2017

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Driven to Discover

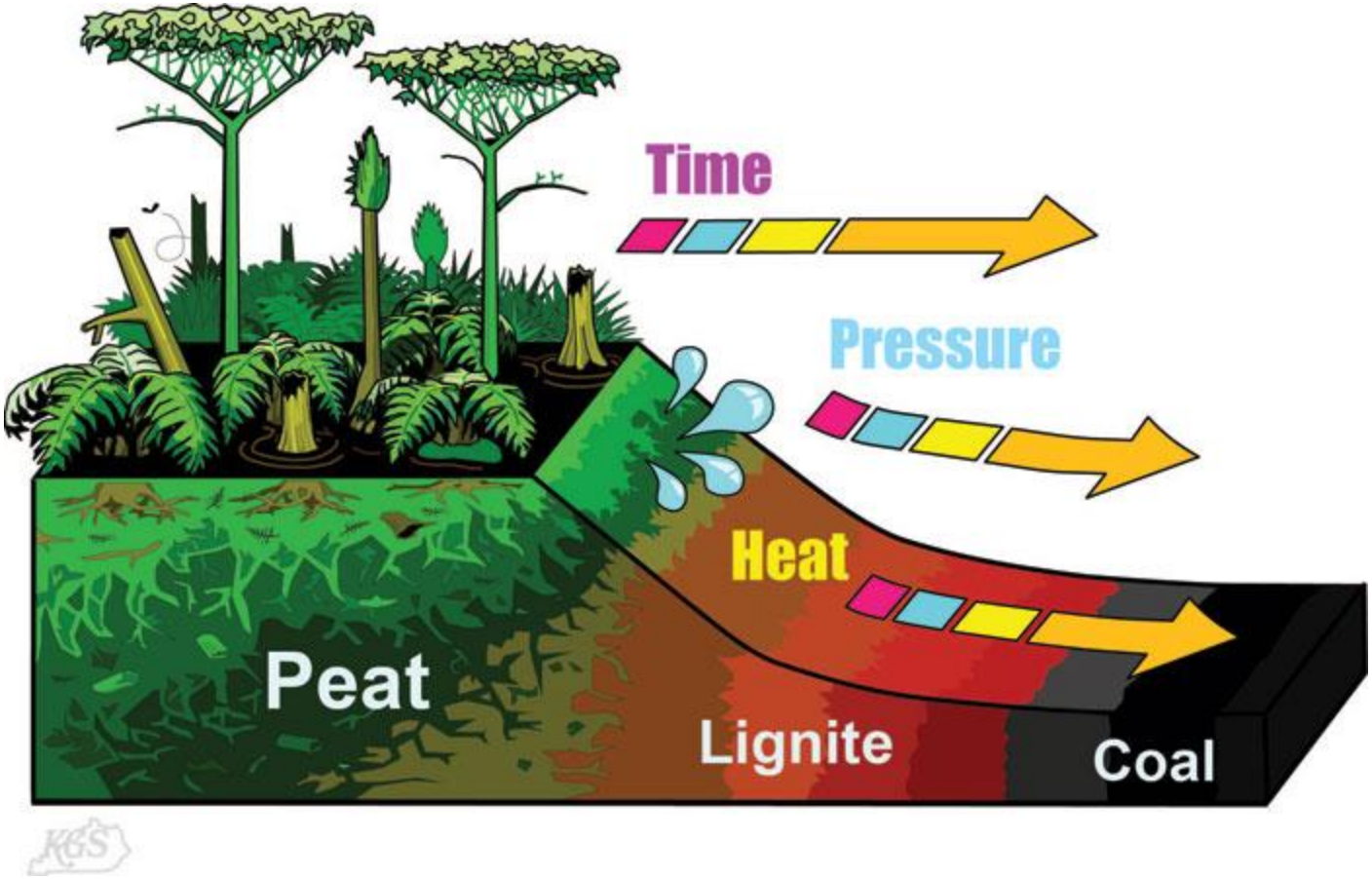
# Pretreatment Creates a Better Fuel Product

- **Various Pretreatment Methods exist and are being developed**
  - **Torrefaction – roasting in an oxygen-free environment**
  - **Hydrothermal carbonization (HTC) – heating biomass under pressure and temperature similar to pressure cooker**
  - **Steam Explosion – similar to HTC, but at lower temperature and pressure levels**

***All methods concentrate energy density and help remove smokey components from the biomass***

# How does mother nature make fossil coal?

- Heat
- Pressure
- Millions of years

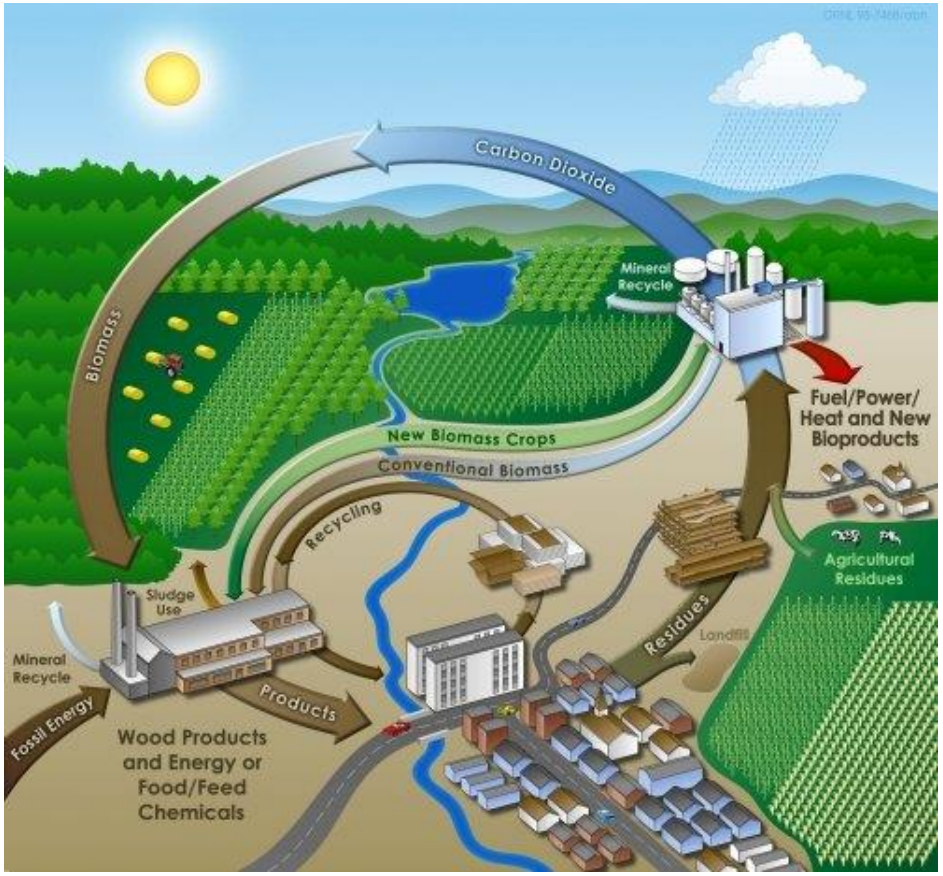


# What variables did mother nature use to form coal?

- Time (millions of years)
- Pressure
- Moisture
- Particle size
- Temperature

# What are the Environmental Benefits of Using a solid BioFuel for making power or for heating?

- Considered to be “carbon neutral” *
- Low sulfur
- Low ash
- Low Mercury
- Low NOx emissions
- Can help manage fire risk
- Provides a market outlet for forest residuals or agricultural residues
- Provides a means to meet emission mandates for older coal fired power and industrial plants




Life Cycle Assessment, Oak Ridge National Laboratory

# Can we emulate these conditions and shorten the time frame?

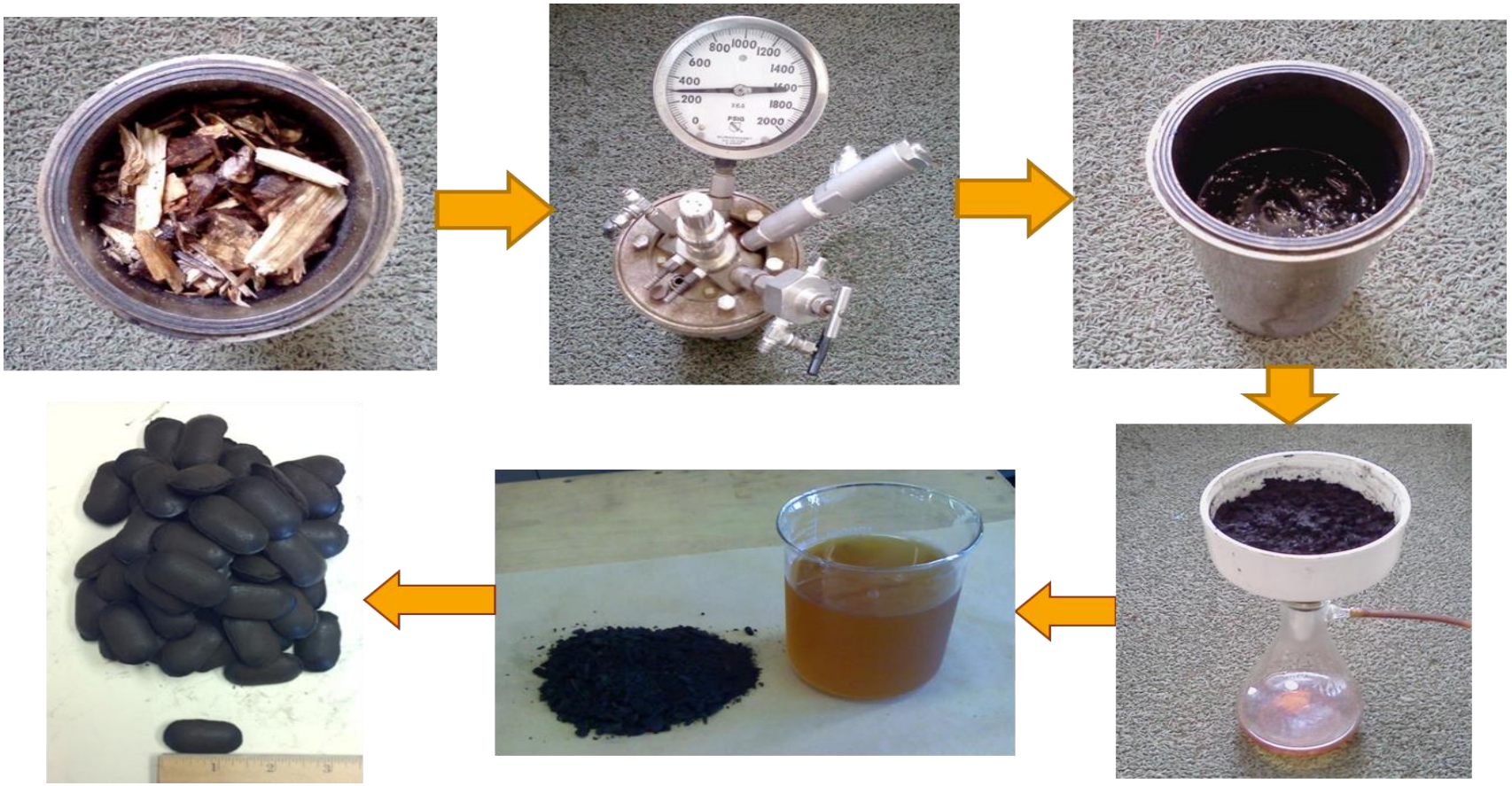
- **Hydrothermal Carbonization**
  - **This is a fancy word for "Pressure-Cooker" or cooking under water!**

Pressure = 750-950 psi (5.71-6.20 Mpa)
Temperature = 240°C - 270°C
Retention Time = 15 - 30 minutes
Water & solids are cooked together

- **Torrefaction**
  - **This is a fancy word for roasting……..kind of like roasting coffee!**

Pressure = ~1-2 psi (6.89-13.8 kPag)
Temperature = 270°C-300°C
Solids are cooked in a hot gas starved of oxygen (~ 20 minutes)

# What happens when wood residues are pressure cooked?




An energy mud is produced that is **easily densified** that burns and looks like fossil coal!

# Examples of what we get when wood is slowly and carefully roasted!

Looks like coal!

Grinds like coal!

Raw wood chips

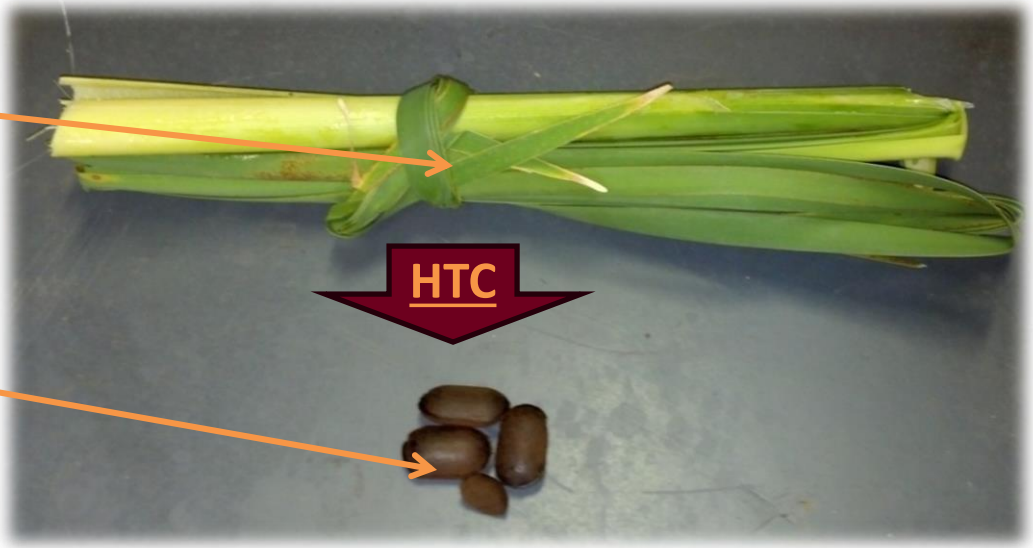
Roast Em' up!

Well roasted wood chips!

# Conversion and Consolidation

***Raw Biomass (Cattails):***
*122.0 g (24.6 g DW);*
$HHV_{DW, AF}$ *= 18.5 kJ/g*

***Biocoal Briquettes:***
*16.0 g (14.5 g DW);*
$HHV_{DW, AF}$ *= 25.9 kJ/g*



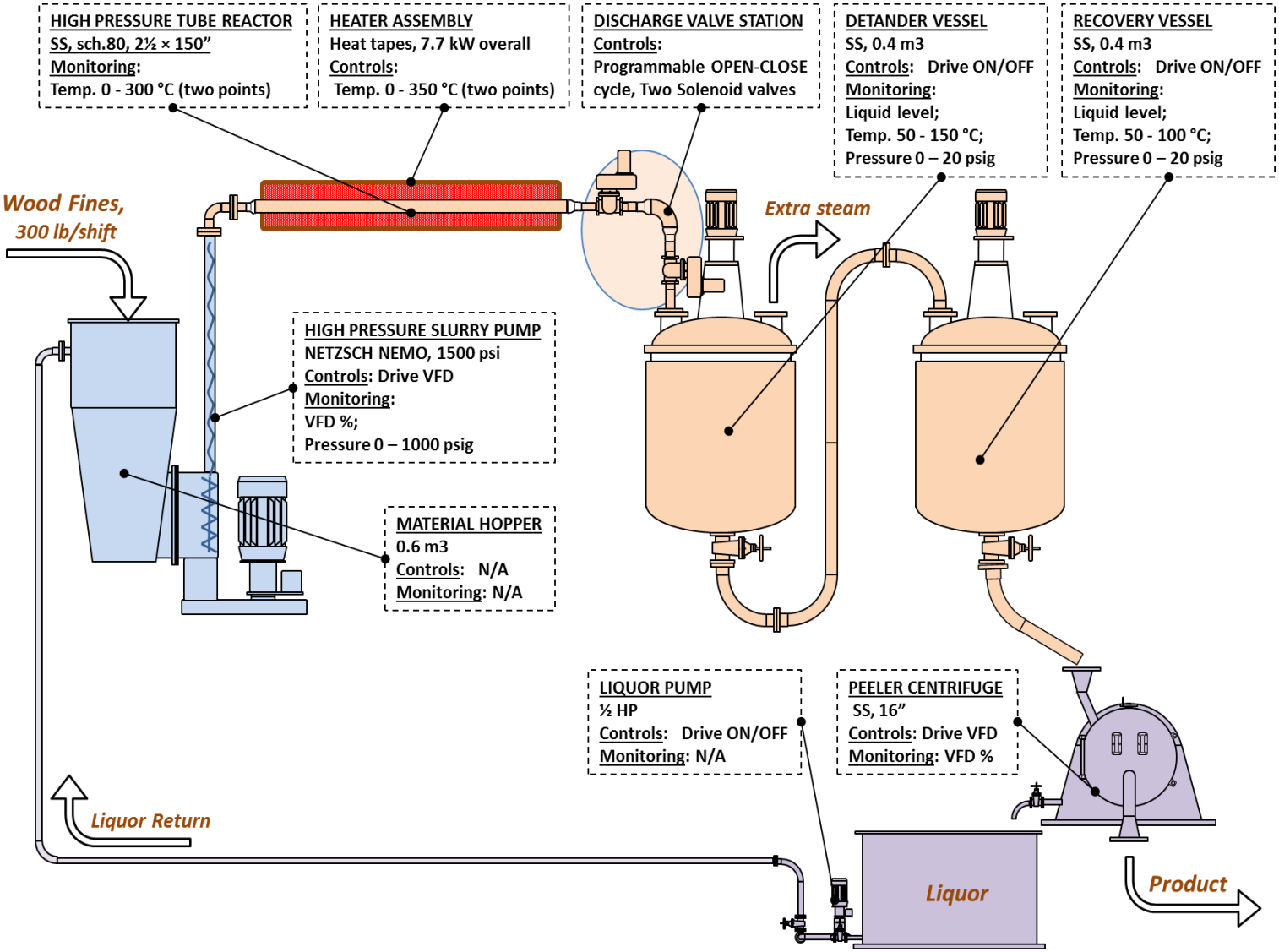

***Hay Semi-Truck:***
*15 bales; 10 ton*
*(8 ton DW);*
*HHV: 150 GJ;*
*LHV: 109 GJ.*

HTC

***HTC-Biocoal:***
*4.7 ton DW;*

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

***171-HTC***




## Schematic of Pilot HTC Facility

**Overview Picture of New Pilot Scale Hydrothermal Carbonization Reactor**

Feed Hopper

Pump Discharge

HTC Reactor

Reactor Discharge

Detander

Product Tank

# Torrefaction Process Mass Balance

- **Based on 24hr/7day operation**
  - **8.2 t/d feed**
  - **45% moisture**
  - **30% Dry Solids Loss (DSL)**
  - **5% Dust loss**
  - **4% Binder**
  - **80% Operating efficiency**
- **Produces 3.1 t/d biofuel briquettes**

# Basic Implications

- Technologies are Developed or Being Developed to process Biomass into better fuel products
- Choice of the technology dictated by type of biomass
- In some cases, combinations of technologies will be used
- Actual form of the produced fuel should be determined by interaction with end user
- Logistical collection of biomass likely can lead to significant employment of local people
- Conversion processes are technically derived, but not overly complicated

# Current Status of NRRI Developments

- Demonstration Plant for Torrefaction is complete and routinely producing particulate solid fuel
- Demonstrated moving bed torrefaction system at pilot scale
- Pilot Plant for both HTC under commissioning
- Densification work on products is now underway – new briquetting scheme to be evaluated at demonstration level
- Future quantities for use in power plant testing will be produced for US and other countries
- Previously processed Typha Australis (cattails) from Senegal River into fuel products
- Various woody and agricultural products have been treated successfully

# Over next year other developments that will be implemented

- Install demonstration scale moving bed torrefaction system at our Renewable Energy Center
  - Main thrust is to take oxygenated hydrocarbons out of the biomass to create a char that is easier to gasify
- After that, work with partners and high pressure gasification to produce a syngas product for fuel and chemical conversion

# Full Program of Activities

- 2017 program activities
  - Torrefaction of Biomass for fuel use monitored at various utilities
  - Demonstration scale 100 kW advanced steam boiler for power generation and moving bed torrefaction system (basic engineering design is nearing completion for both systems)
  - Hydrothermal carbonization pilot plant design is done and equipment construction completed. Commissioning Underway.
  - New binder development using biomass is proceeding with initial good properties
  - Preliminary developments on value added products begun (e.g., activated carbon)

# Demonstration Plant in Pictures

- Equipment at a size for engineering scale-up to commercial units

**Truck Trailer with moving floor in position for wood delivery**


**Wood chips in receiving hopper**


**Conveyor to Shaker Screen and Tramp Metal Magnet**


**Transfer System Overview to Screen**


**Pneumatic  blower for transport of sized materials**


**Texas Shaker used to size incoming biomass materials**

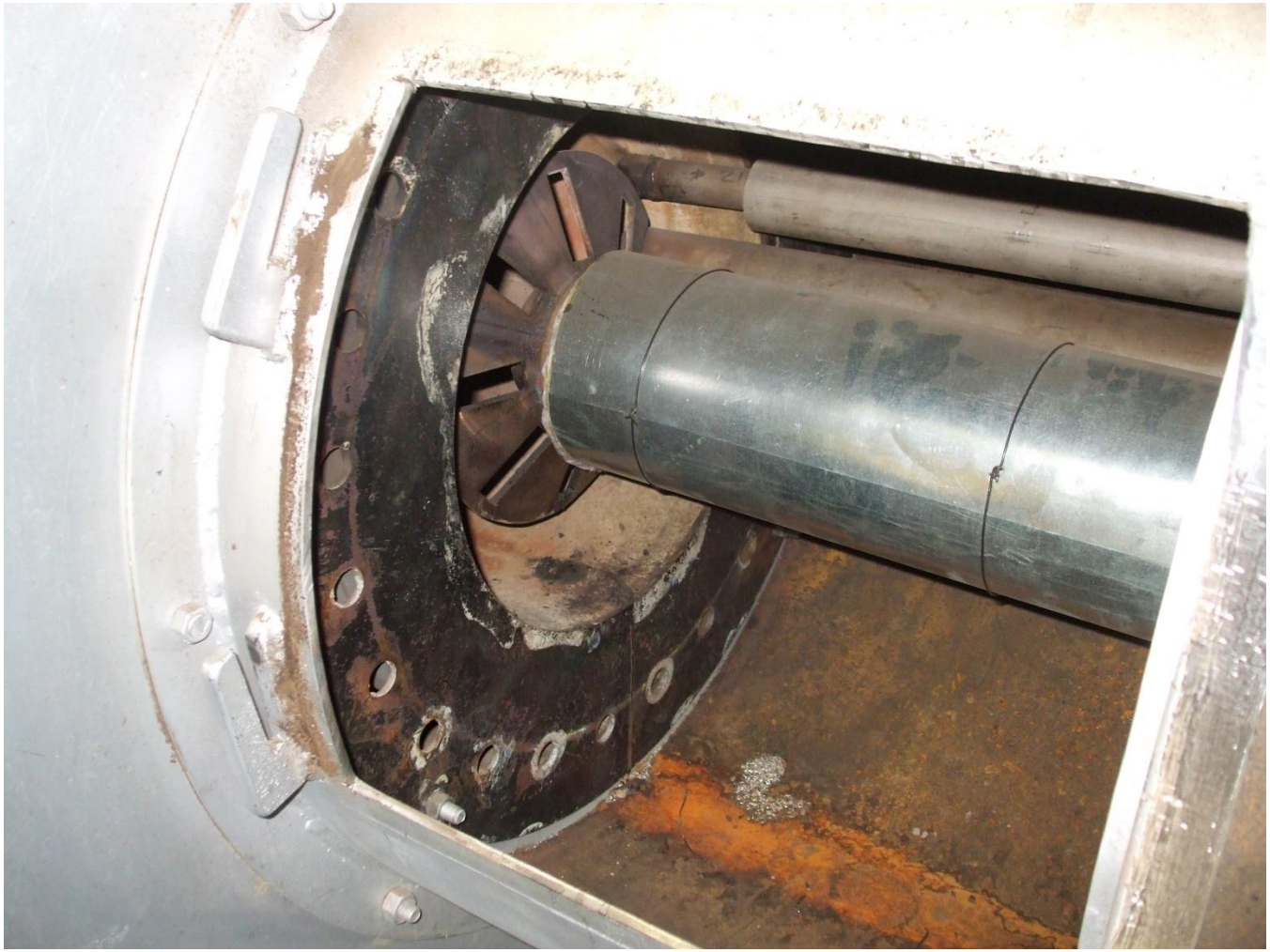

**Over/under size particle removal and dust collector fan**


**Dust Collector for Densification Room**

**Pneumatic transfer piping and air movement ducting**


**Surge Hopper for receiving sized biomass materials (4 hour capacity)**


**Conveyor to MEC Receiving Bin for Sized Materials and Combustion Chamber for Drier**



**View into Combustion Zone for Dryer**

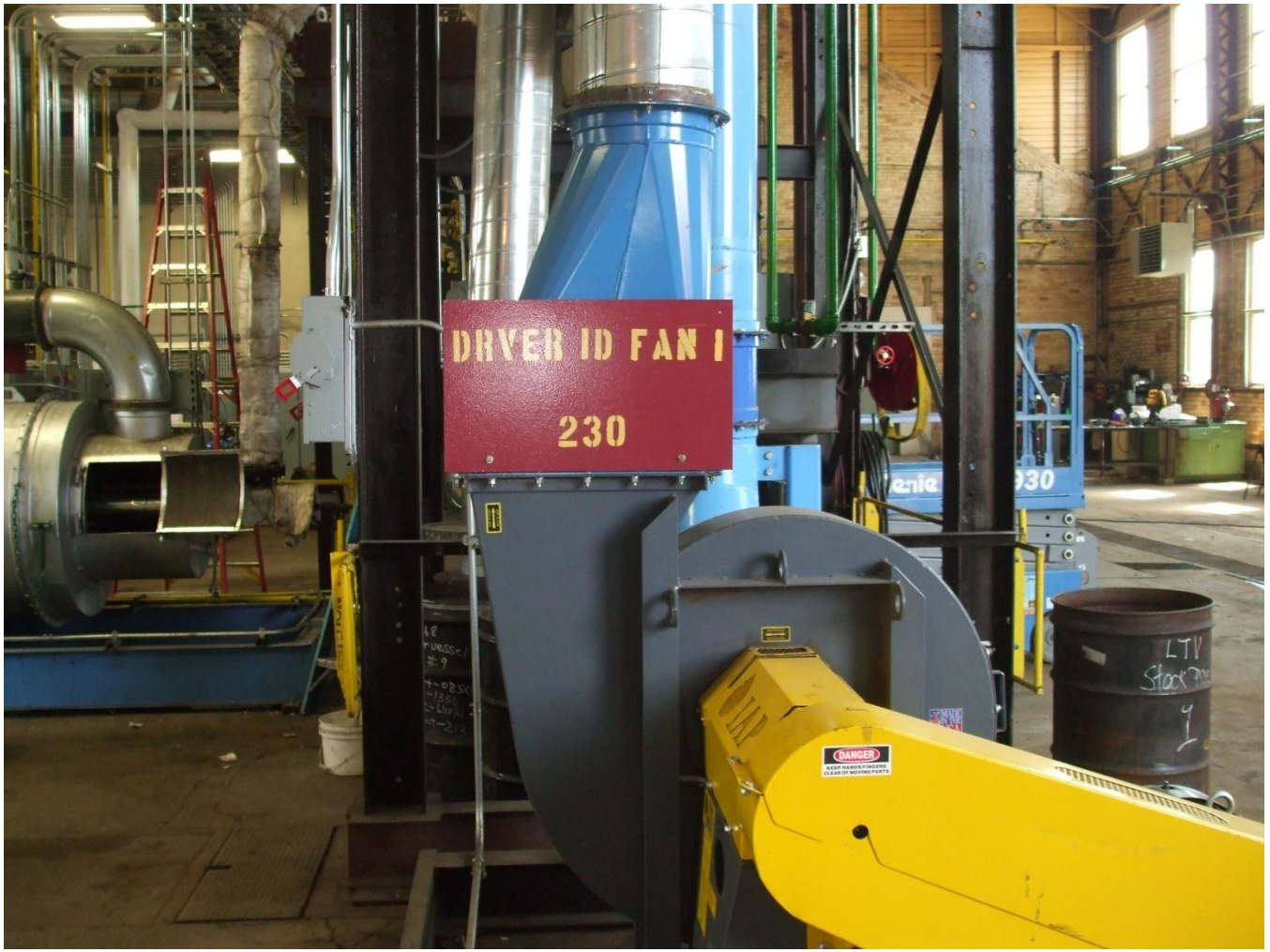

**Hydraulic System Used for Moving Floor Trailers**

**Port for Air Modulation at Combustion Chamber Exit**

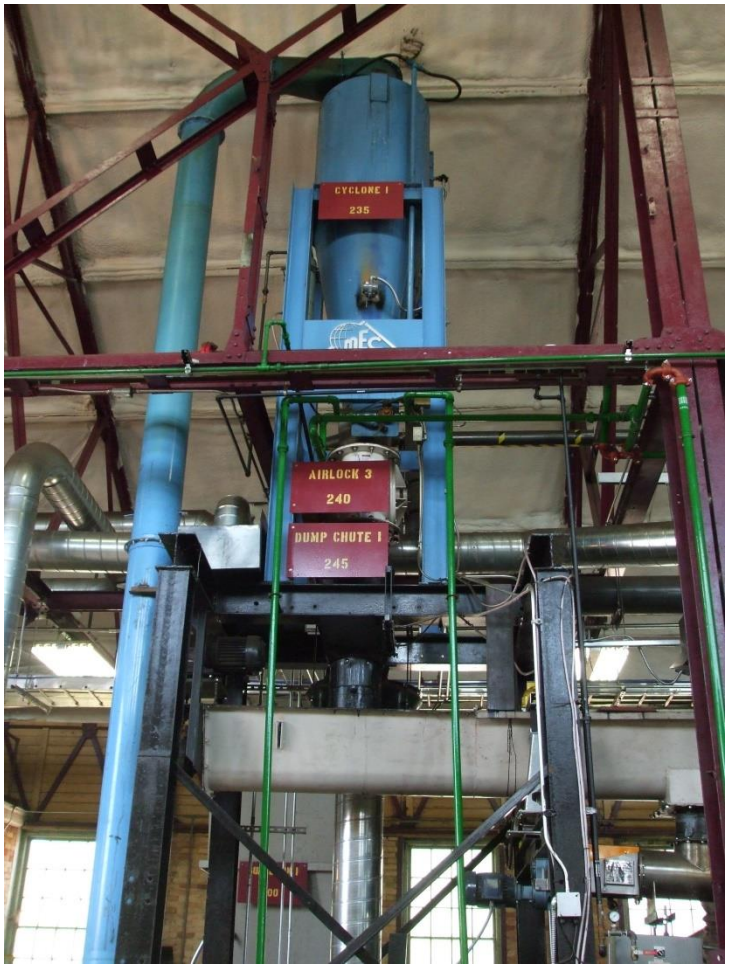

**Weigh Scale to Monitor Feed to Dryer**

**MEC Dryer for Processing Raw, Sized Wood or other Biomass Materials**

**Overview of Ductwork and Dryer Assembly Equipment**




**ID Fan Used tp Drive Pneumatic Transport from Dryer to Cyclone**




**Receiving Cyclone to Feed Auger to Kiln**

**Material Feed to Torrefaction Kiln**


**H&P Kiln Used for Torrefaction**


**H&P Kiln Discharge End to Discharge Auger**

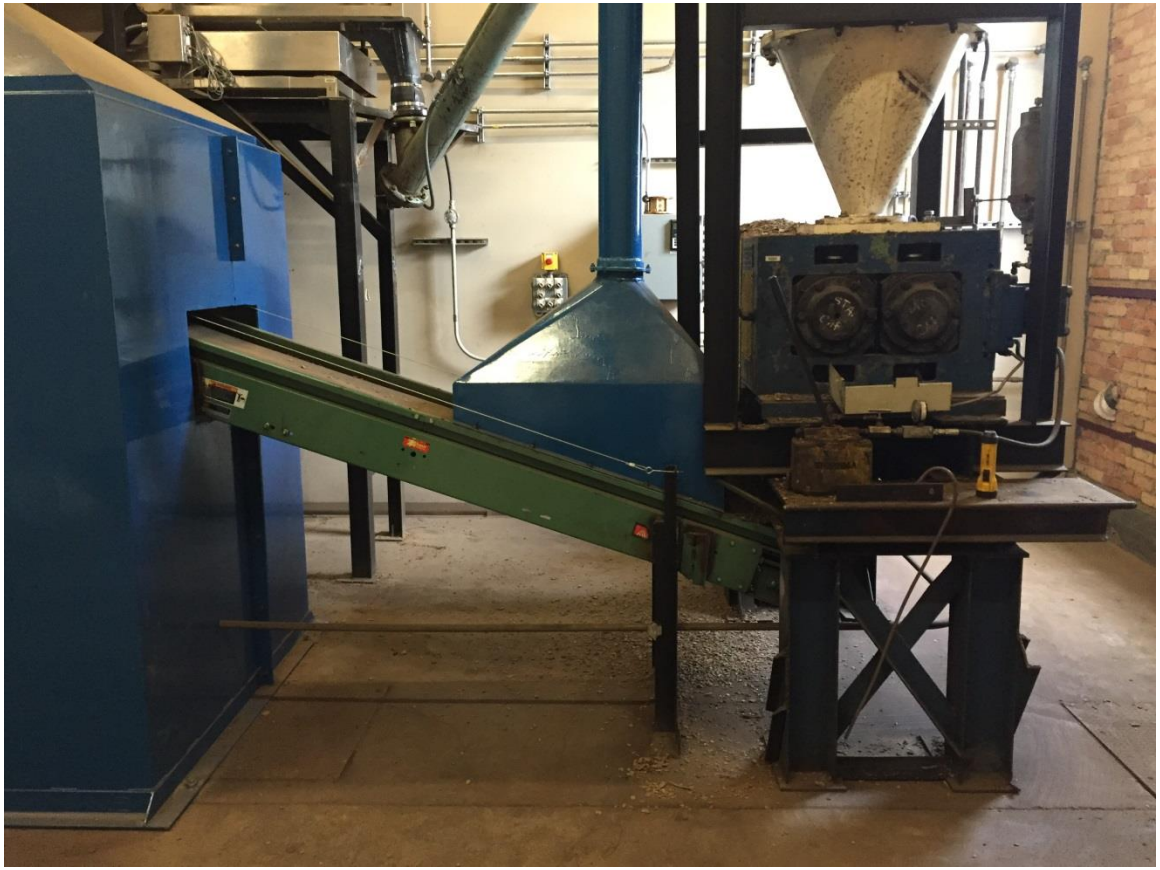
**Auger from Kiln Discharge to Bucket Elevator for Material Movement**


## Densification Room for Product


**Torrefied Material Receiving Hopper and Conveying Equipment in Densification Containment Room**

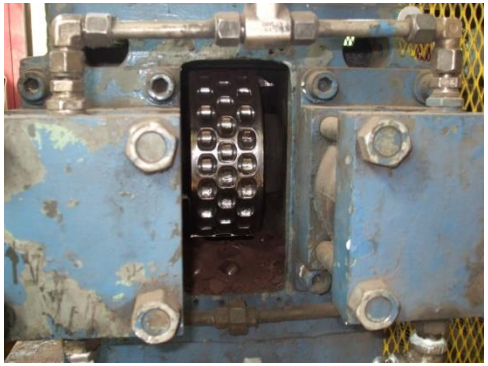
**Ribbon Mixer to Prepare Materials for Densification**

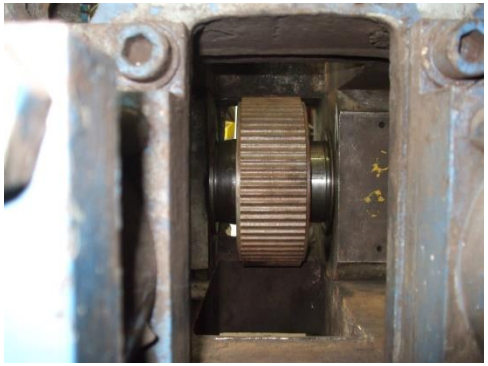
TorriefiedBiomass2017.mp4



**One Example  of Densification Configuration -- Briquetting Equipment**
**Other Equipment Can be Brought Into the Room**

# Various Densification Equipment is Available



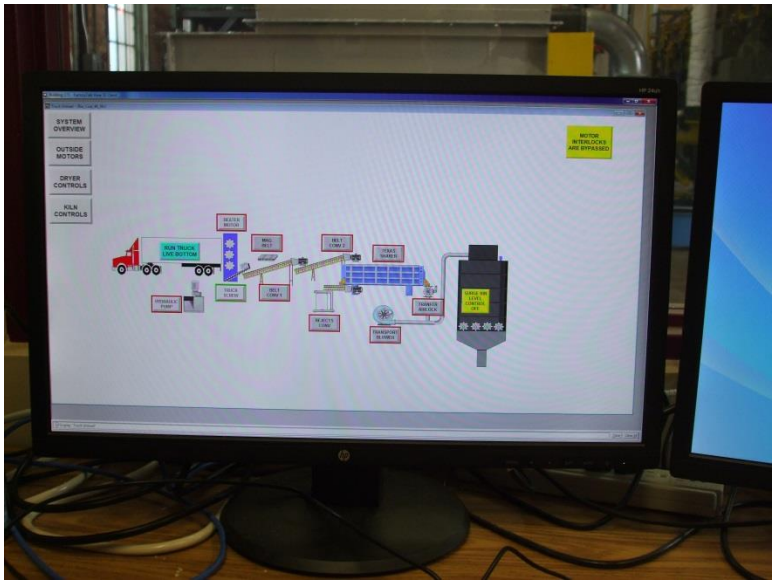



# Auxiliary Equipment

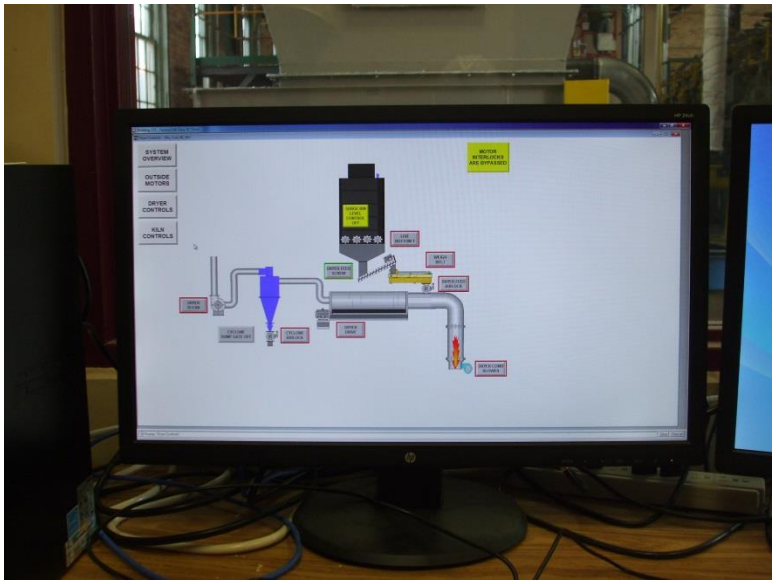

Steam Generator

Nitrogen generator

# Process Control Screens

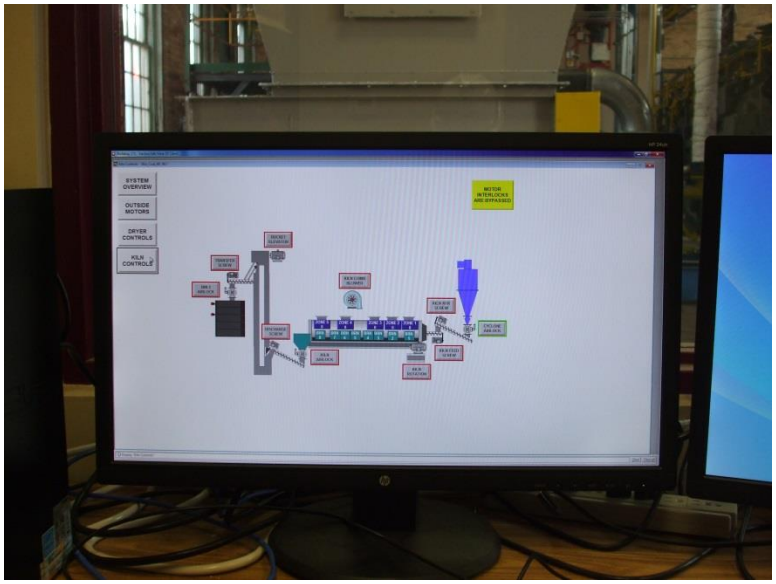



Material Delivery

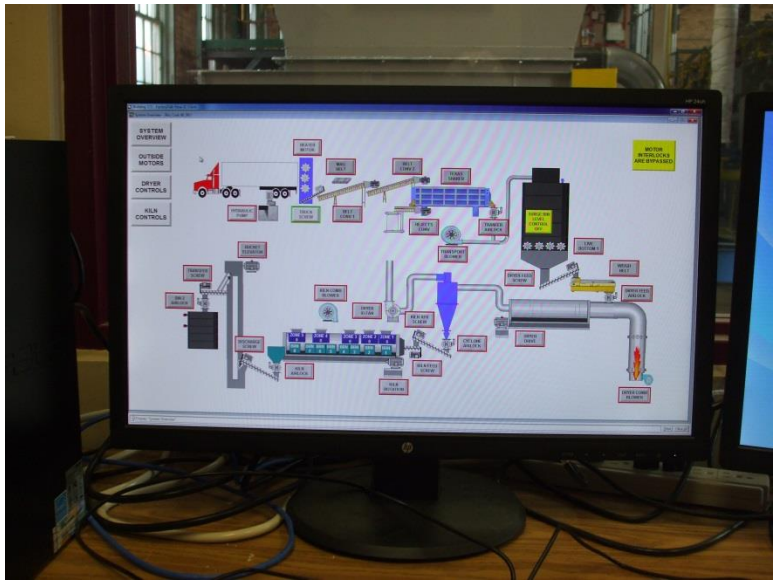



Drier Operation

# Process Control Screens




Kiln Operation

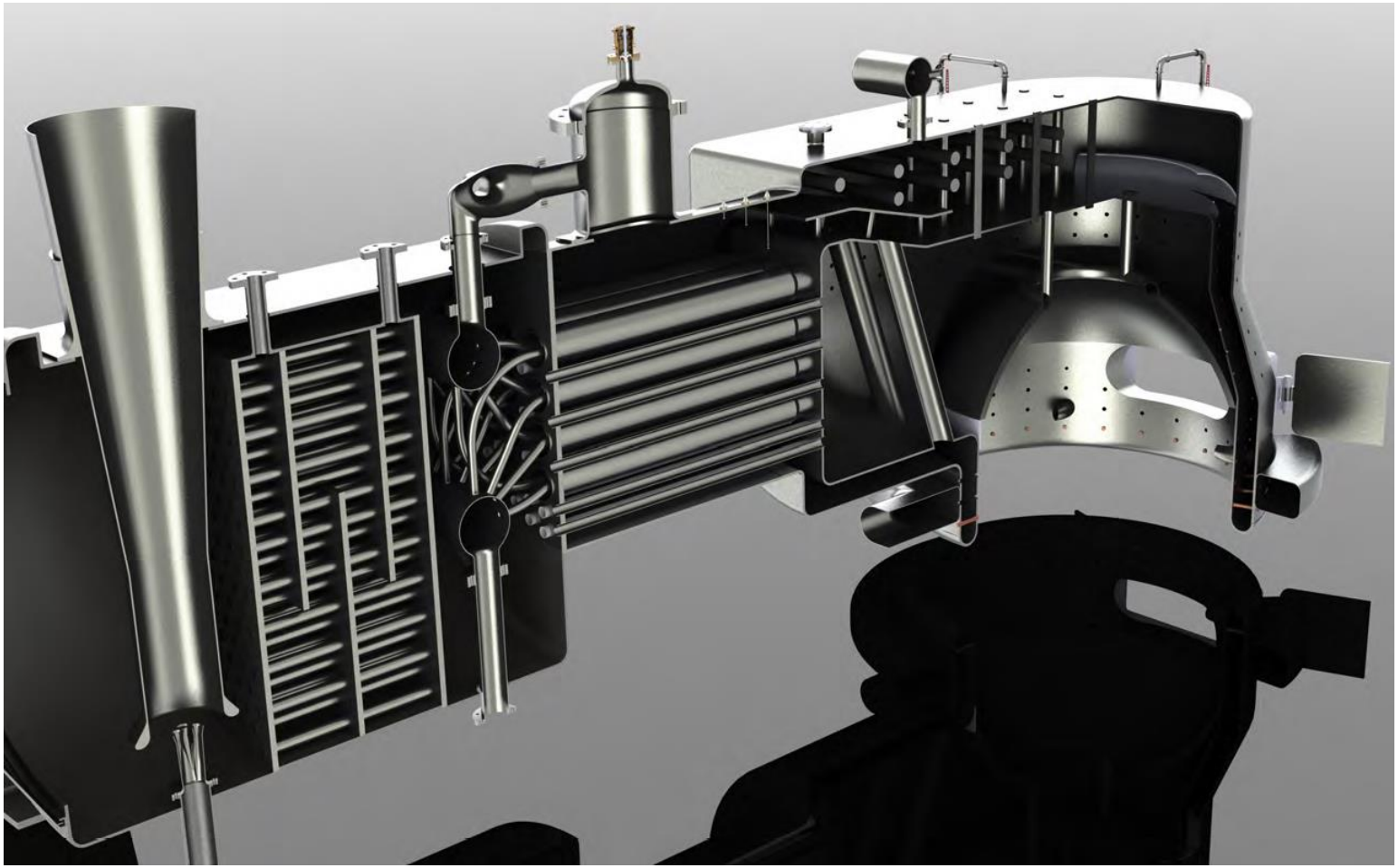



Overall System

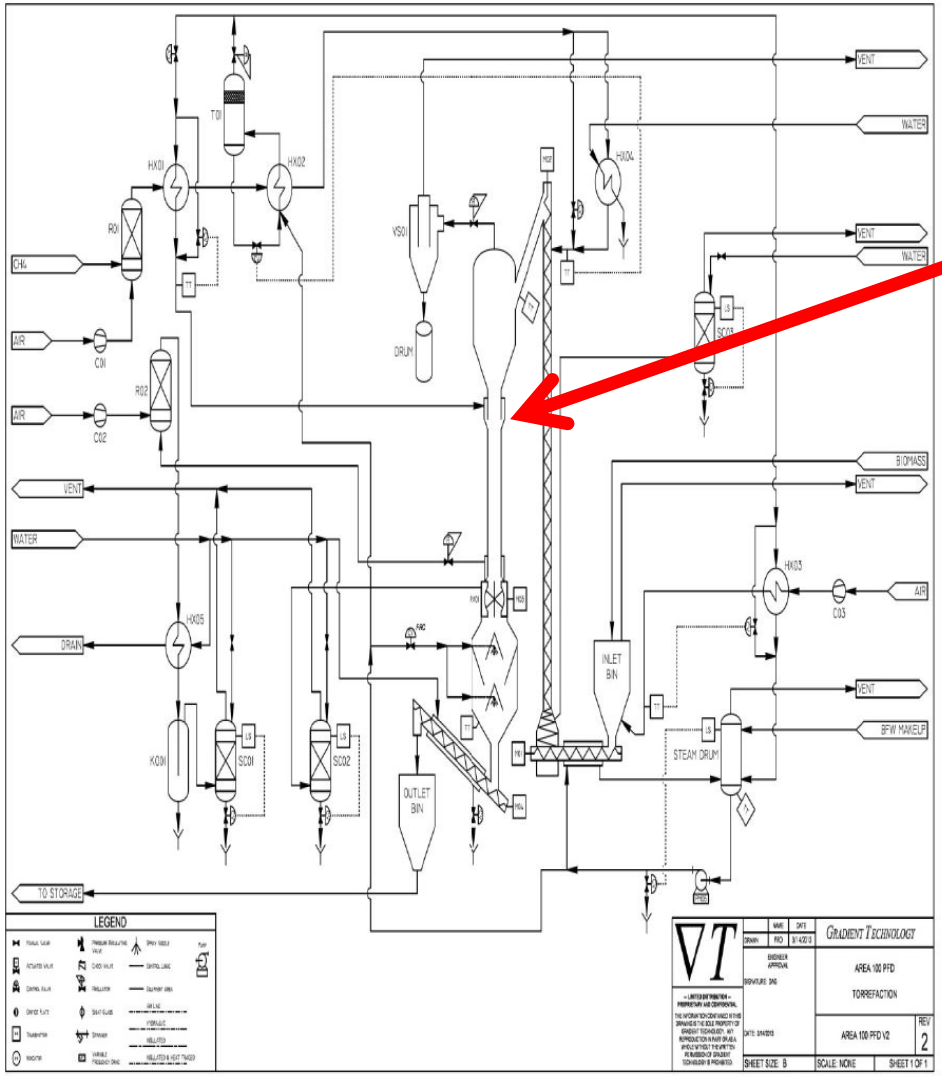
# Moving Bed and Boiler Generator Program - Funded by Xcel RDF Fund

- Sustainable Rail to Construct an advanced Boiler/Generator System to Produce 100 kW Using Porta Design from Argentina
- Syngas Technologies to Construct a Moving Bed Torrefaction System (3 t/d capacity) and Erect system at CMRL
- NRRI to operate both systems to demonstrate viability at Renewable Energy Center Using Fuels Produced from woody Biomass and Moving Bed System and Produce Electricity that will be sent to grid

# Basic Design of Boiler Generator – can supply heat and power



# Demonstration Scale Moving Bed Design




**Vertical Design to Use Gravity Material Movement**

**Current NextGen Program Verifying Concept at Pilot Level ~ $523k**

Pilot Machine at Gradient Technology Used as Basis for Design


**Pilot Scale Moving Bed Torrefaction System**

# Construction and Commissioning/Demonstration Activities

- Boiler/Generator – Built at Twin Cities Location, Tested and Commissioned, then Moved to CMRL
- Moving Bed Reactor – Built in Elk River and then erected at CMRL
- Grid Connection at CMRL with System Operations at same site to Produce Electricity Using Produced Fuel and Boiler/Generator
- Demonstration for 7 day Period

# Summary

- Various developments are being undertaken to convert biomass to a more concentrated energy and chemical product
- Concentration of energy and chemical constituents should enable conversion of forest products and herbaceous materials into various value added products
- NRRI/UM has made strategic investments to allow demonstration of the technologies at scales that should help lead to full commercialization
- Adoption of the techniques can be facilitated with new funds for engineering support and facility and logistical planning
- Conversion of similar plant materials around the world can be demonstrated if financial support is provided

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