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Sewage sludge valorization by pyrolysis using a mechanically fluidized reactor

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Sewage Sludge Valorization by Pyrolysis using a Mechanically Fluidized Reactor

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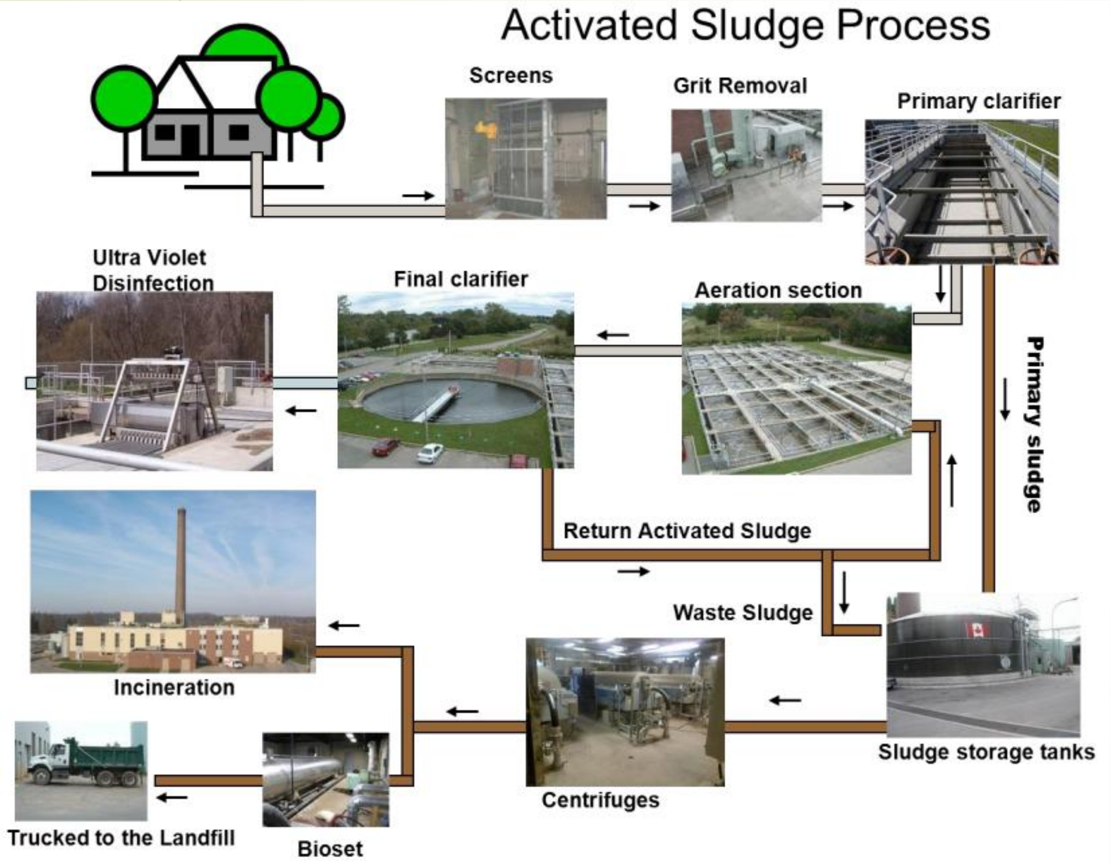
MOTIVATION AND BACKGROUND

- Municipal sewer sludge (bio-solids) **disposal**:
  - Incineration
  - Landfilling
  - Agricultural applications

- No general agreement on most appropriate method

- Our research: utilisation of bio-solids as a **“resource”** for:
  - Energy
  - Chemicals
  - Fertilizers
  - Materials and catalysts
  - Activated carbon

Wastewater Treatment in London, Ontario

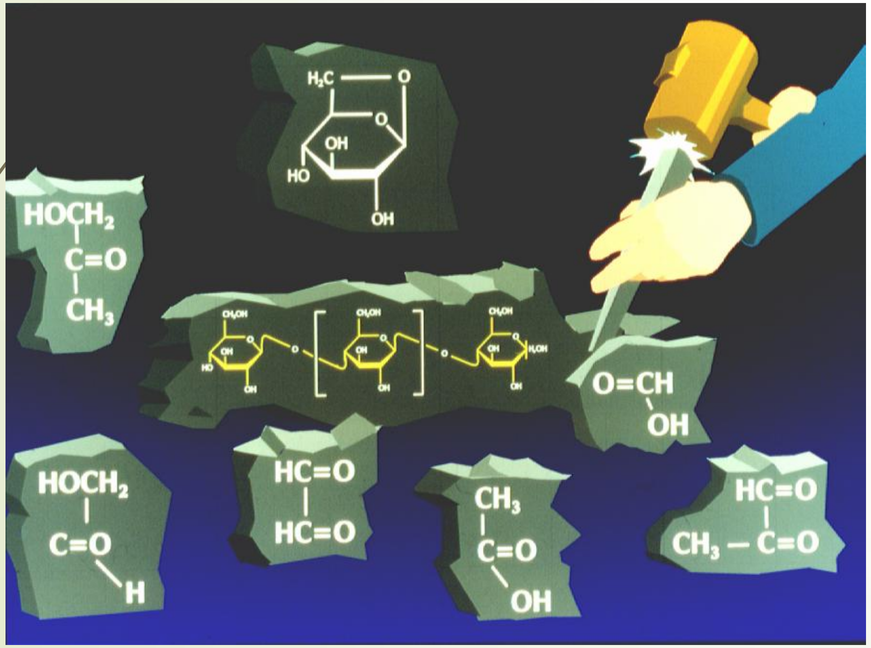


Sludge produced average day	Cubic metres (normalized to 3% solids)
Adelaide	293
Greenway	1,030
Oxford	100
Pottersburg	243
Southland	2
Vauxhall	105

Source: City of London, Environmental & Engineering Services, Wastewater Treatment Operations Division, March 2013

PYROLYSIS

Thermal decomposition (thermal cracking) of organics in inert atmosphere, producing:



Bio-Oil

Char

Gas

PYROLYSIS

Feedstocks: <u>any</u> organic material

Temperature: 450 to 550 ˚C

Processing time: seconds to minutes

Vapor residence times at temperature: ~ 2 seconds

Thermal or **Catalytic**

Reactors: need to provide good heat and mass transfer (i.e. good mixing)

- Gas-solid fluidized beds
- Auger-type of reactors
- Mechanically mixed vessels
- Rotating kilns

PYROLYSIS OBJECTIVES

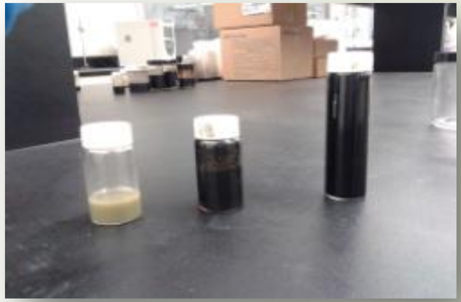
- Reduction in waste volume
- Destruction of pathogens
- Production of energy
- Production of liquid fuels
- Production of value-added chemicals
- Stabilization of metals in solid matrix
- Production of value-added solid char:
  fuel
  reducer for metallurgical processes
  catalyst
  adsorbent (activated)

PYROLYSIS YIELDS

~ **35%** on a db

Char

~ **50%** on a db



Bio-Oil

~ **15%** on a db

Gas

PYROLYSIS PRODUCTS

Bio-oil:

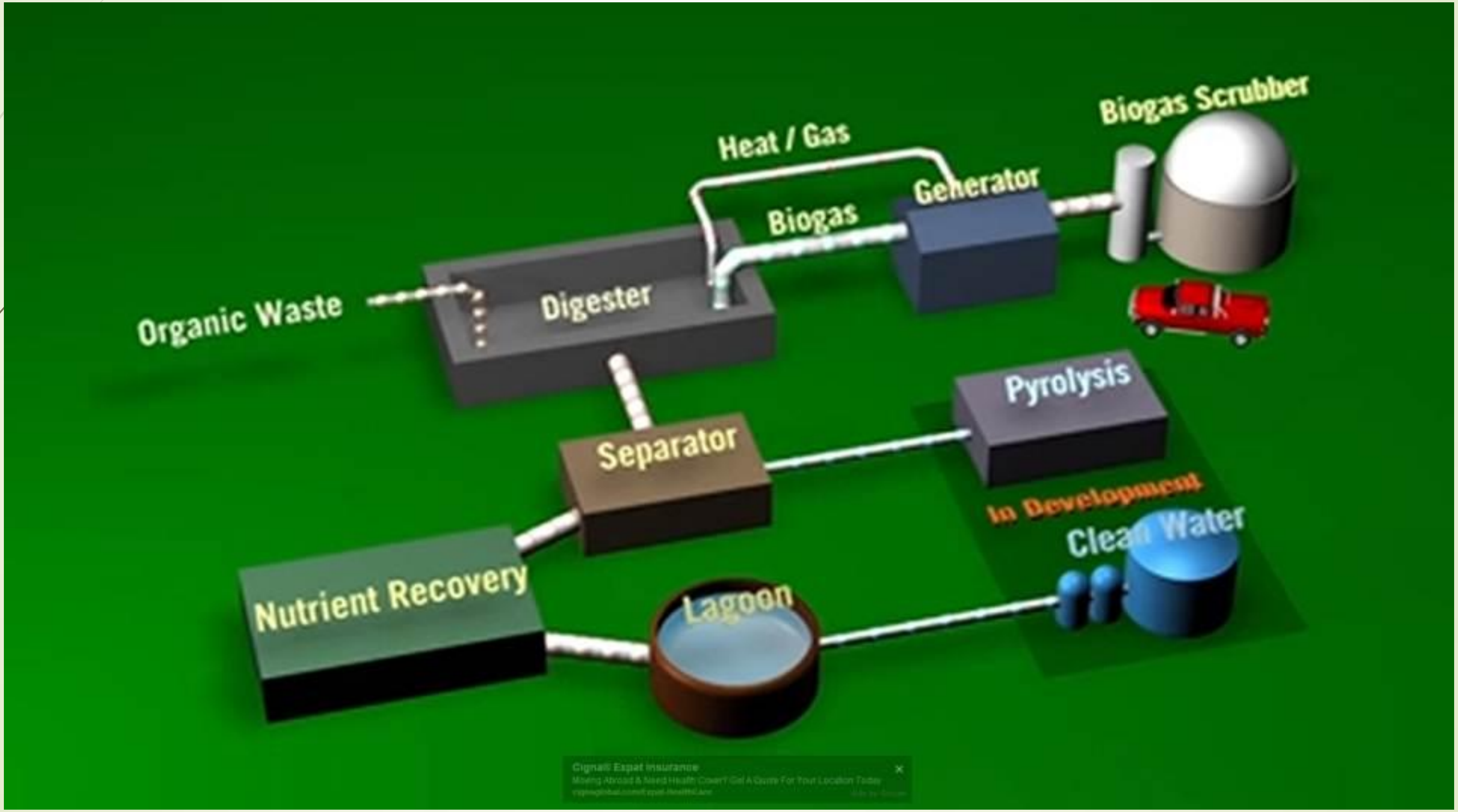
- Dark, brown, low viscosity aqueous and high viscosity organic fractions, basic pH
- Aqueous fraction could become a fertilizer
- Organic fraction could become a fuel oil (HHV > 30 MJ/kg)
- Low metals content
- Alkanes, alkenes, aromatics, carboxylic acids, fatty acids, aldehydes, ketones, phenols, nitriles, amides…..
- Source of pesticides, anti-oxidants..

Char:

- High ash content in a porous carbon matrix
- Metals strongly incorporated as oxides, sulfides, carbonates, alumino-silicates
- Adsorbent with porosity of 5 – 150 m^2/g (can be activated to > 1,500 m^2/g)
- HHV ~ 5 to 20 MJ/kg
- Catalytic properties for H_2S and NO_x removal

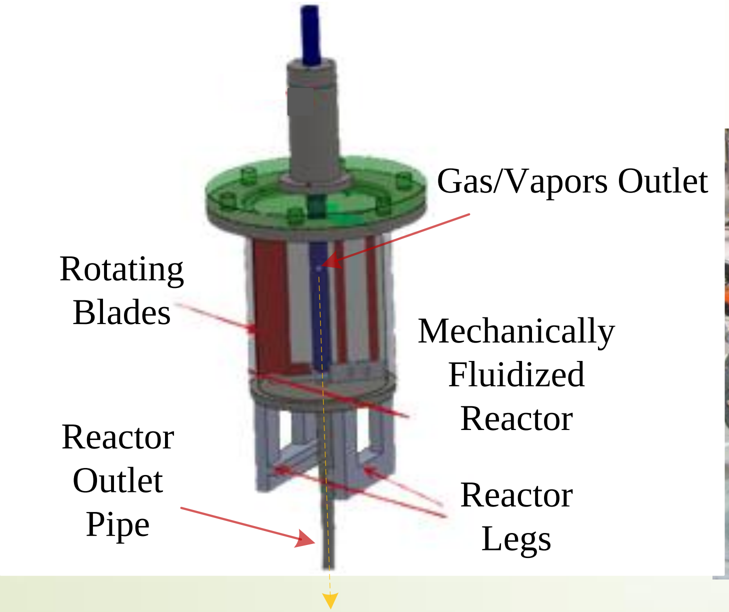
Gas: CO, CO_2, CH_4, H_2,… some N_2O

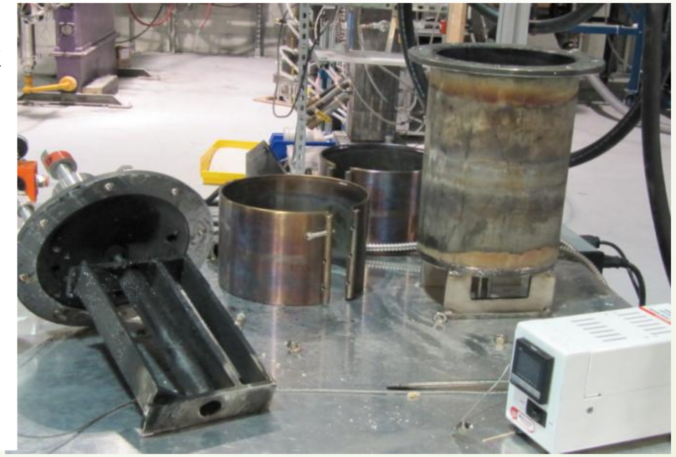
PLANT INTEGRATION



OBJECTIVES

Investigate fractional separation and condensation of pyrolysis vapors produced from bio-solids, using a **bench-scale batch mechanically fluidized reactor (MFR) to achieve products of potential value**

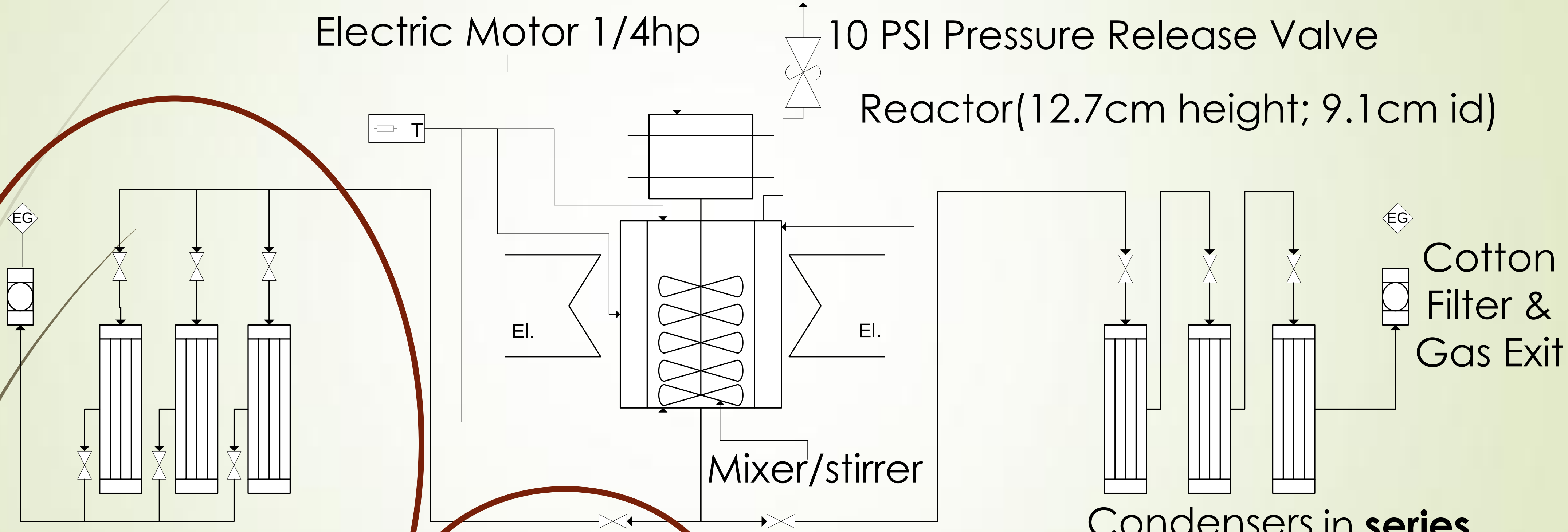




2 L batch MFR

1 t/day continuous MFR

2 Pyrolysis and Condensation Strategies



Condensers in **parallel**

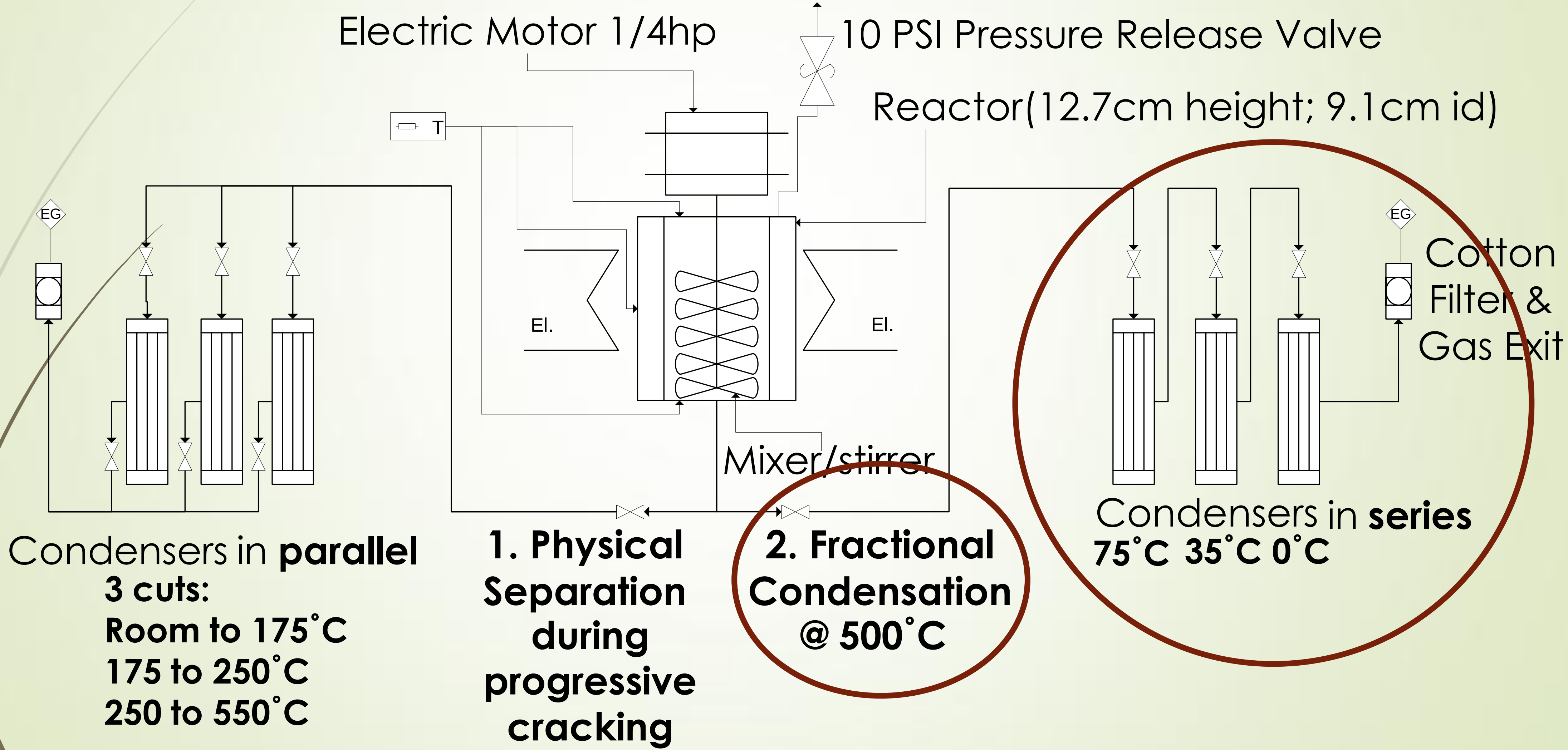
3 cuts:
Room to 175˚C
175 to 250˚C
250 to 550˚C

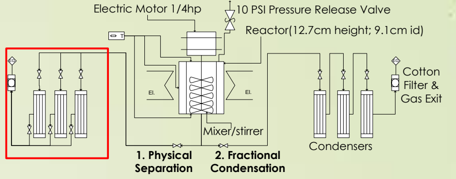
1. Physical Separation during progressive cracking

2. Fractional Condensation @ 500˚C

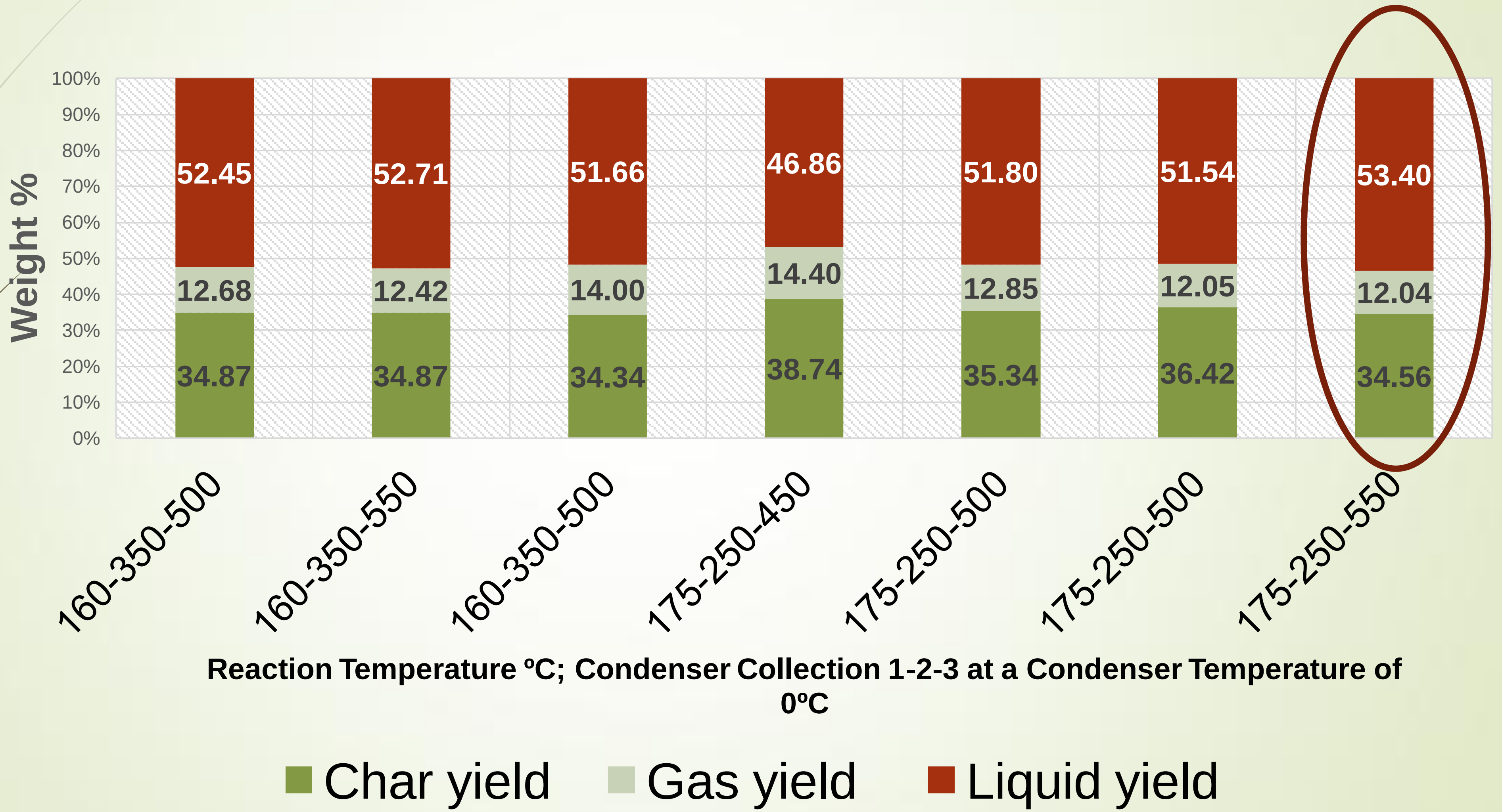
Condensers in **series**
75˚C 35˚C 0˚C

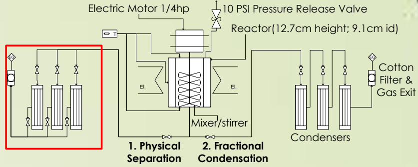
2 Pyrolysis and Condensation Strategies



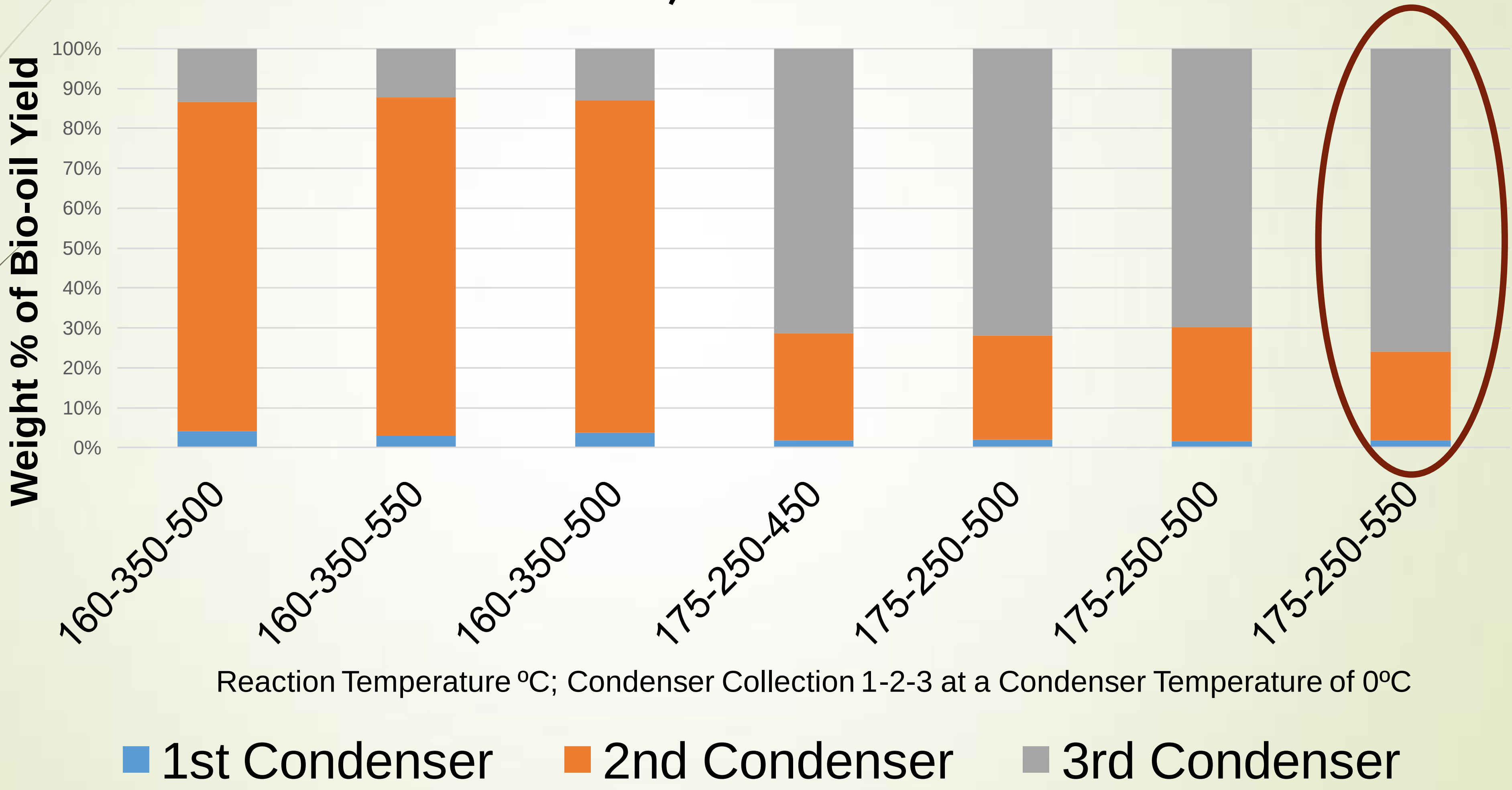


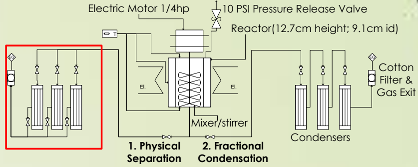
Parallel Scheme: Pyrolysis Yields



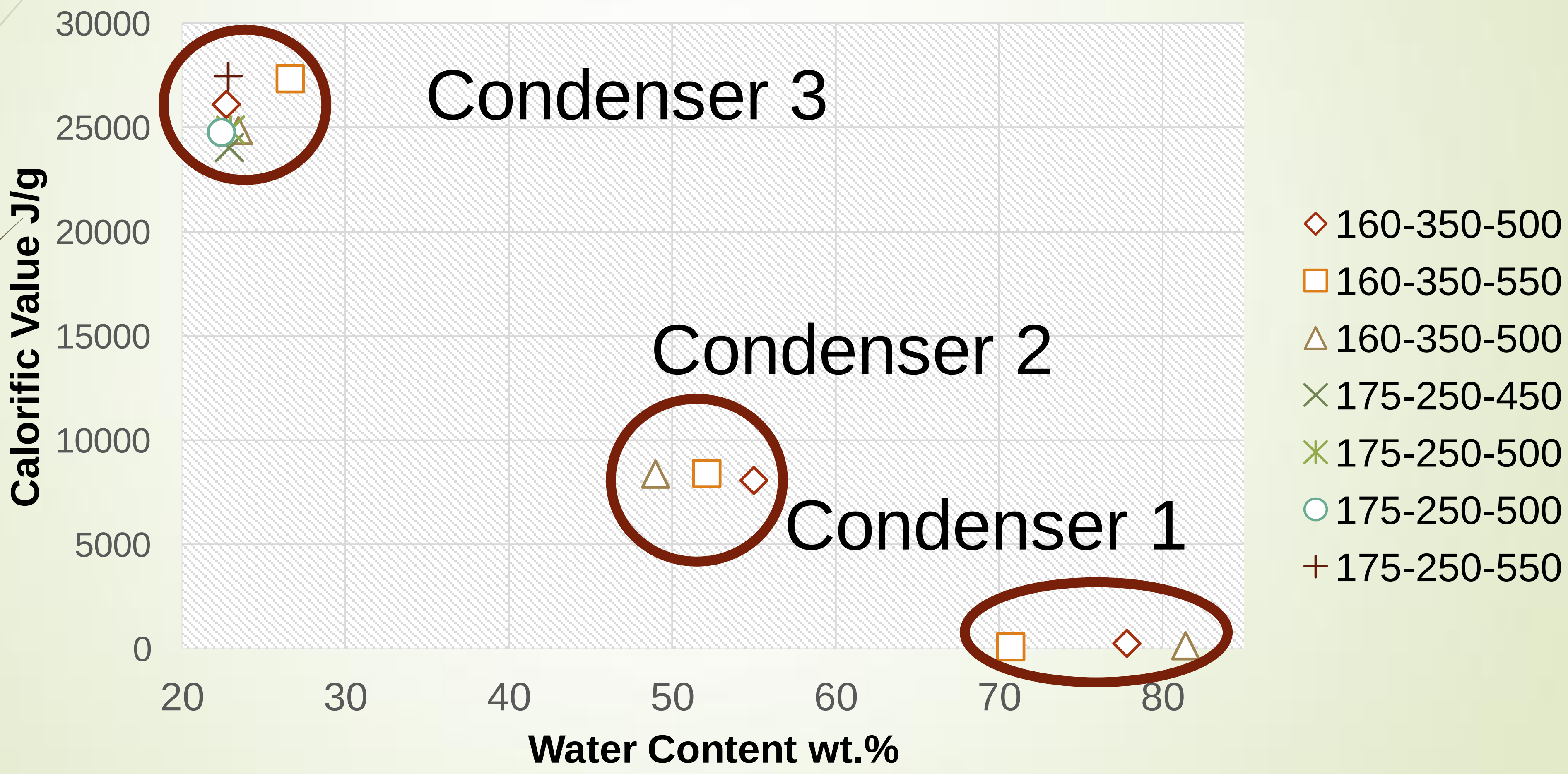


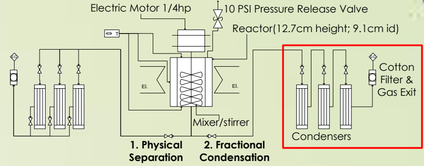
Parallel Scheme - Ratio of Collected Bio-oil in Condensers 1,2 & 3



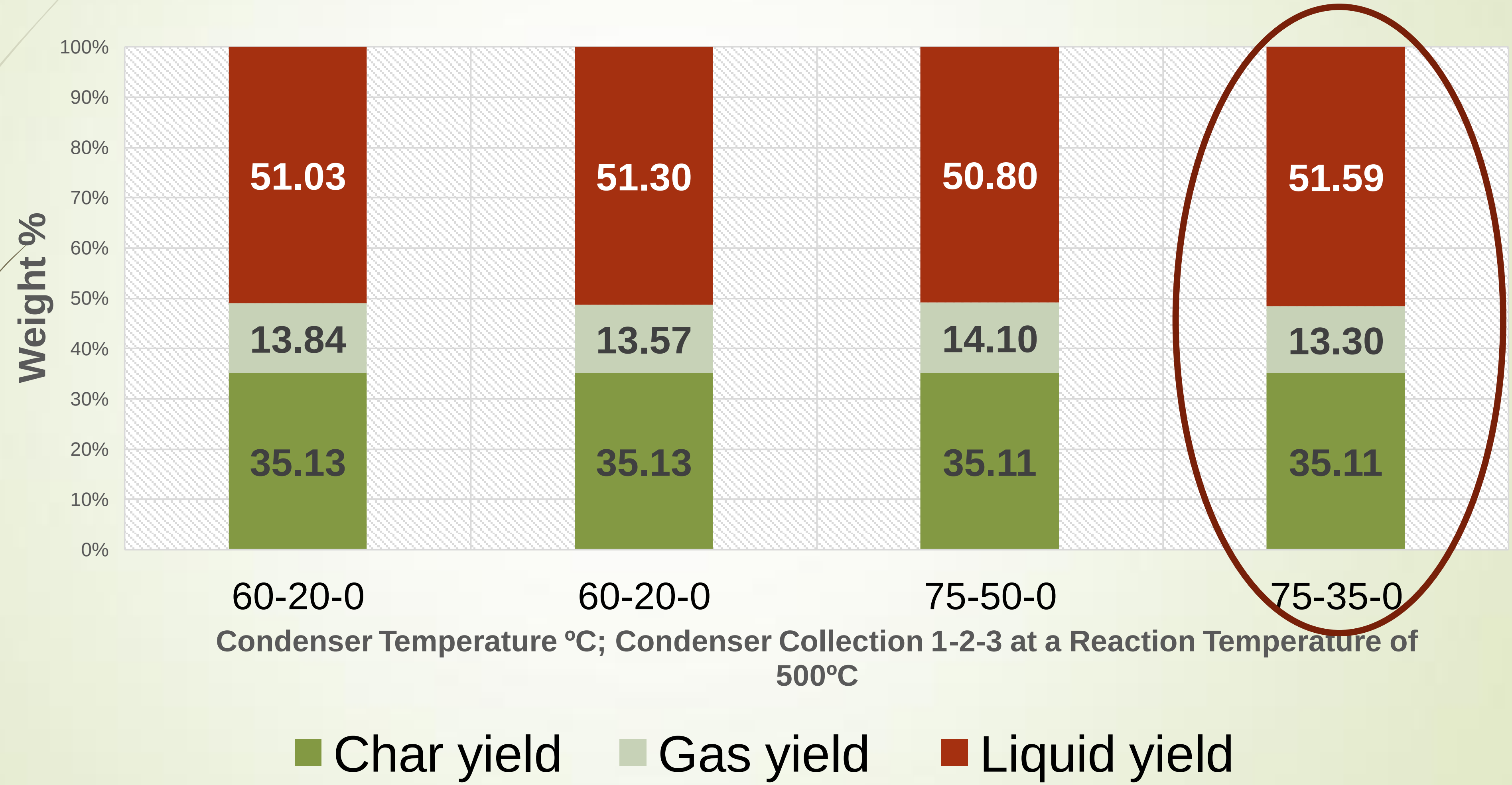


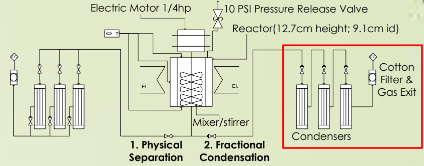
Parallel Scheme - Calorific Value vs. Water Content for Condensers 1,2 & 3



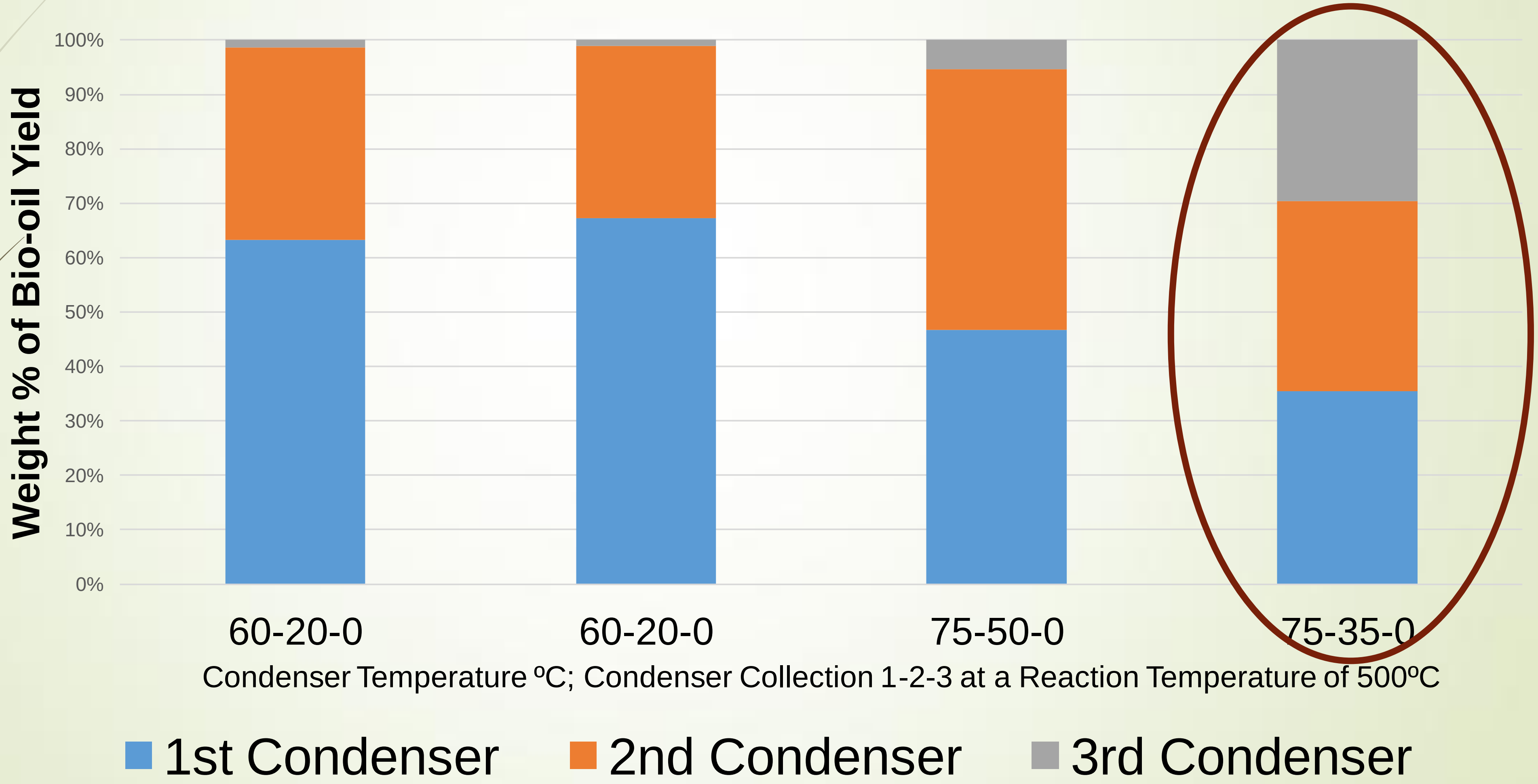


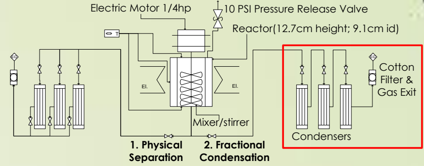
Series Scheme – Pyrolysis Yields





Series Scheme - Ratio of Collected Bio-oil in Condensers 1, 2 & 3





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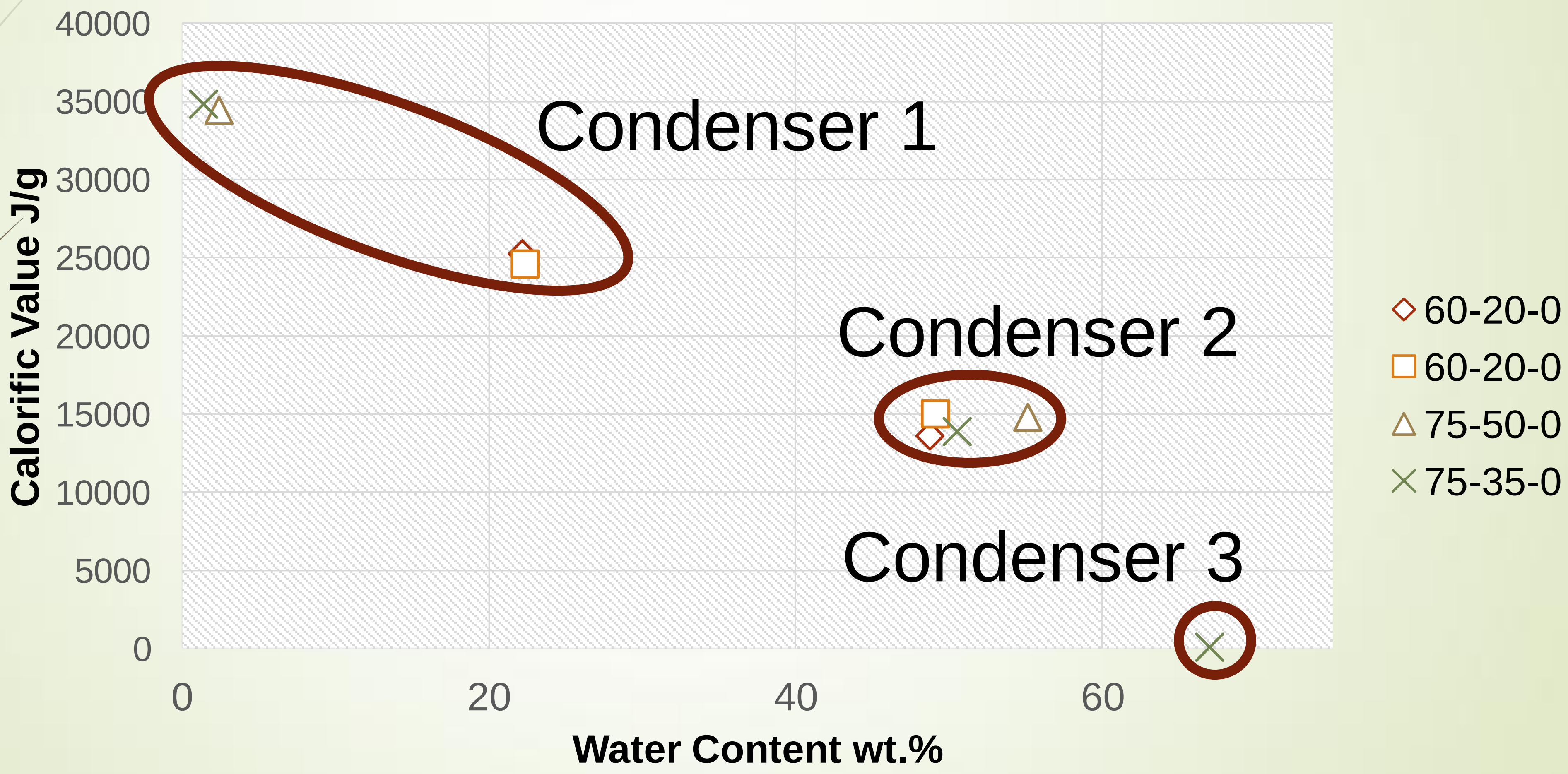
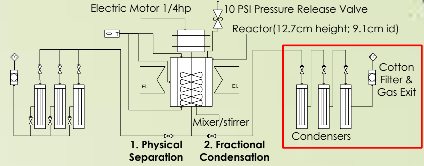
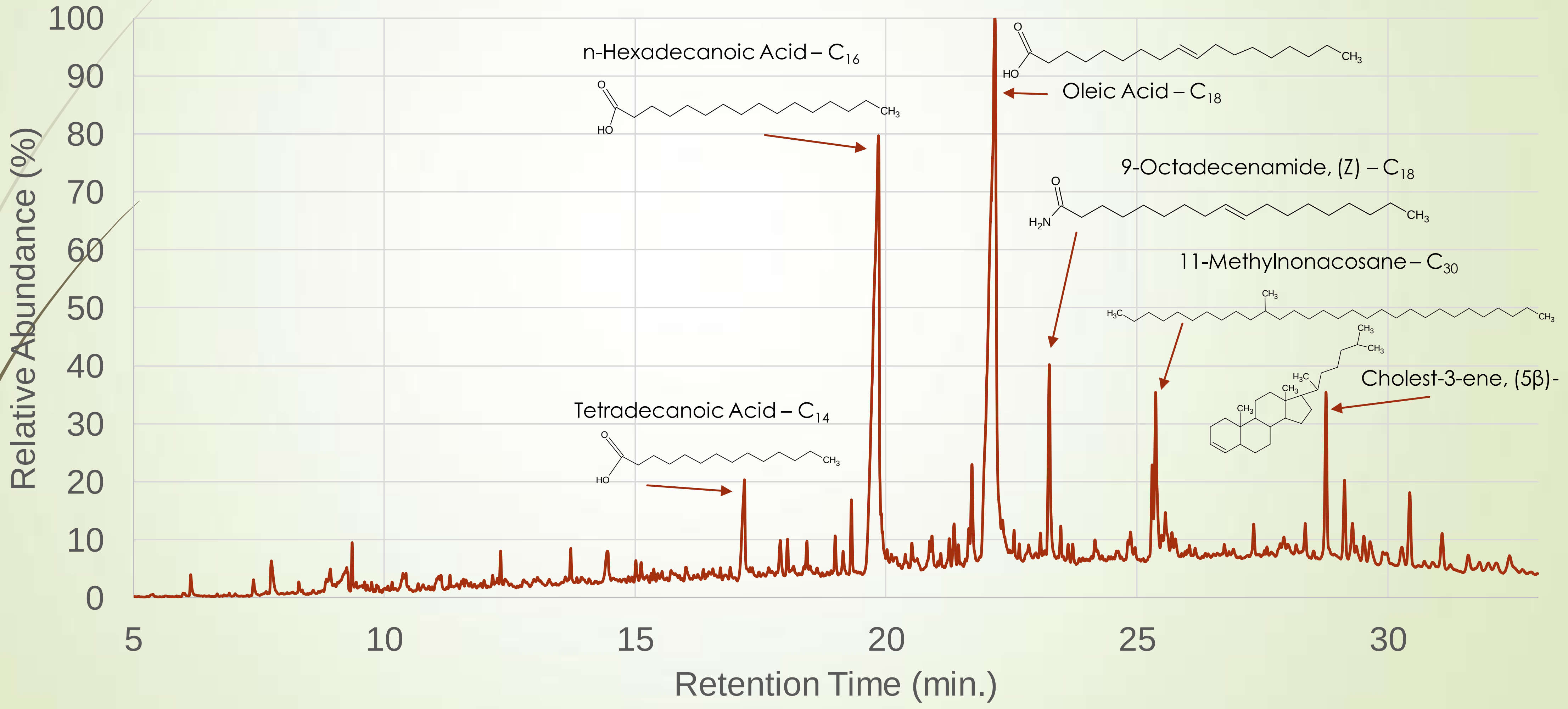


Series Scheme 75-35-0ºC

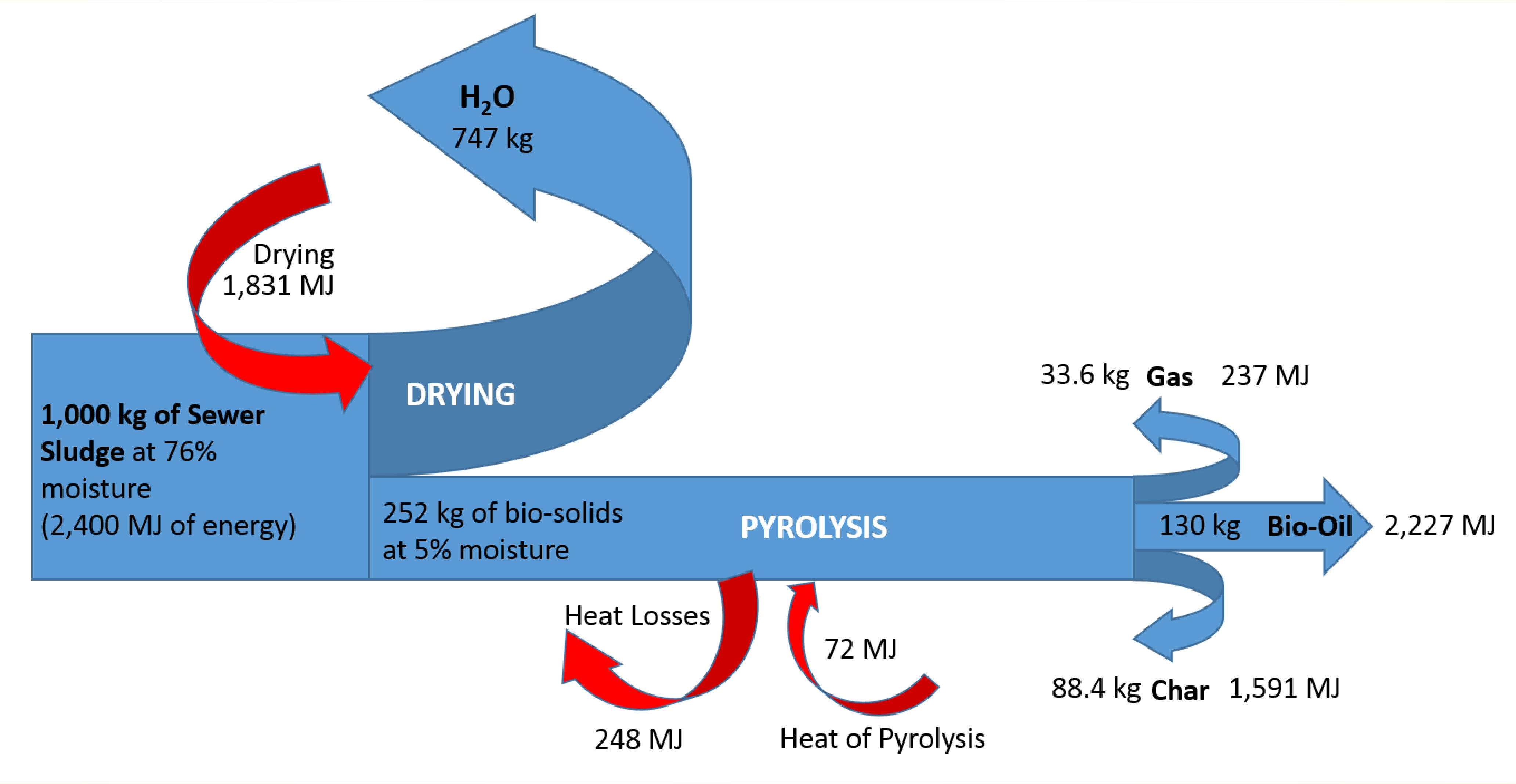


Bio-oil Analysis

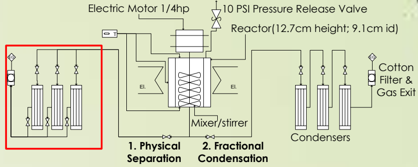
Condenser 1, Water Content of 1.40 wt.%



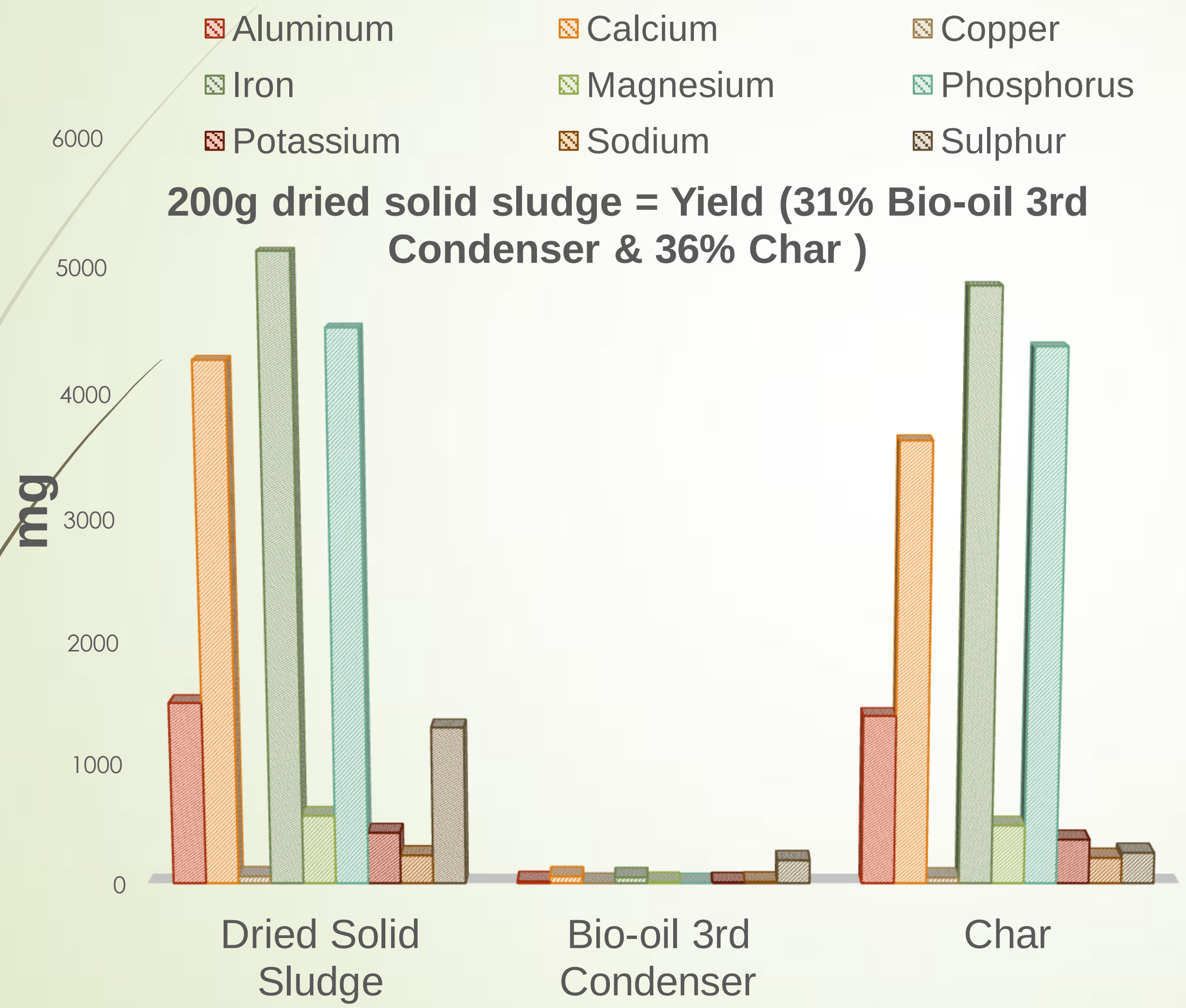
Heat and Mass Balance (optimal conditions for Series Scheme)

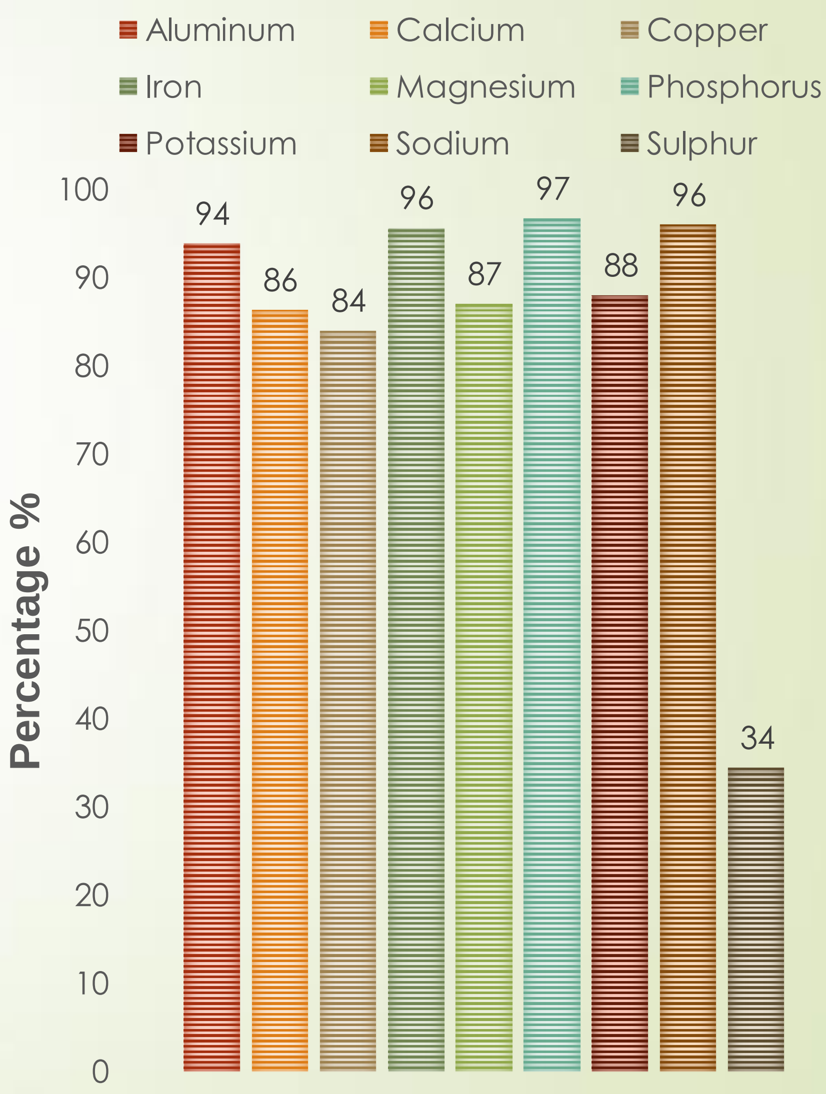


Parallel Scheme 175-250-500



Inorganic Transfer and Recovery





Conclusions

- Bio-oil yield, calorific value and water content are functions of pyrolysis process and fractionation scheme.
- Both fractionation schemes are effective de-watering techniques.
- Through optimisation of the fractional condensation scheme (series), a bio-oil with a calorific value of ~35 MJ/kg and water content of ~1.5 % is achievable.
- Good recovery for most inorganics in char, except for sulphur.

Acknowledgements

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