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# *Nitrogen partitioning during pyrolysis and combustion of biomass fuels*

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# Future Conventional Power Consortium

**Future conventional power research consortium**

**Aim**

*"To accelerate progress towards achieving operational excellence for flexible, efficient, controllable, safe and environmentally sustainable thermal power plants"*

Research Councils UK Energy For a Low Carbon Future

GE Power

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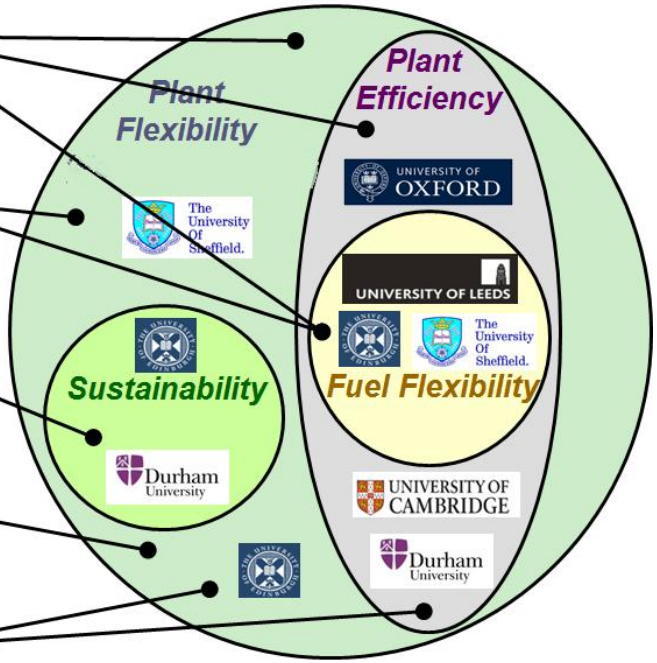


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# Future conventional Power Consortium
# Fuel Flexibility Theme

**Pulverized coal power plant**

Biomass

Low carbon energy

- Strict limits on NOx emissions
- Carbon dioxide emissions target

## Fuel Flexibility challenge

- Nitrogen partitioning
- Combustion behavior
- Potassium partitioning

# Fuel nitrogen and NOx formation

Nitrogen oxides are hazardous to human health and contribute to:

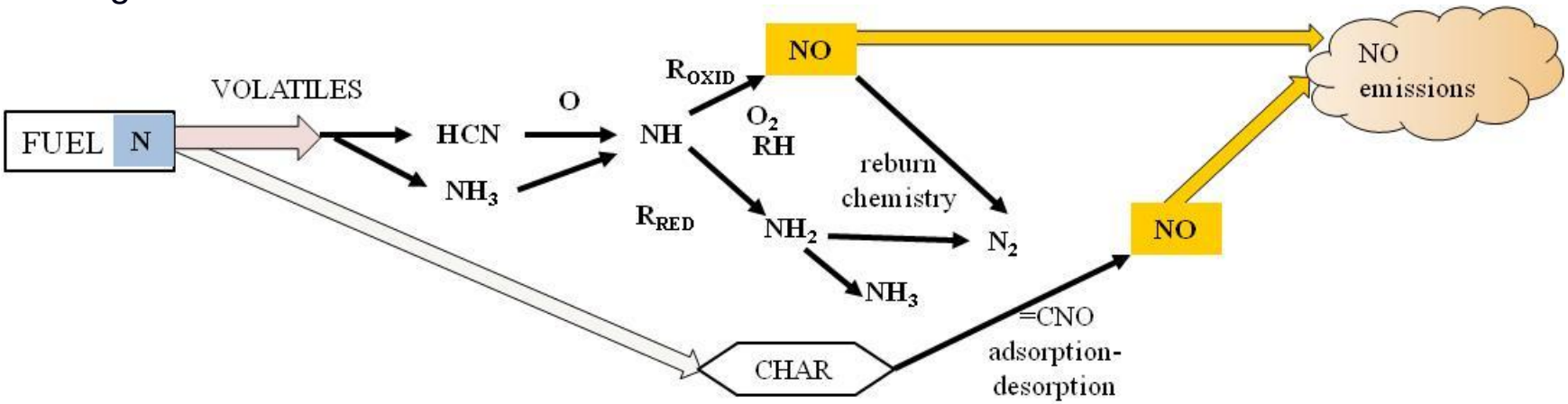
- Environmental acidification
- Formation/accumulation of tropospheric $O_3$

Three primary sources:

- Thermal NOx
- Prompt NOx
- Fuel-bound N oxidation

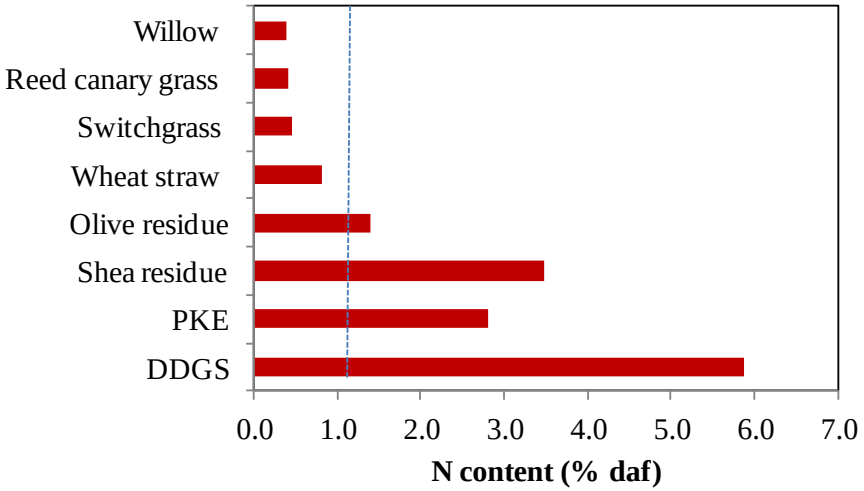
...but for pf combustion conditions prompt NOx are considered negligible

Fuel Nitrogen in volatile and char form NOx emissions




The Char-N can form NO directly by a heterogeneous process

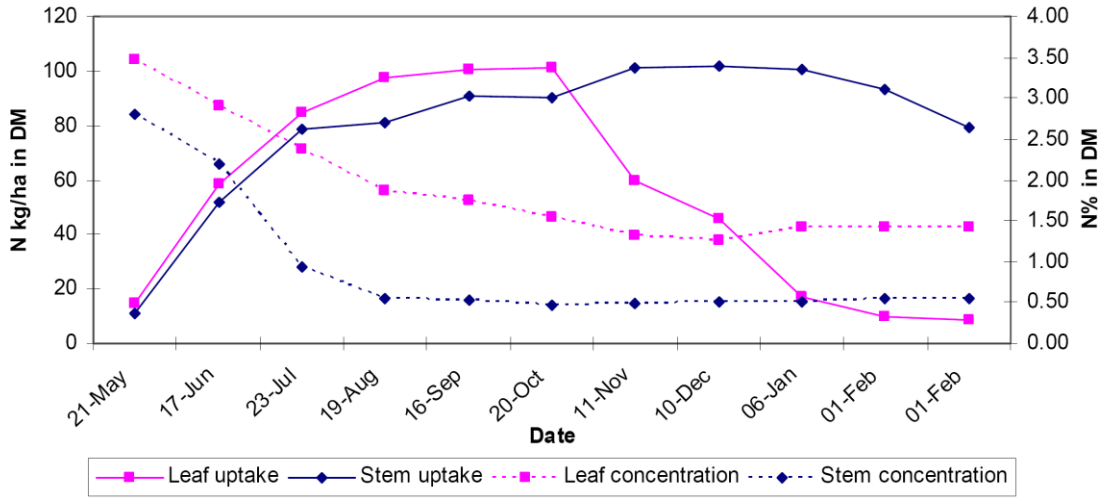
# Nitrogen in solid biomass fuels




External factors:

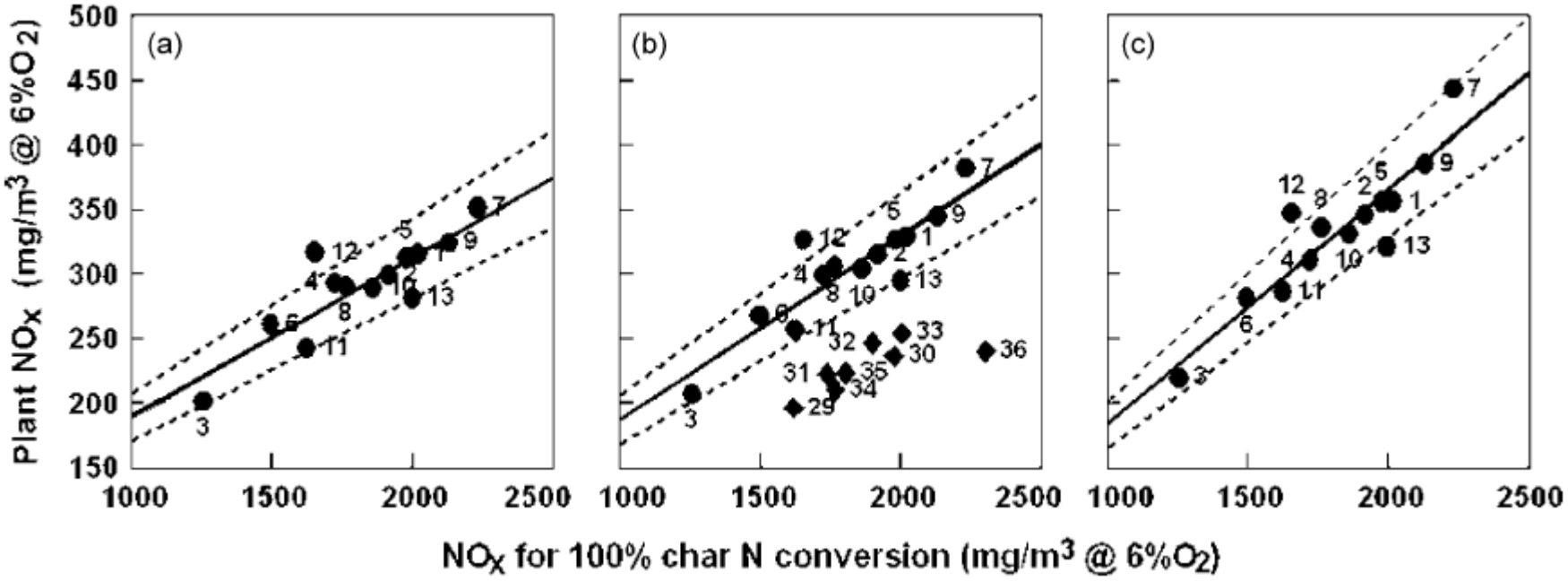
- geographical location
- climate
- growing and harvest conditions

***Nitrogen content is variable!***




The nitrogen dynamics of a Miscanthus crop through the year (Rothamsted, 1998)

# Coal char N content as source of NOx




Comparison between measured plant NOx values with 100% char N conversion values for a primary zone stoichiometry of 0.8 and economiser exit oxygen values of 3, 3.5, and 4.5% v/v.

From: Coal characterisation for NOx prediction in air-staged combustion of pulverised coals. C.K. Man, J.R. Gibbins, J.G. Witkamp, J. Zhang. Fuel 84 (2005) 2190–2195

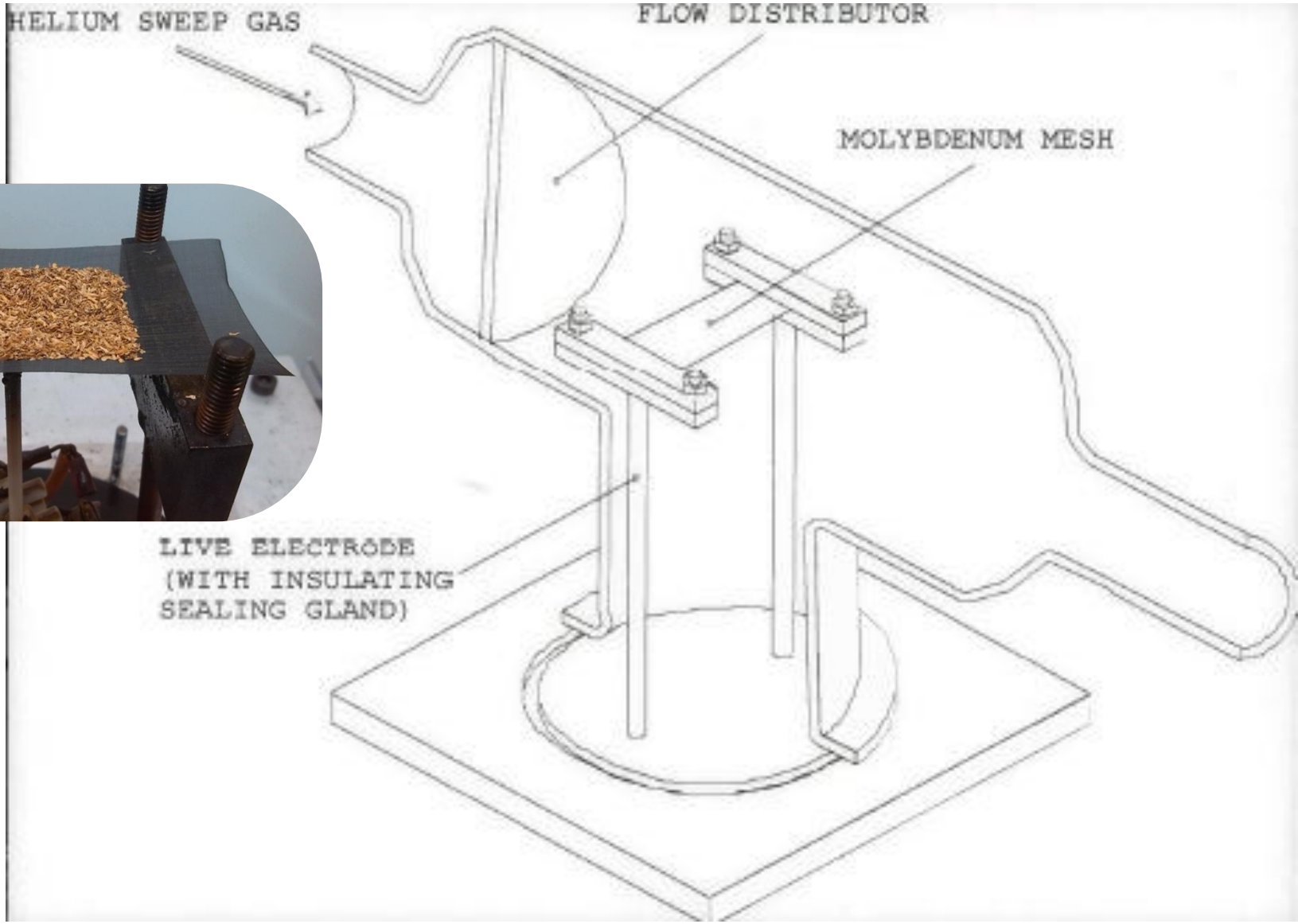
# Objective

- Evaluate the volatile yield at high temperatures (1600 °C) and the fate of nitrogen released during the pyrolysis as volatile matter and the intrinsic nitrogen retained in the char itself for different biomass samples.

# Materials and methodology

- High Temperature high heating rate wire mesh device:
  - Final temperature 1600 C
  - Estimated heating rate $10^4$ K/seg
- Chars produced using size fractions 500- 710 μm of:
  - Olive Waste
  - Steam pellet
  - US Pellet
- Size Fractions effect on Volatile yield and N release studied on Wood pellet biomass using:
  - 300 - 500 μm
  - 500- 710 μm
  - 1120 - 1400 μm

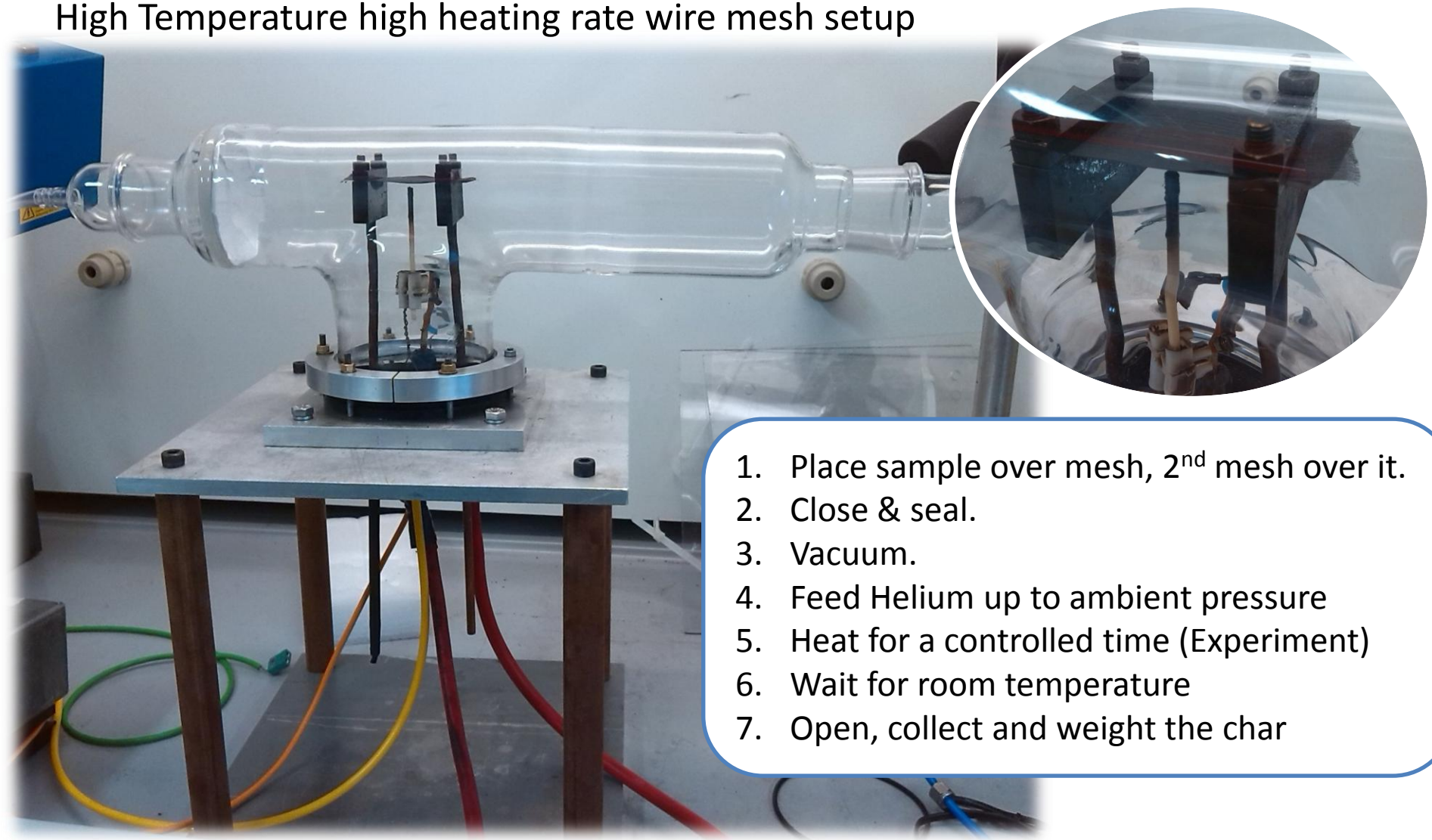
# Experimental setup




High Temperature high heating rate wire mesh setup

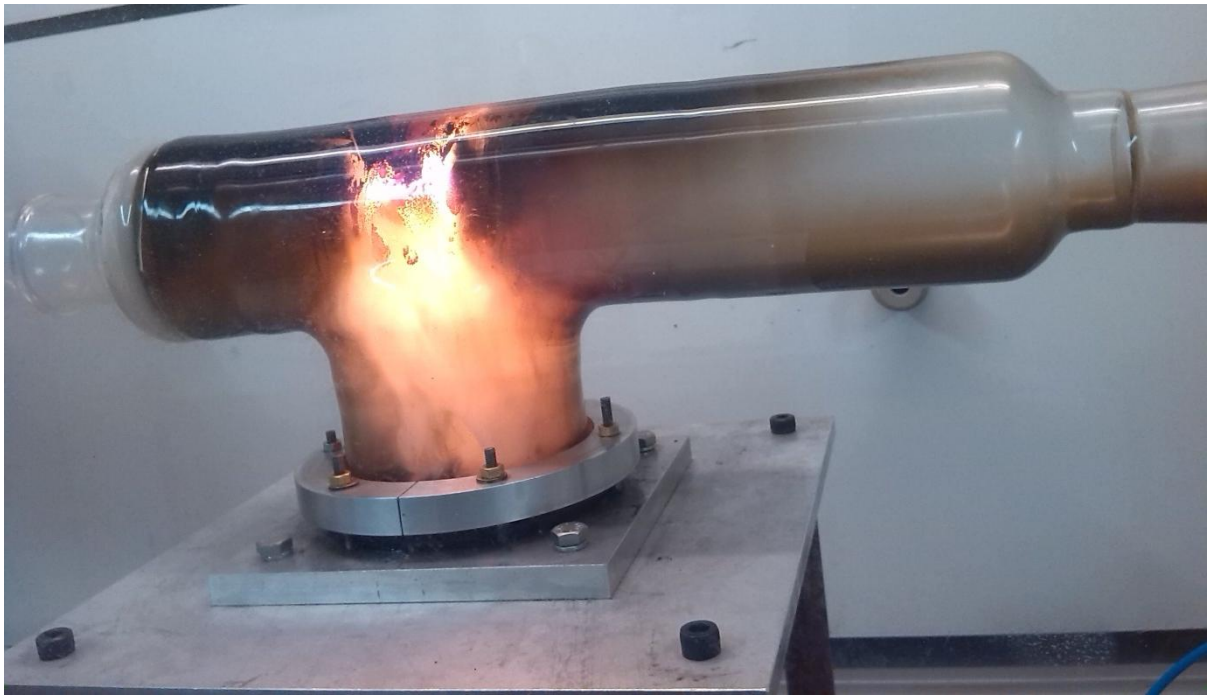
# Experimental setup

High Temperature high heating rate wire mesh setup



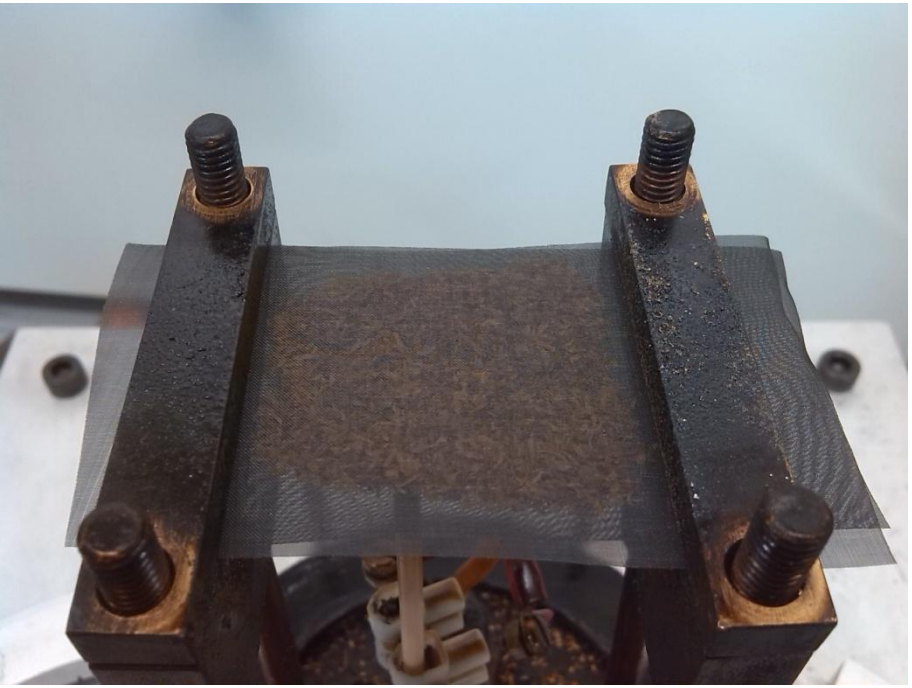
1. Place sample over mesh, 2nd mesh over it.
2. Close & seal.
3. Vacuum.
4. Feed Helium up to ambient pressure
5. Heat for a controlled time (Experiment)
6. Wait for room temperature
7. Open, collect and weight the char

# Experimental setup



High Temperature high heating rate wire mesh setup

# Experimental setup



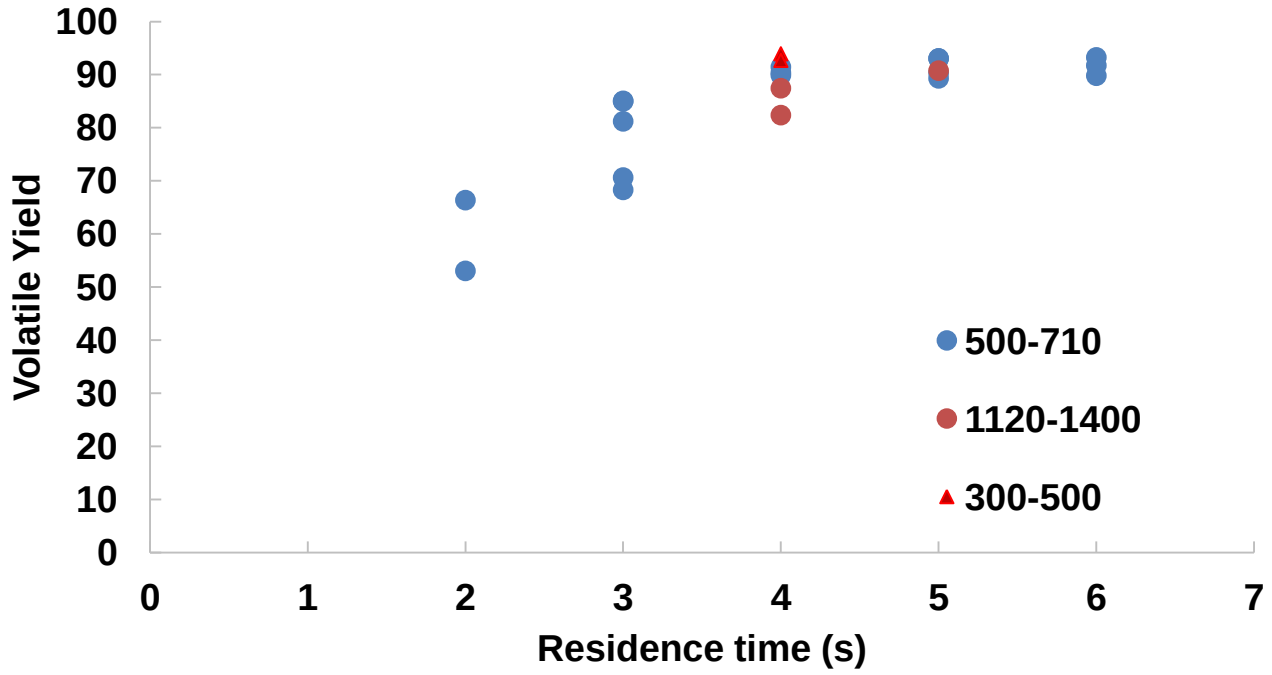
High Temperature char

# Samples used

| | | Olive residue | Black pellet | White Wood Pellet | basis | units |
|---|---|---|---|---|---|---|
| **Proximate Analysis** | **moisture content** | 5.9 | 7.2 | 6.7 | as received | %wt |
| | **ash content** | 7.6 | 4.2 | 0.8 | dry | %wt |
| | **volatile content** | 80.1 | 79.4 | 84.3 | daf | %wt |
| | **fixed carbon** | 19.9 | 20.6 | 15.7 | daf | %wt |
| | **GCV (dry)** | 20.1 | 20 | 20.8 | dry | $MJ.kg^{-1}$ |
| **Elemental Analysis** | **C** | 52.8 | 52.7 | 52.3 | daf | %wt |
| | **H** | 6.5 | 5.8 | 6.8 | daf | %wt |
| | **O** | 39.1 | 41.2 | 40.7 | daf | %wt |
| | **N** | 1.6 | 0.2 | 0.2 | daf | %wt |

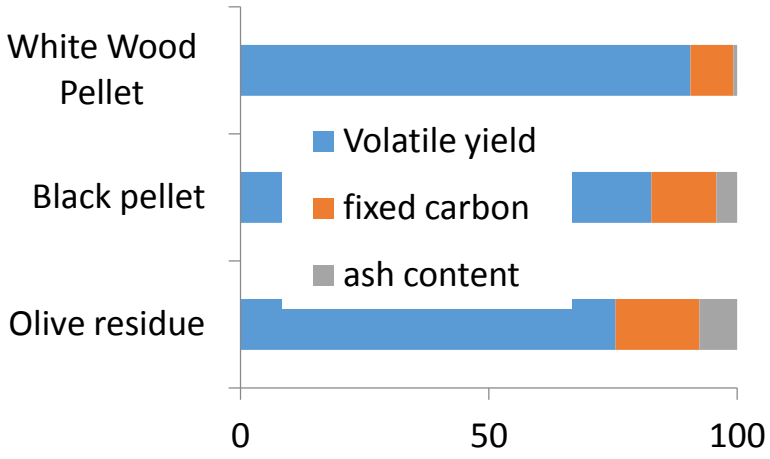
# Volatile release vs residence time

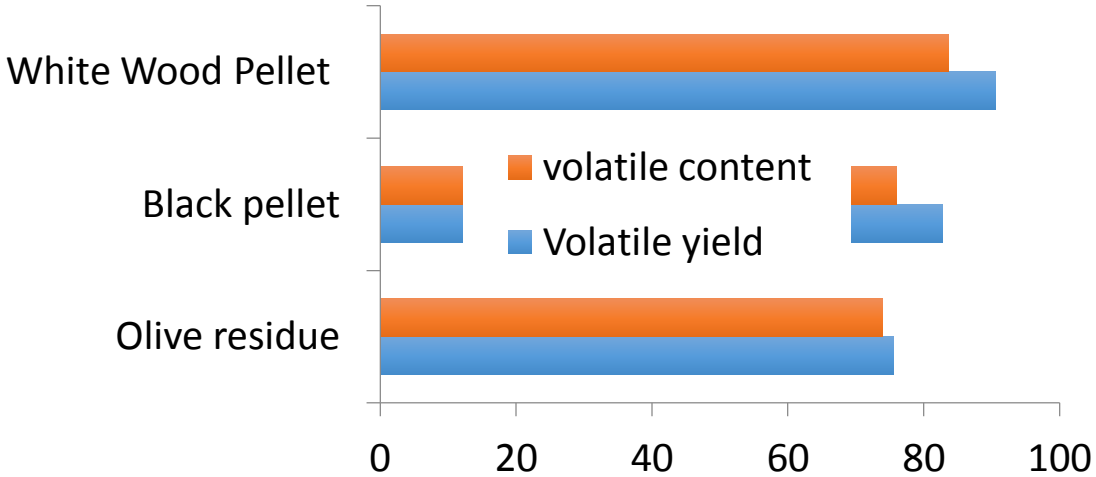
## Wood Pellet



# Volatile Yield Results

| | | Olive residue | Black pellet | White Wood Pellet | basis |
|---|---|---|---|---|---|
| proximate analysis | ash content | 7.6 | 4.2 | 0.8 | dry |
| | volatile content | 74 | 76 | 83.7 | dry |
| | fixed carbon | 18.4 | 19.7 | 15.5 | dry |
| High temperature wire mesh 1600ºC 4s | Volatile yield | 75.5 | 82.7 | 90.6 | dry |

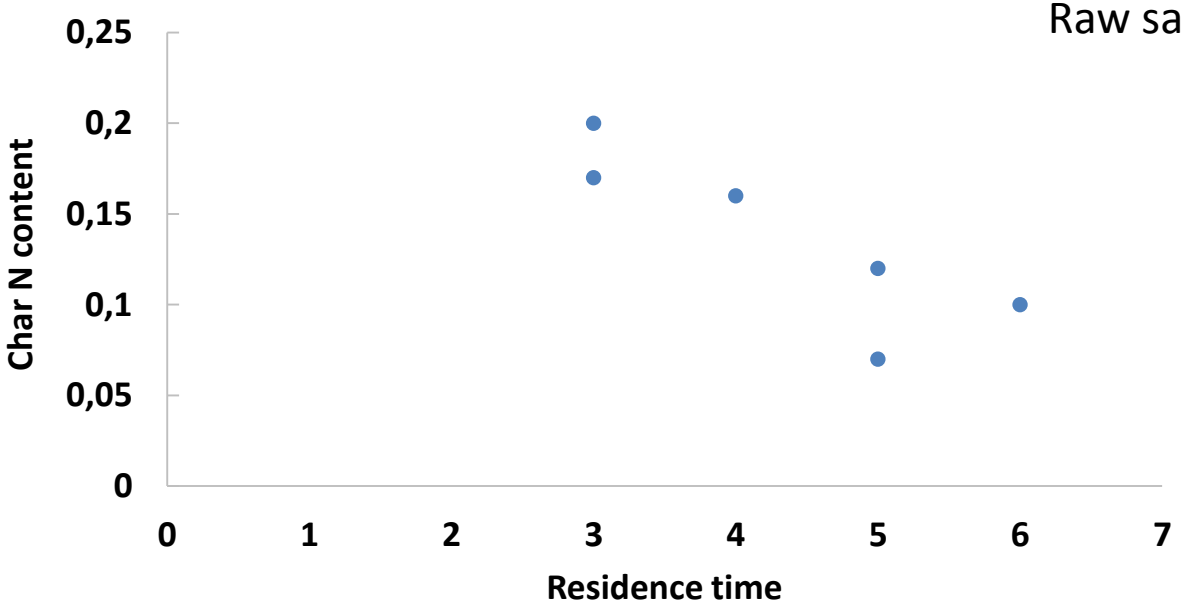


# Results

- Nitrogen release

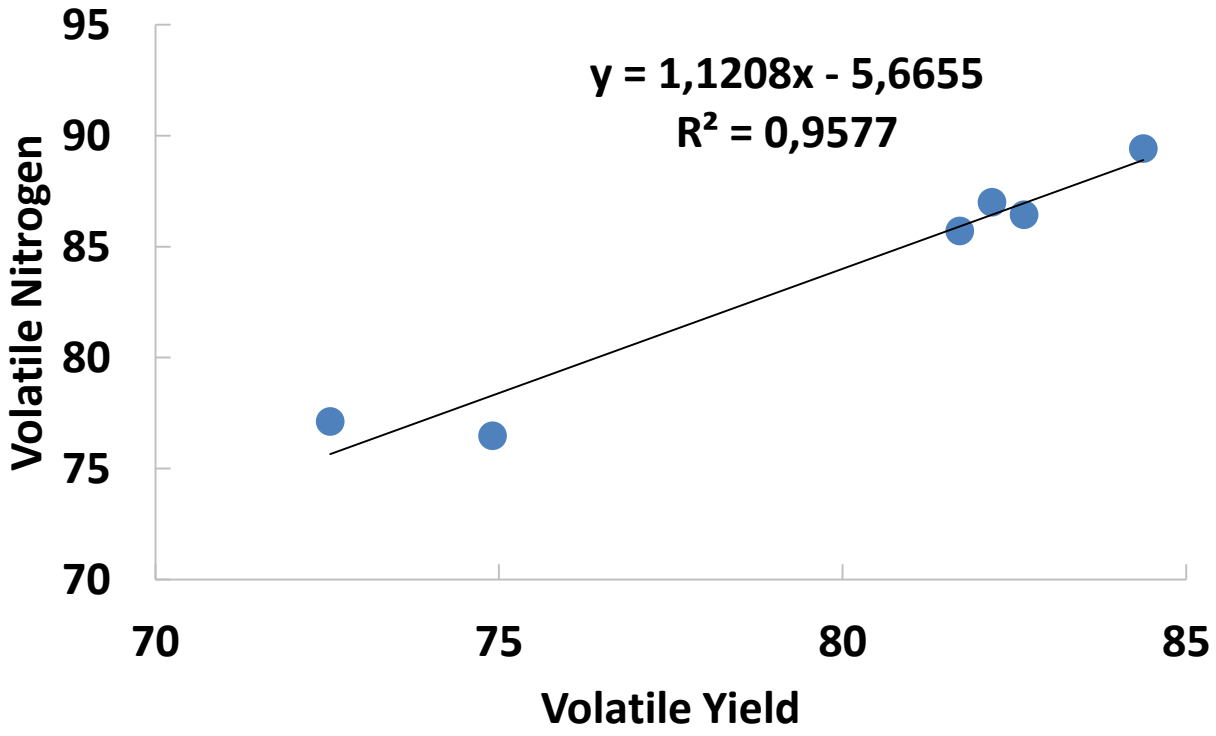
Wood pellet biomass
500- 710 µm
Raw sample 0,15 % N dry



# Results

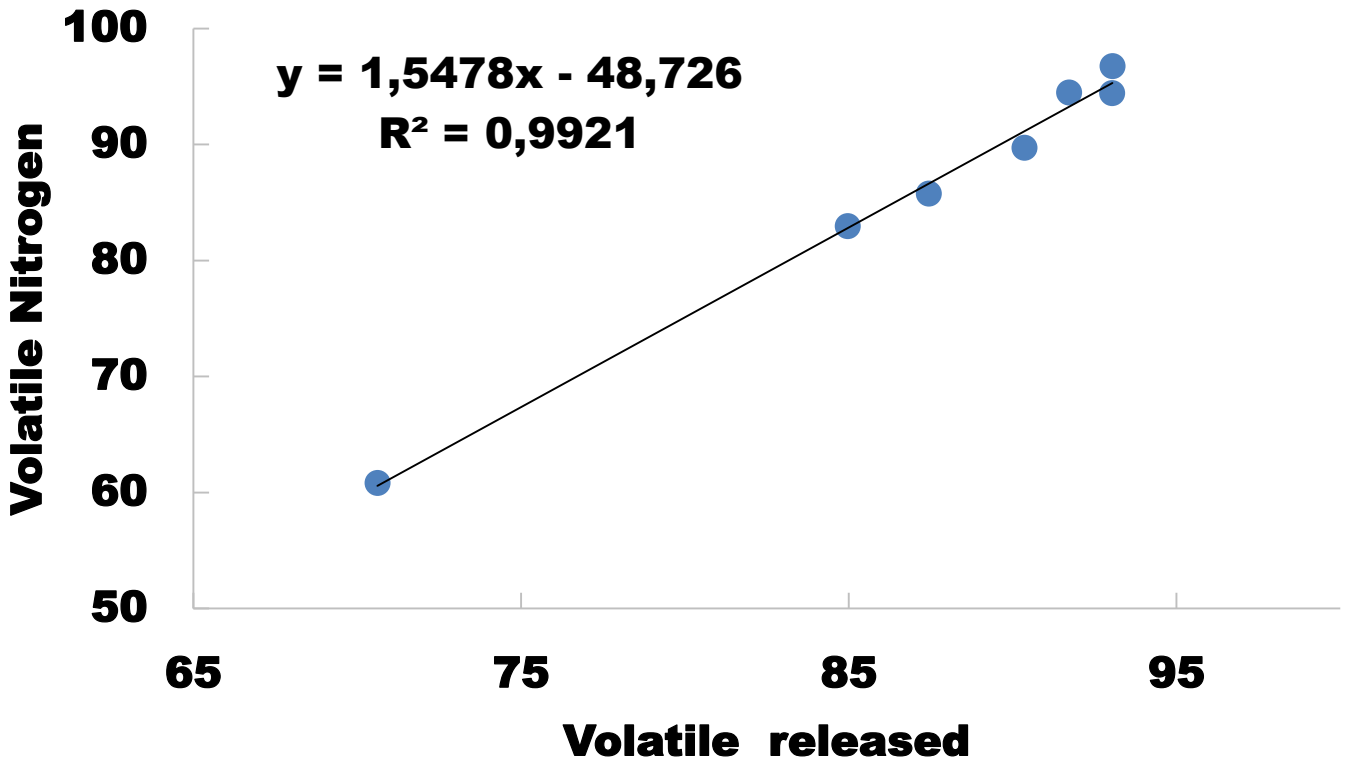
Nitrogen release

Olive waste 500- 710 μm



# Results

Wood Pellet 500- 710 μm



# Conclusions

- Volatile yield obtained on the high temperature wire mesh was above proximate analysis values after 4 s residence time for all samples.
- Nitrogen content on the char was under detection limit (<0.3) for most HCN elemental analyzers. Low Nitrogen analyzer was needed.
- Nitrogen is proportionally released with volatile matter.
- The proportion of volatile Nitrogen (4s) was:
  - 94 % Olive residue,
  - 87 % Black pellet,
  - 88 % White Wood Pellet

# *Thanks for your attention*

## Acknowledgements

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*https://www.dur.ac.uk/dei/projects/futurepower/*

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