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Challenges and Opportunities of Slow Pyrolysis Reactors

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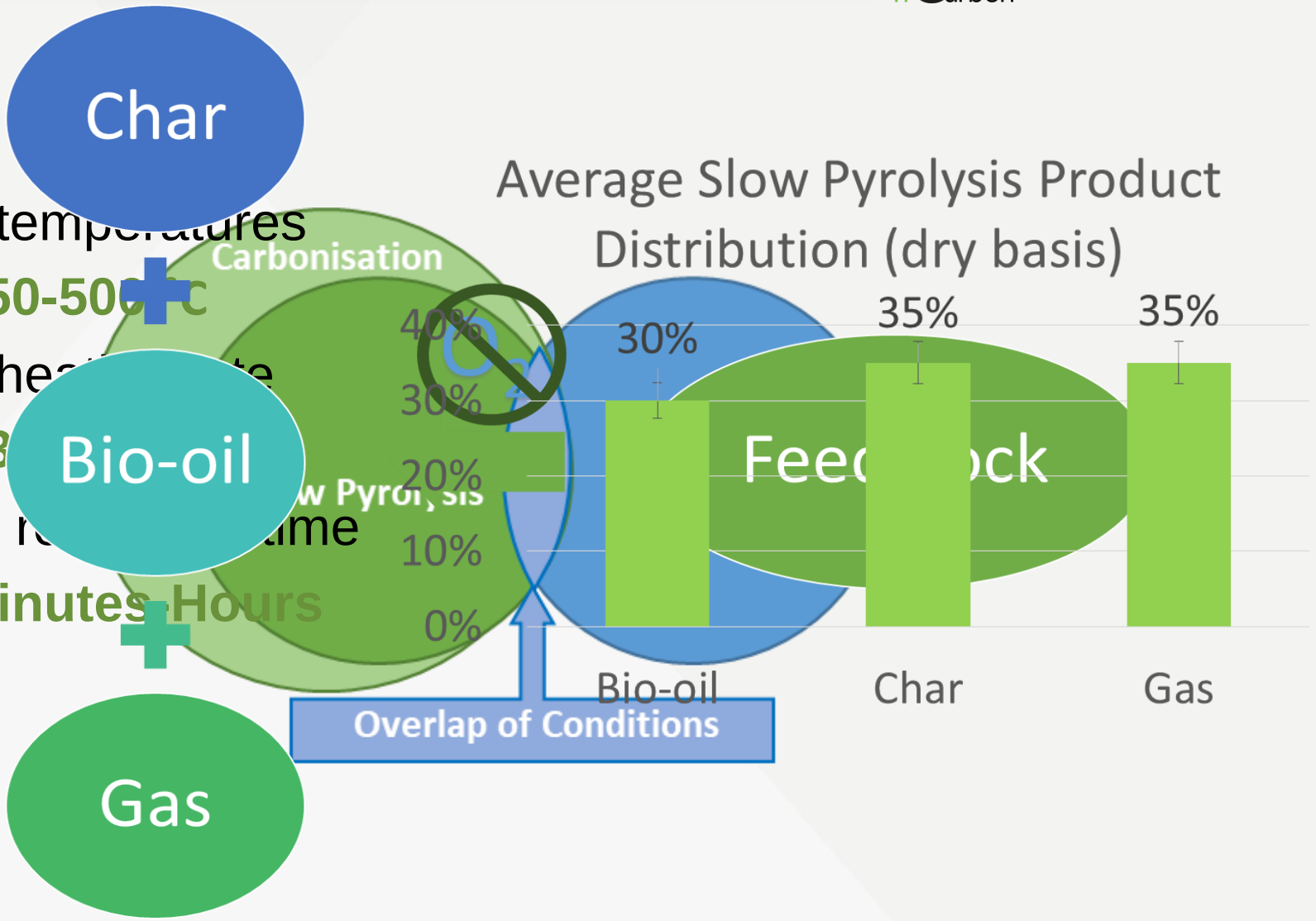
Agenda

- Slow Pyrolysis
- Char
- Slow Pyrolysis Reactors
  - **Batch**
  - **Semi-Continuous**
  - **Continuous**
- Criteria for the selection
- Challenges and Opportunities
- Conclusions

Slow Pyrolysis

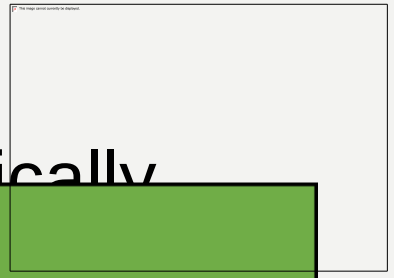
- Low temperatures
  - **350-500°C**
- Low heating rate
  - **<3**
- Long residence time
  - **Minutes-Hours**



Char

- Porous
- Rich in carbon content
- Stable biologically and chemically
- Diff

Crushed Char



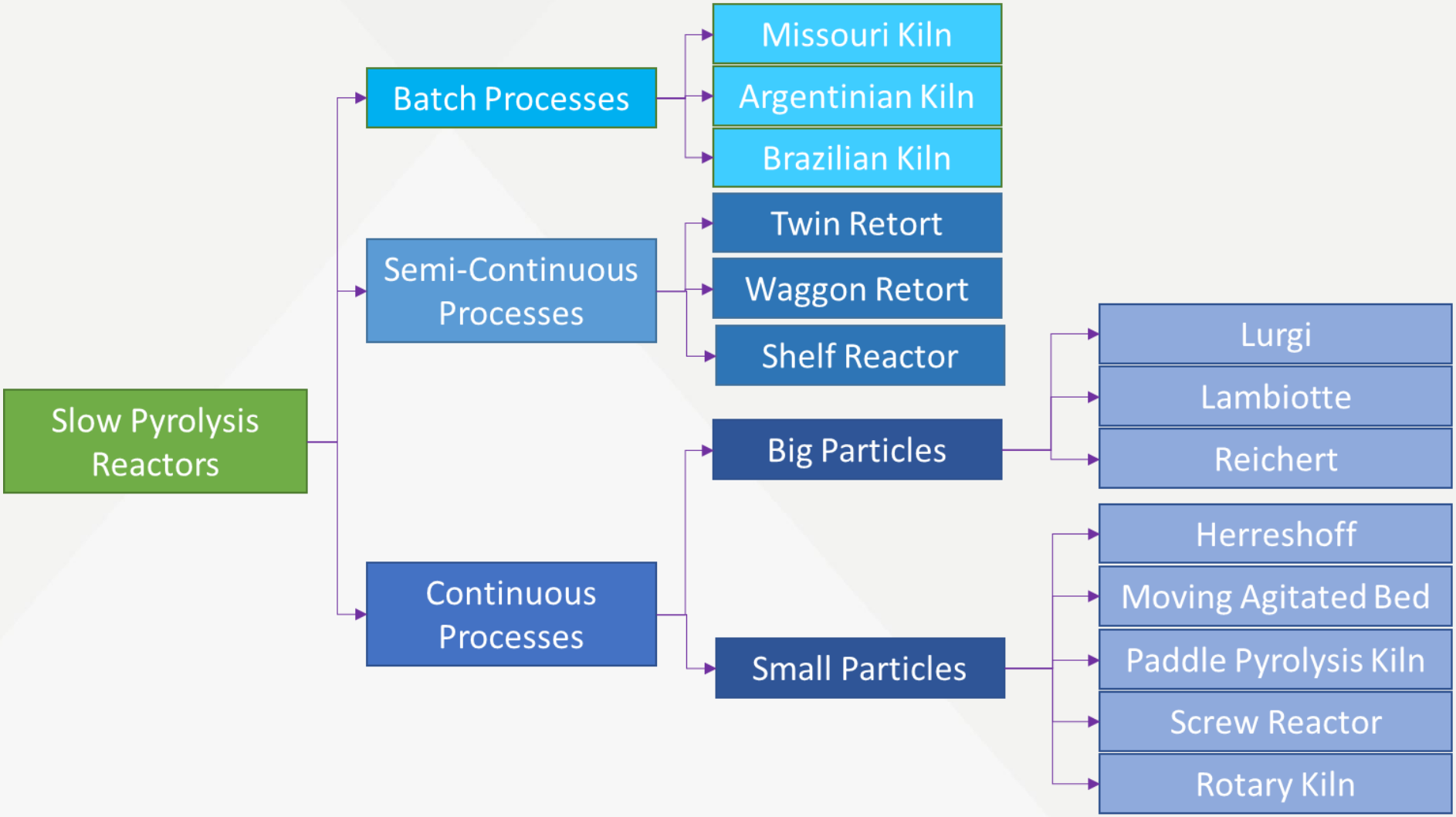
Char Pellets

- **Smelting and sinte[illegible] of iro[illegible]s**
- **Water and gas purification**
- **Soil remediation**

Typical HHV

Substance	HHV [MJ/kg]
Char	30.0-34.3
Natural Gas	52.2
Bio-oil	20-28
Gasoline	43-46
Pyrolysis Gas	5-10

Slow Pyrolysis Reactors

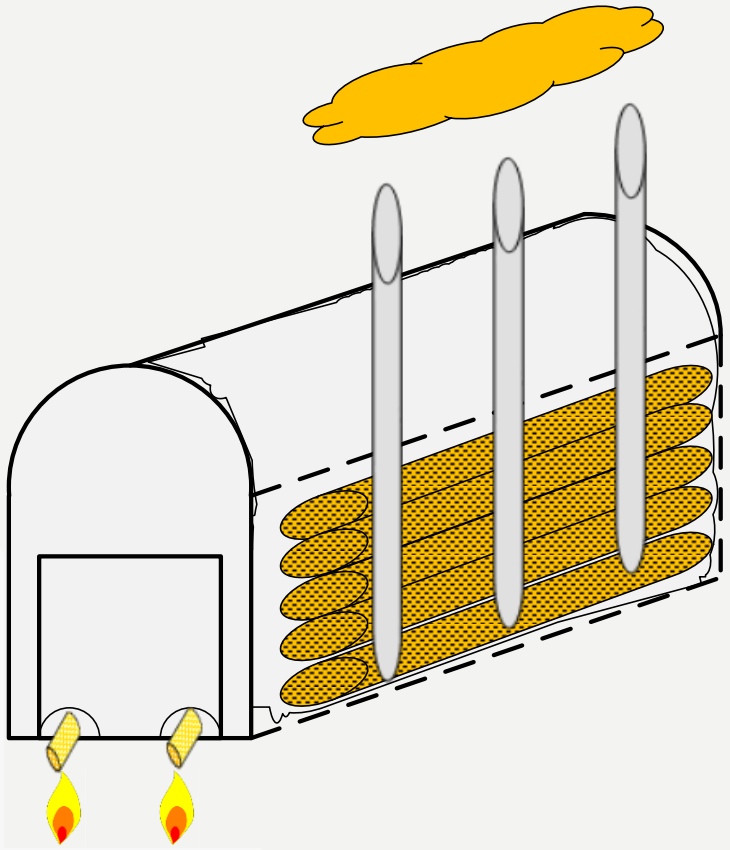


Batch Process

Missouri Kiln

- Simplest technology
- Used since ancient times
- Reactor volume: 4-350 m^3
- Long operation time
  - **25-30 days per batch**
- Low char yield
  - **5-20 wt.%**
- Flexible on feedstock
- Relative low CAPEX
- Low process control

Missouri Kiln

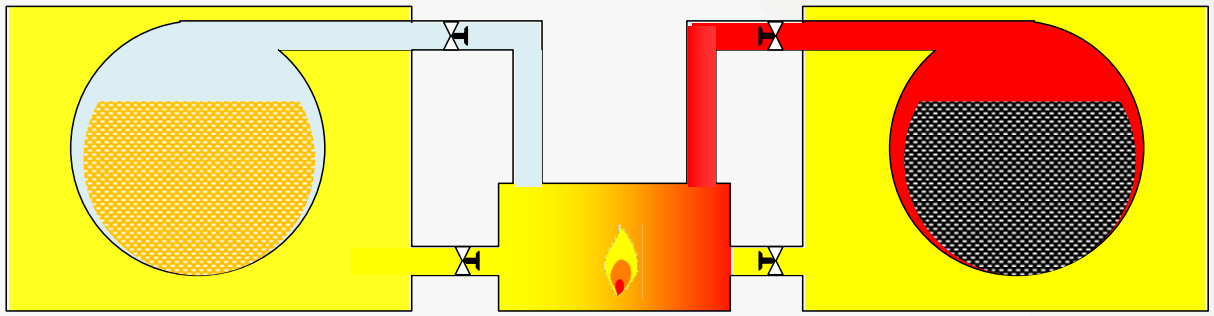


Semi-Continuous

Twin Retort

- 8-12 hours of operation per vessel + cooling time
- Different capacities: 4.5 – 16.5 m^3/vessel
- 30-32 wt.% char yield
- It can produce up to 7,000 char tons per year
  - **12 vessels**
  - **3 workers per shift**
  - **24-hour basis**

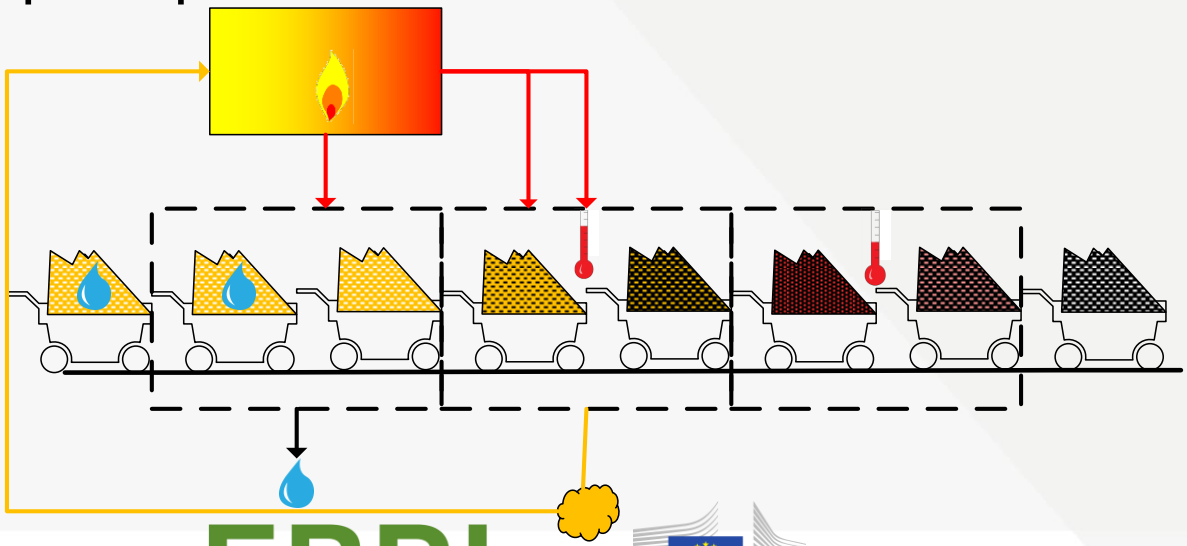
Carbo-Twin Retort



Semi-Continuous

Waggon Retort

- Tunnel (45 m long) divided in three chambers
  - **Drying, pyrolysis and cooling**
- The wagon cycle varies from 25 up to 35 hours
- One plant can produce 6,000 tons of char per year
- Perforated steel walls
- Same principle as Shelf Reactor



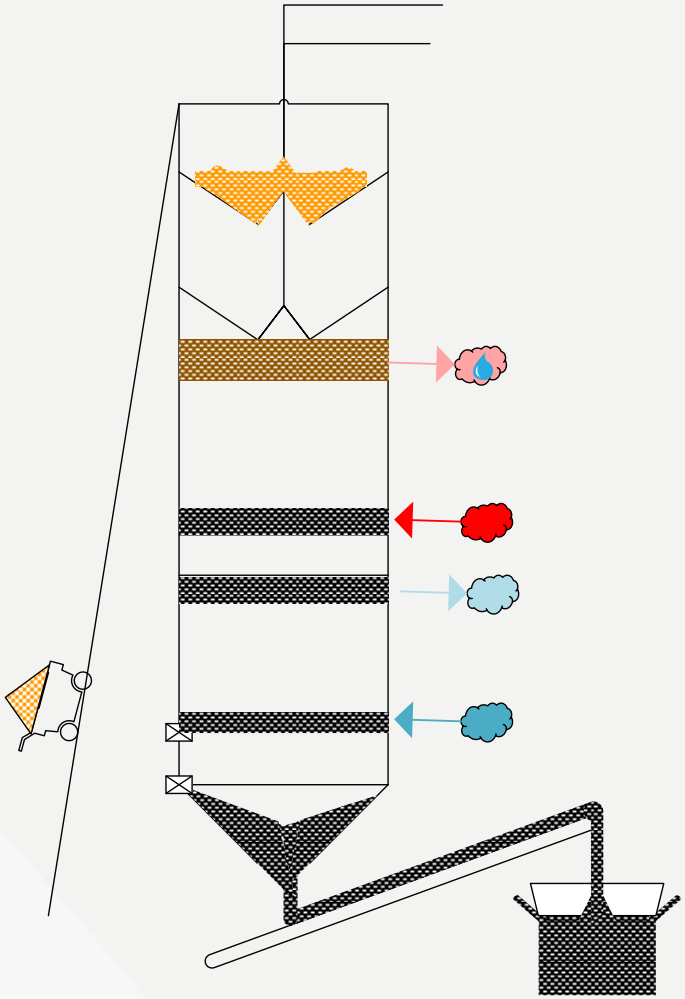
Continuous

- Continuous feeding and operation
- Higher CAPEX
- Need of external source of energy
- No portable
- Higher char yields
- Higher product quality
- Recovering of by-products
- Heat provided from one of the products
- Size difference
  - **Logs**
  - **Pellets**

Continuous

Lambiotte

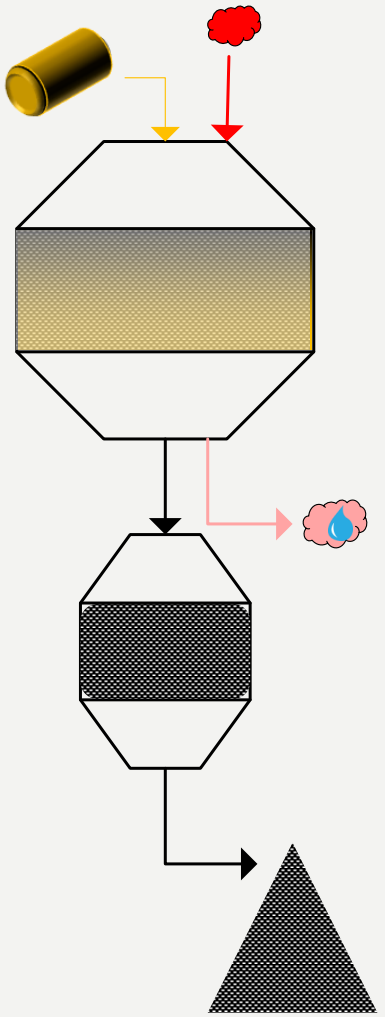
- Two variants, SIFIC and CISR
  - **Difference on pyrolysis vapours treatment**
- Limited by the moisture content (<25 wt.%)
- Divided in hearths
  - **Drying→Pyrolysis→Cooling**
- Counter-current flow of inert hot gas
  - **Dry the wood**
  - **Increase the temperature**
- Cycle: 11 hours
- Acetic acid recovery
- High Char Yield
  - **30-35 wt.%**



Continuous

Reichert

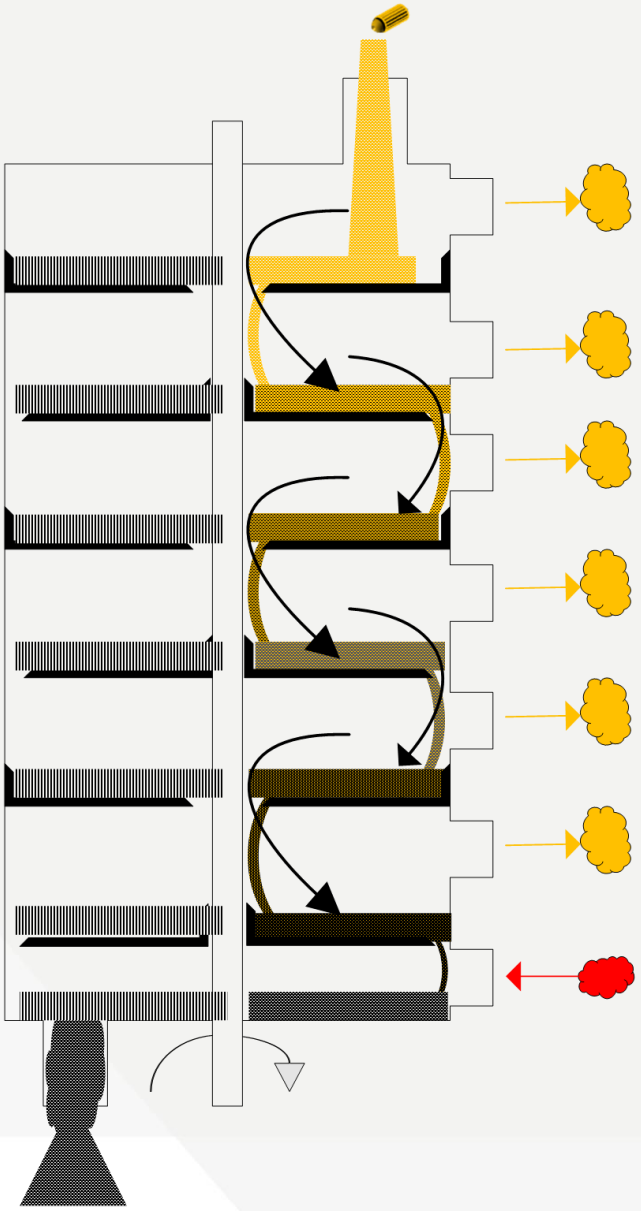
- 100 m^3 volume reactor
- The cycle takes from 16 up to 20 hours
- Carbonisation moves down slowly to bottom
- Gases entering at 450-550 °C
  - **70,000 annual tons beech wood capacity**
  - **24,000 annual char tons production**
  - **500 annual tons of acetic acid**



Continuous

Herreshoff

- Several circular hearths
  - **4-10 hearths**
- Rotating shaft with paddles
  - **1-2 rpm**
- Goes to next hearth from the side and the middle
- Process temperature 500-600 °C
- Char yield is 25 wt.%
- Handle a wide variety of materials
- Small particles→ Char needs briquetting



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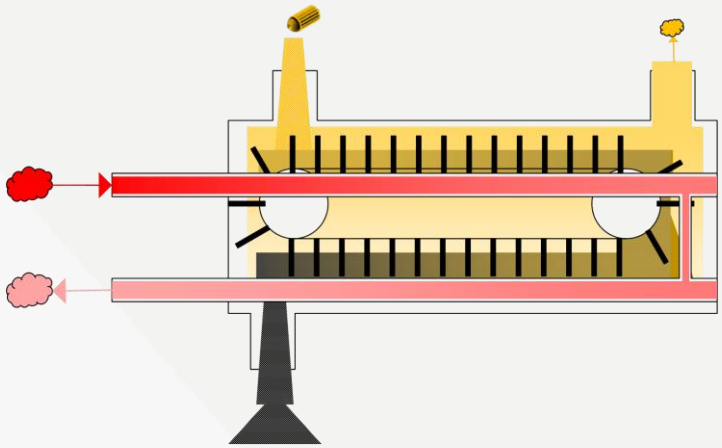
Moving Agitated Bed

- Low height → few cm
- Horizontal heated surface over which the biomass is conveyed
- Heated my molten salts (KNO_3, $NaNO_3$ and $NaNO_2$)
- Bio-oil yield up to 50 wt.%

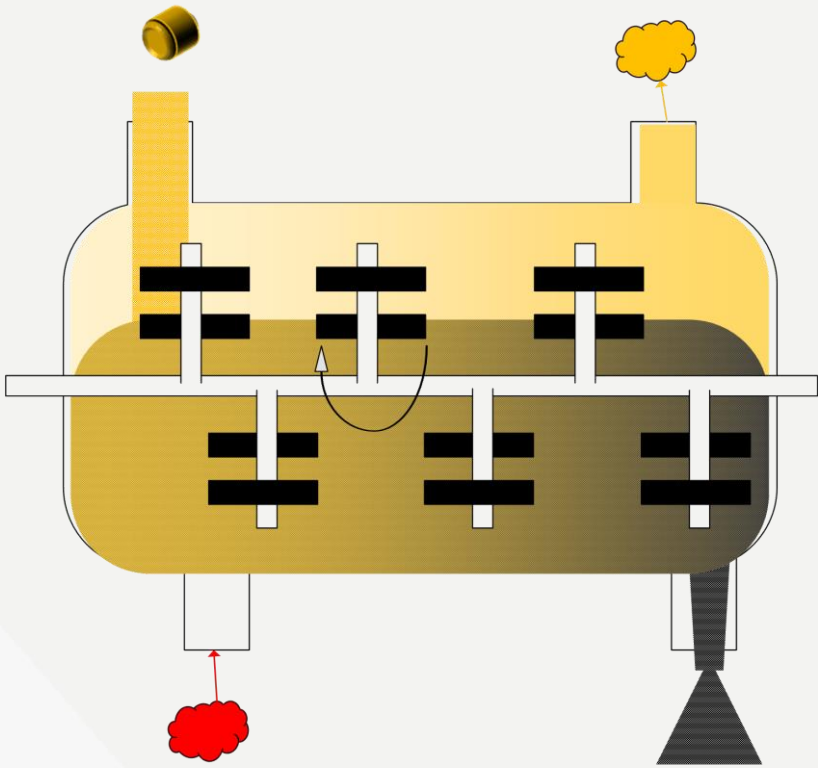
- One pilot plant (3 t/h) was constructed in Saguanay Quebec, Canda
  - **Problems with condensation towers**



Continuous

Paddle Pyrolysis Kiln

- Internal mechanism that moves and mixes the biomass
  - **Paddles increases the heat and mass transfer**
- Flexible process
- Externally heated shell
- It takes some minutes to go through the kiln



Continuous

Screw Reactor

- Screw inside a horizontal reactor
  - **Single or twin-screw design**
- Residence time controlled by the rotation speed
- Heat carriers can be added to increase heat transfer
- Simple and flexible
  - **Char yields: 17-30 wt.%**
- Max. capacity found: 2.1 t/h

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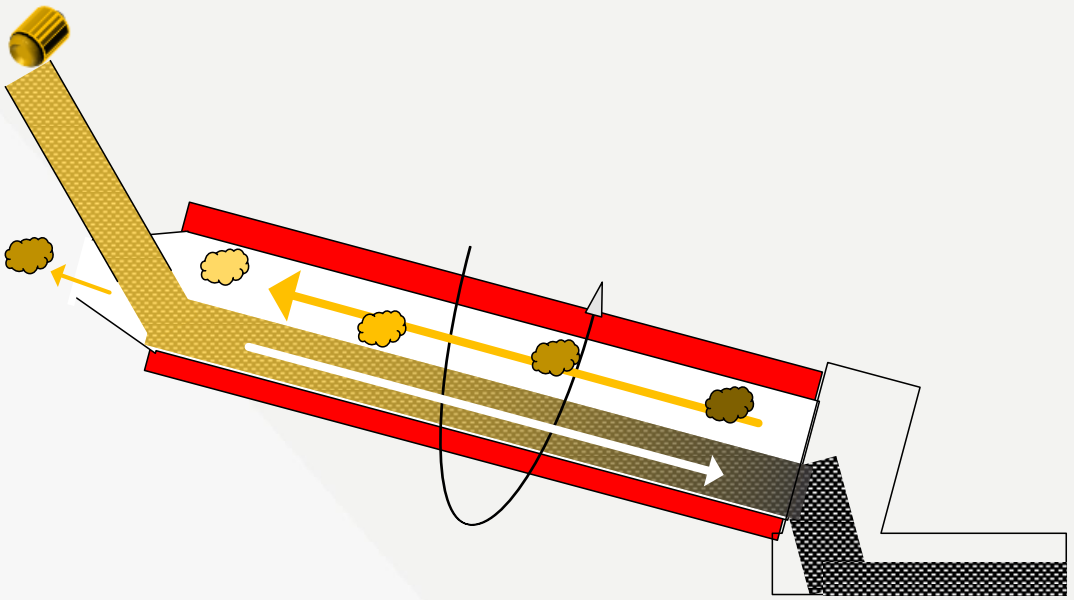
Rotary Kiln

- Residence time controlled by drum angle and rotation speed
- Rotation speed and the radius determines the mixing inside
- Balance between yields
  - **Bio-oil: 37-62 wt.%**
  - **Char: 19-38 wt.%**
- Heated externally
- Up to 12 t/h capacity
  - **3.6 t/h production**



Criteria

- Dimensions
- Position
- Capacity
- Production
- Raw material
- Material Shape
- Temperature
- Pressure
- Pre-treatment needed
  - **Moisture**
  - **Shape**
- Feeding method
- Process Control
- Cycle time
- Targeted Product
- Product Yields
- Heating method
- Portability
- Loading and discharge methods
- CAPEX
- OPEX

Challenges and Opportunities

Challenges

- No preferred method for char production
- Char yield
  - **<38 wt.%**
- Lack of methodology for the design in slow pyrolysis
  - **Heating**
  - **Reaction**
- Biomass can be very heterogeneous

Opportunities

- Many different technologies developed along the time
  - **Different heating methods**
  - **Different configurations**
- Similarities with other industries
  - **Dryers**
  - **Cement industry**

Conclusions

- Char is a promising source of energy
- Each new design has to be selected carefully
- The design has to integrate together
  - **Heat transfer**
  - **Kinetics**
  - **Heating method**
- Further study for a design methodology

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Many Thanks!

Questions?