Torftech Energy

POWER GENERATION FROM RICE HUSK

CHALLENGES AND SOLUTIONS




October 2016

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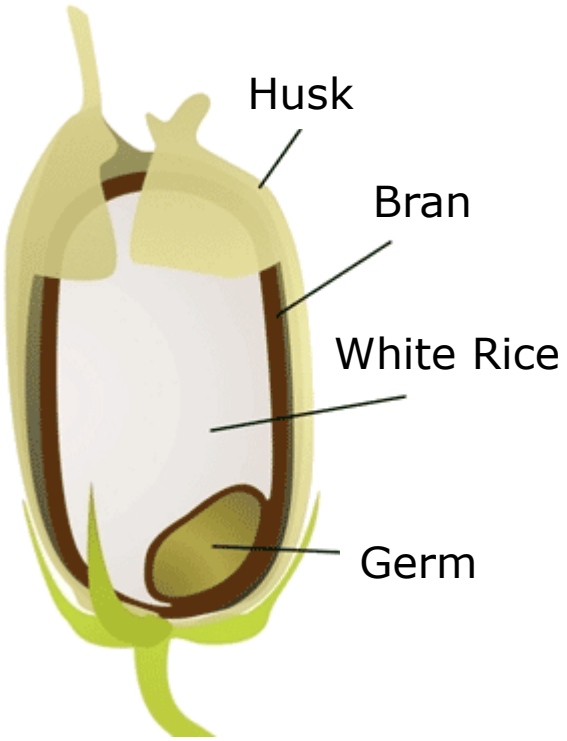
Section I

Rice Husk Fuelled Generation

Rice Husk Fuelled Generation

Introduction

- World paddy rice production is forecast to be ~745.5 million tonnes per annum in 2016.*
- Of this, ~675 million tonnes will be produced in Asia.
- Rice husk accounts for ~20% of paddy rice production by weight.
- Much is treated as a waste and either thrown into rivers or put to landfill, often creating pollution problems as it decays or simply returned to the fields where it can become airborne.
- Some is combusted or gasified to produce heat or power……at current rice production levels, there is enough husk to support up to 10GW of low carbon generating capacity.
- ~20% by weight of rice husk is ash.
- Unless the process of combustion or gasification is very carefully controlled, this ash is highly carcinogenic and if put to landfill, returned to fields or just left lying, will impact those who breathe it in.
- If combustion is carefully controlled, the ash has value.



Source: UN FAO

Rice Husk Fuelled Generation

The Issues

Processing rice husk requires accuracy. Correctly used, rice husk is a fuel with a value added ash. Incorrectly used, the ash is carcinogenic and possibly a fire hazard

Correctly Processed ✓ → Very low carbon free amorphous silica ash which has application and market value in the cement and other industries

Incorrectly Processed X → A light, crystalline silica ash which is carcinogenic*

OR

Carbon contaminated amorphous silica, which is useless and can be dangerous to dispose of

OR

A mixture of both

The great proportion of rice husk power or heat generators, large or small, are not accurate and produce carcinogens, often in significant quantities

**See WHO International Agency for Research on Cancer*

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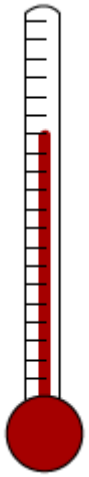
Rice Husk Fuelled Generation

Process Challenges

Rice husk is fragile and needs accurate processing

Too high a temperature or too long a time at heat → **Crystalline Silica Ash**



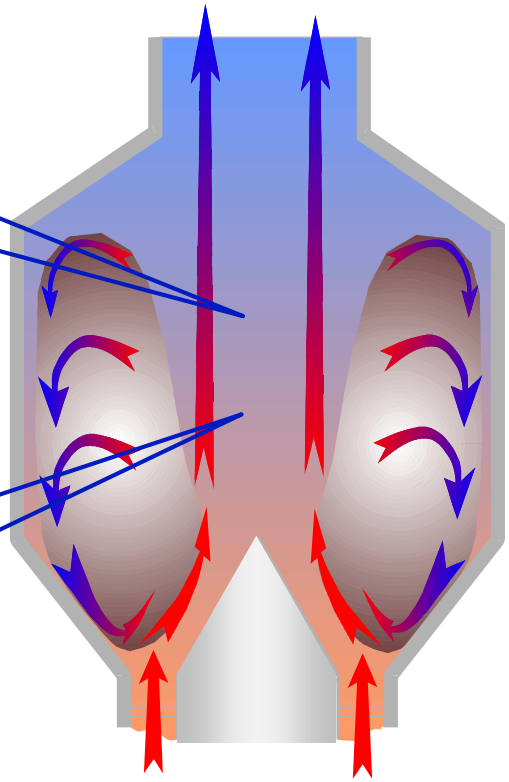
Too low a temperature or too little time at heat → **Carbon Rich Ash**

Rice Husk Fuelled Generation

The TORBED Expanded Bed Reactor and Rice Husk

Close temperature control (830°C±~5°C) avoids crystalline ash formation and permits sufficient residence time to burn out carbon

Ash tested by independent laboratories and shown to be free of measurable crystalline ash and also to contain minimal residual carbon



The TORBED reactor provides a scientifically verified, referenced route to safe distributed biomass fuelled generation from rice husk.

It also provides a value added by-product; amorphous silica which has a wide range of potential industrial uses.

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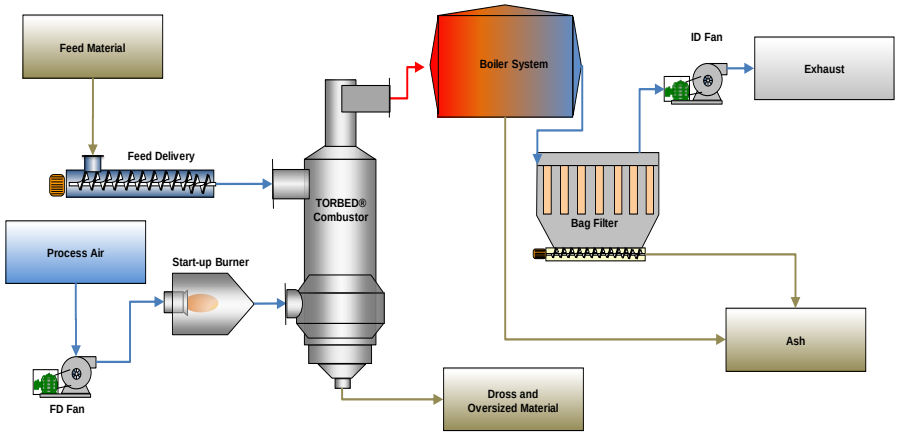
RICE HUSK FUELLED GENERATION

TORBED Reactor Economic and Operational Parameters



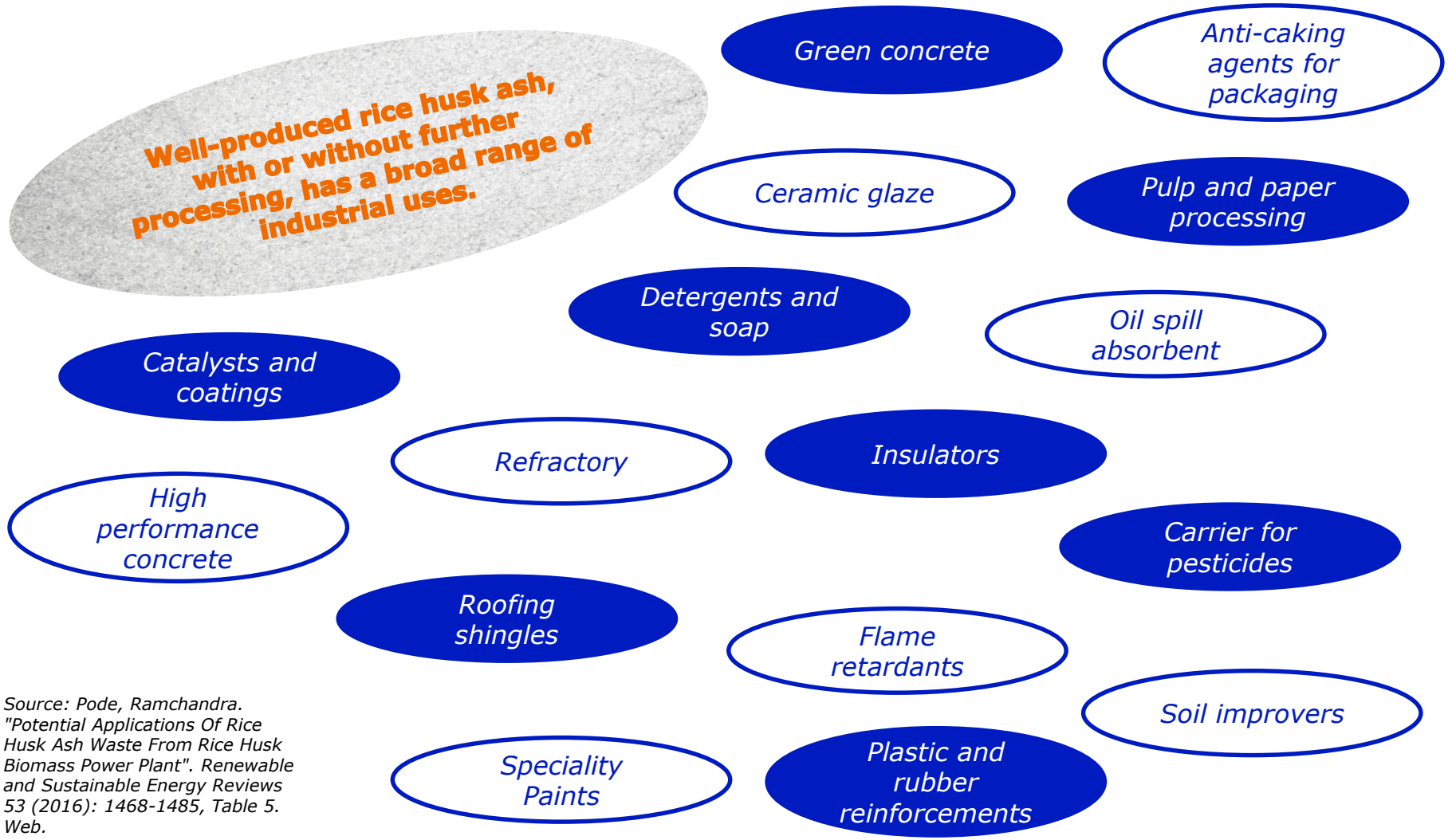
Schematic of the TORBED combustor/boiler circuits from a power plant

- Ideal plant size range 2-10MWe (although smaller prototypes down to 50kW are in final stage development and testing).
- Economies of scale reduce cost per MW for larger plants.
- Ideal for distributed generation projects in areas where rice husk is plentifully available.
- Requires ~1 tonne of rice husk per MWh.
- Depending on specific rice husk characteristics, will produce amorphous ash at the rate of ~17-20% of fuel used.
- Reference plant operating in Cambodia.
- Further plants under development in Vietnam: the first has an offer of debt financing from Malaysian Exim Bank.

**Estimates subject to adjustment for individual project requirements and exclusive of EPC, civil and interconnection costs.*

RICE HUSK FUELLED GENERATION

Uses of Well Processed Rice Husk Ash



Source: Pode, Ramchandra. "Potential Applications Of Rice Husk Ash Waste From Rice Husk Biomass Power Plant". Renewable and Sustainable Energy Reviews 53 (2016): 1468-1485, Table 5. Web.

Appendix 1

References and History

Rice Husk Combustion References: Angkor Bio Cogen

- Initial rice husk-fired combustion plant based in Cambodia and completed in 2011.
- Owned and operated by Angkor Bio Cogen Limited.
- Sited 23 kilometres from Phnom Penh.
- Capacity of 2MWe.
- Financed under the Clean Development Mechanism pursuant to the Kyoto Protocol; financing administered by the UN Framework Committee On Climate Change as project number 363

View into the vortex of ABC's TORBED EBR as it combusts rice husks

- Validation report procured by UN from Den Norske Veritas Certification Ltd available on the UNFCCC website.
- Four independent operational monitoring reports also available on UNFCCC website.
- Power is now sold to the local grid.

Transportable Rice Husk Combustion

- In late 2015, TEL was approached by the Japanese company Yanmar, which was looking to produce a transportable paddy drier fired by rice husk and which would reliably produce amorphous rather than crystalline ash, a point of significant CSR concern to Yanmar.
- The objective set for TEL was to design a small scale unit that would be capable of being transported and perhaps of containerization in the medium term.
- This prototype unit, based on a 75cm diameter EBR, completed factory acceptance tests in September 2016 and is due to start field trials in November 2016.
- The unit produces approximately 350kW$_{th}$.
- Subject to success of the field trials, it is intended to bring the unit into production in the first half of 2017.
- Ash tests from commissioning runs show the silica to be amorphous.
- Consideration is being given to the coupling of this scale of Torbed combuster to an organic Rankine cycle generation system in order to produce a very local rice-husk fired CHP generation system as an alternative to diesel generation.

TORBED Reactor History

No TORBED, properly used, has ever been the subject of mechanical or structural failure within its design life

- First commercial sale in 1985.
- 169 units sold, of which key concentrations have been:
  - 41 for waste processing,
  - 60 to the food processing industry, and
  - 17 for vermiculite manufacture and processing

  with the balance being used in highly-customized, one-off applications or for research.
- TORBED reactors have a design life in excess of 25 years.
  - The oldest currently operational TORBED reactor was installed in 1989 and has been in continuous operation, subject to routine maintenance, since that time.
- In excess of 5,000,000 fleet operating hours of which more than 1,000,000 are on waste-related applications.
- Correctly operated and maintained, based on the data available to Torftech, they have historically attained availability figures of 90-95% depending on the application and the detailed design of the individual TORBED reactor.

TORBED Heat and Power References

Client	Application	Year	Status	Country
Combined Heat and Power				
Ecocycle	Gasification of waste wood for power and heat generation	2012	Detailed operational data not available	UK
Angkor Bio Cogen	Combustion of waste rice husk to fuel CHP	2011	In its fifth year of operation, load following client rice mill with no reported availability problems	Cambodia
Heat Generation				
MZEC	Gasification of biomass and waste to fuel a district heating system	2010	Operating satisfactorily on a batch process basis owing to feedstock availability restrictions. No reported technical availability problems	Poland
Remijn	Gasification of general and wood waste to produce industrial process heat	2006	Ran continuously for four years until the host plant was closed in 2010	The Netherlands
Atlantic Packaging	Combustion of paper sludge to produce industrial process steam	2006	No detailed operational/availability data available	Canada
PSC	Rice husk combustion to produce process heat for a rice mill	2003	Detailed operational data not available	India
Komeco	Combustion of waste wood to produce industrial process heat to dry fertiliser	1999	Two reactors ran on a continuous basis for five years until the host plant was closed in 2004	The Netherlands

References and History

TORBED General Waste References

Client	Application	Year	Status	Country
	Waste treatment			
CET	Zeolite drying for sewage sludge dewatering	2012	Detailed operational data not available	China
SAPPI	Use of waste process heat to dry paper sludge for disposal	2004	Has run continuously, subject to scheduled maintenance, since installation	The Netherlands
Aura Metallurgie	Removal of waste to enable recovery of metals from spent catalysts	2001	Has run continuously, subject to scheduled maintenance, since installation	Germany
Heijmans	Recovery of aggregate by combusting used asphalt	2000	Detailed operational data not available	The Netherlands
Shell	Removal of waste to enable regeneration of spent catalyst	1997	Has run continuously, subject to scheduled maintenance, since installation	US/Luxembourg
RTZ/Comalco	Gas scrubbing to remove Hf and other pollutants from waste process gasses	1997	6 TORBED Reactors have run continuously, subject to scheduled maintenance, since installation	Australia
RTZ/Sumitomo	Gas scrubbing to remove Hf and other pollutants from waste process gasses	1996	13 TORBED Reactors have run continuously, subject to scheduled maintenance, since installation	New Zealand
Comalco	Burn off of Carbon and cyanide from spent aluminium smelting pot liner	1986-1994	2 TORBED Reactors have run continuously, subject to scheduled maintenance, since installation	Australia

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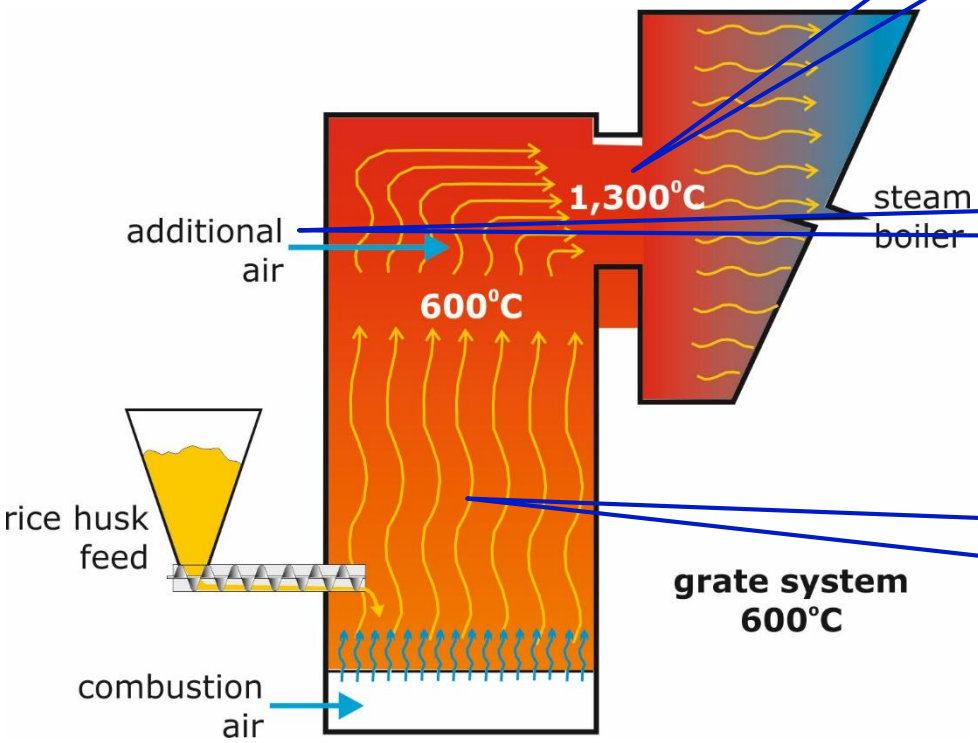
Appendix 2

Issues with Other Generation Approaches

Issues with Other Generation Approaches

Conventional Grates

Conventional Grates are widely used not only in power generation applications but also for heat at a range of scales from domestic to industrial



Introduction of additional air increases combustion temperatures but at 1300°c, formation of crystalline silica ensues rapidly

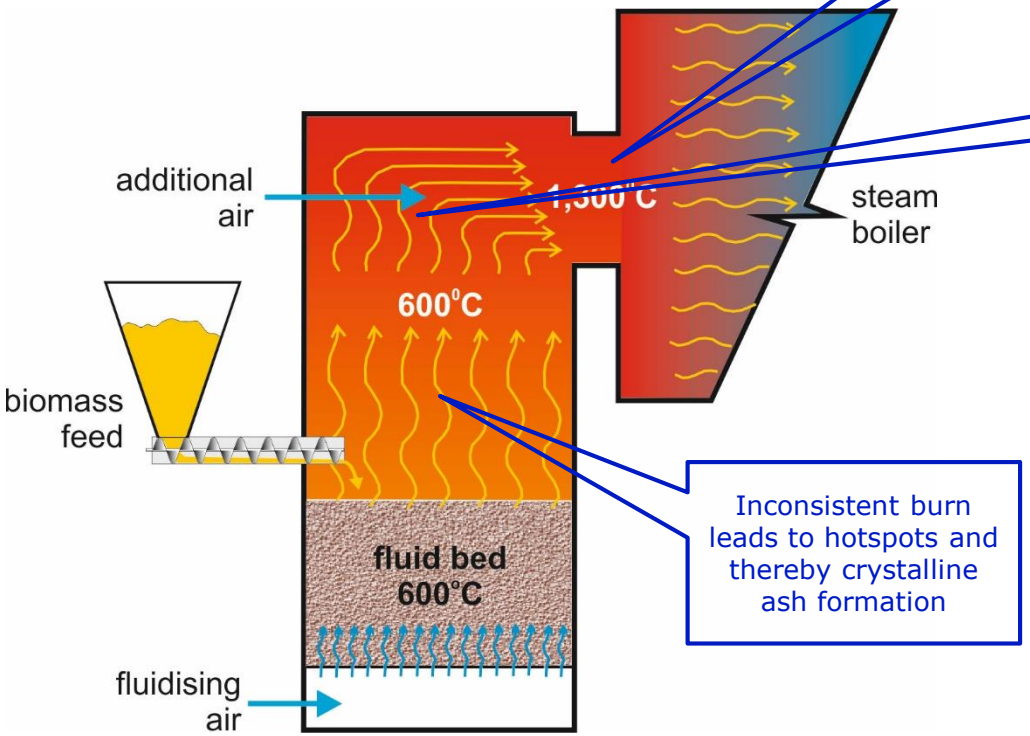
With less or no additional air, carbon burnout is incomplete

Inconsistent burn leads to hotspots and thereby crystalline ash formation

Issues with Other Generation Approaches

Fluidised Bed Combuster

Sand-based fluidised beds are widely used in South Asia as an alternative to conventional grates but suffer from similar challenges



Introduction of additional air increases combustion temperatures but at 1300°c, formation of crystalline silica ensues rapidly

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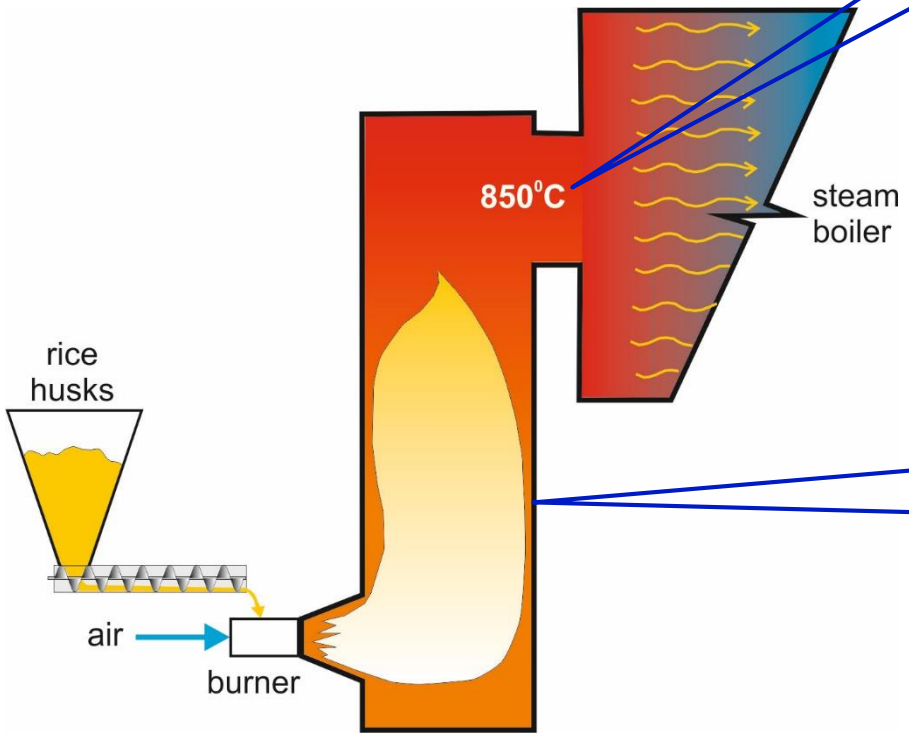
Inconsistent burn leads to hotspots and thereby crystalline ash formation

Note. This process is frequently referred to as gasification. Technically it is not. Volatiles are driven off from the rice husk in the fluid bed and then combusted. For gasification to occur, these complex hydrocarbons would need to be cracked to form a syngas.

Issues with Other Generation Approaches

Suspension Fired Combuster

Feeding ground rice husk into a suspension fired burner offers greater temperature control



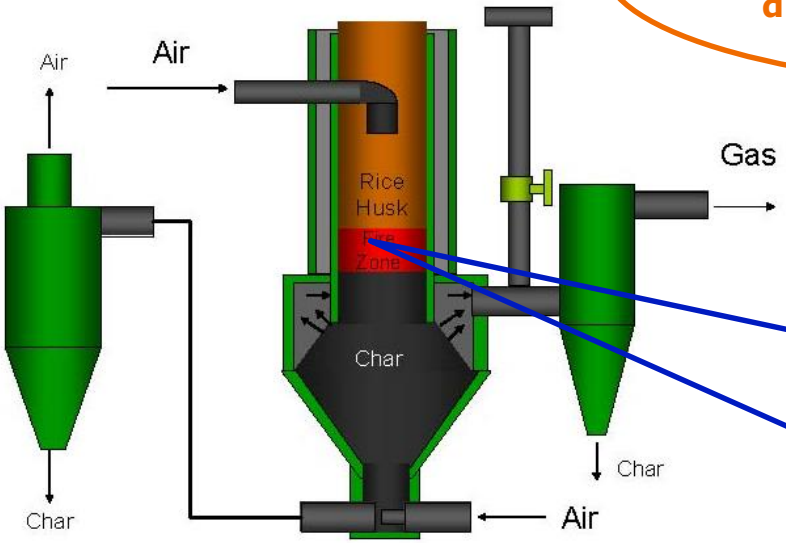
Accurate temperature control avoids formation of crystalline ash but results in incomplete carbon burnout

In theory height could be increased to complete carbon burnout but this creates challenges in terms of space required, high-temperature structural engineering and cost

Issues with Other Generation Approaches

Gasification

The high gas pressure loss through a bed of rice husks in a downdraft gasifier make it a difficult process to operate and control



Poor temperature control in and across the bed allows very high temperatures to be generated in 'hot spots' thus producing crystalline ash or indeed silica slagging which prevents the gasifier from operating