

# Consecutive recovery of three high-value products from waste tyres via pyrolysis in a rotary kiln

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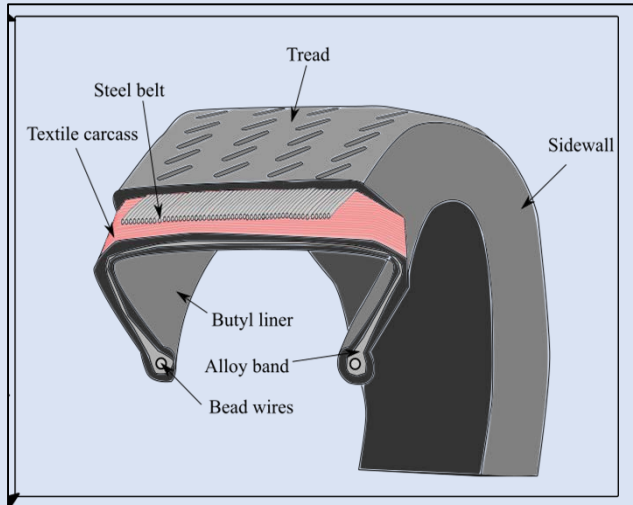
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**1: Waste tyres**



Problematic

1) Energy intensive to produce



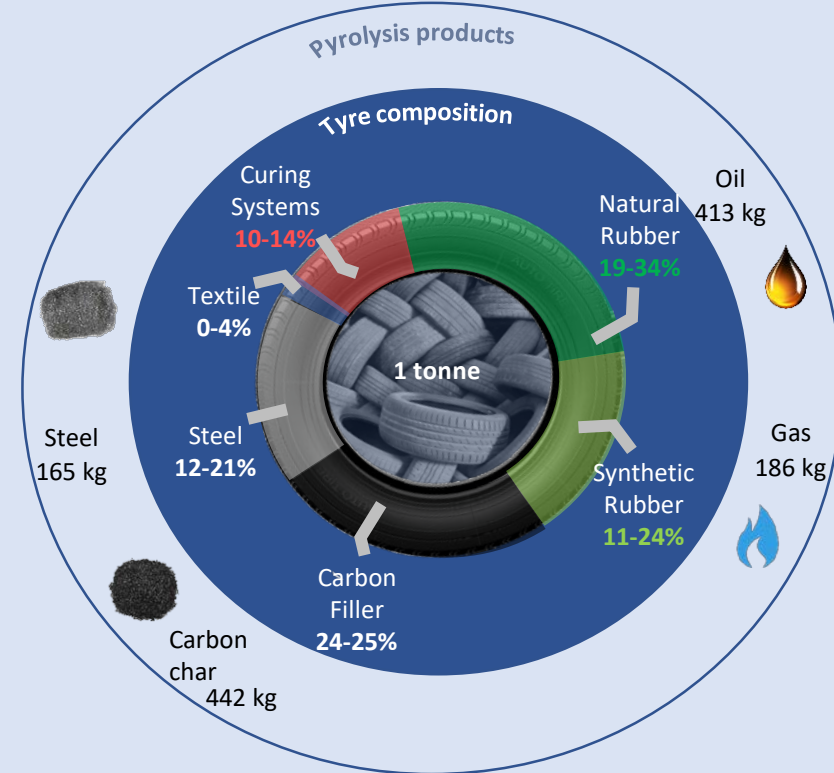
Heterogenous composition

2) Abundant and hard to recycle<sup>[1]</sup>



Tyre fire in Kuwait

**2: Pyrolysis process**



H<sub>2</sub>, CO<sub>2</sub>, CO, C1-C4 hydrocarbons



Linear & aromatic C4-C20+ hydrocarbons  
Sulphur & metal contaminants



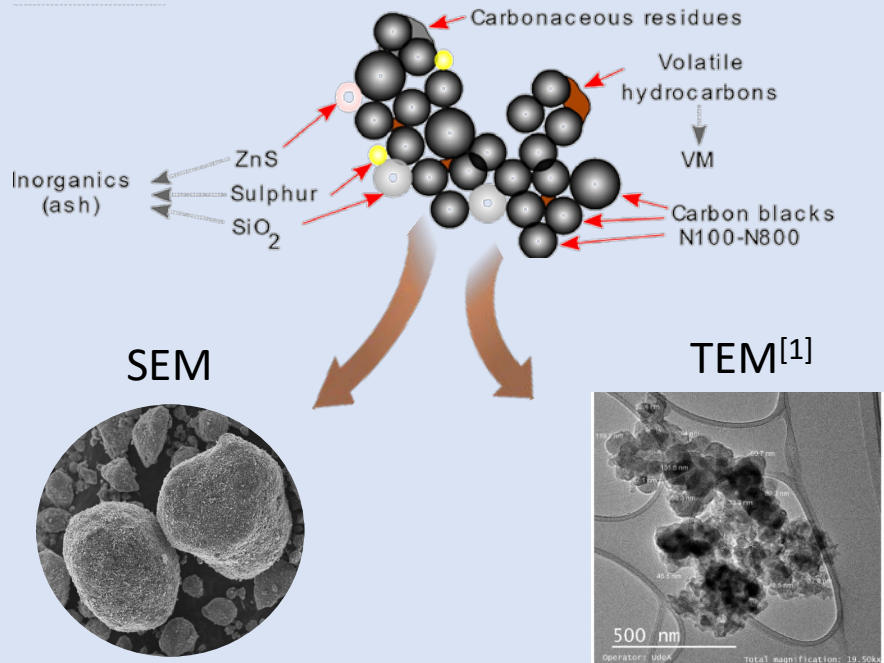
Highly aromatic hydrocarbons  
Inorganic residues

[1] - A. J. Bowles, G. D. Fowler, Resour. Conserv. Recycl. **182**, 106277 (2022).

**Pyrolysis products**

**3: Recovered Carbon-black (RCb)**

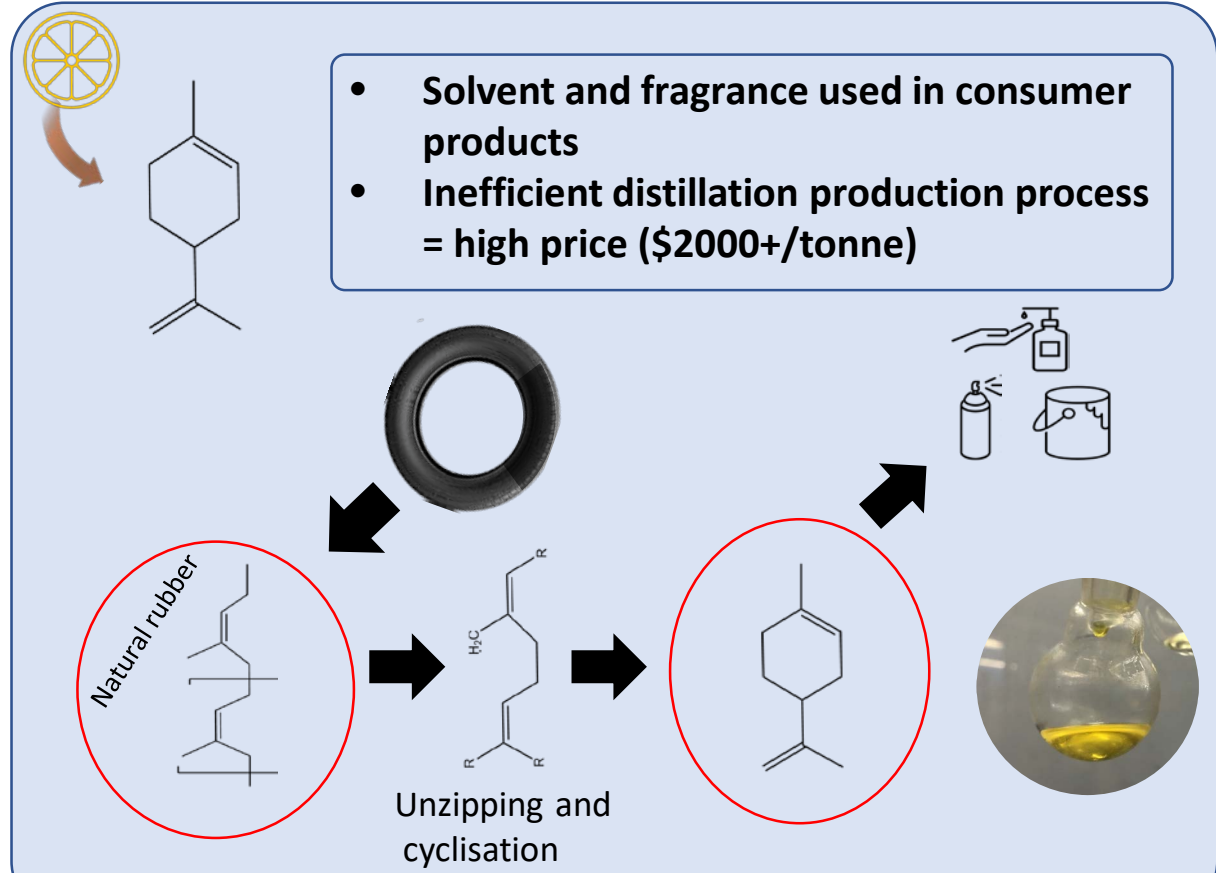
- Carbon black is a fossil fuel derived filler used in tyres, plastics, and inks
- RCb is a recycled filler material produced from tyre pyrolysis char



**Question #1: Can we produce high-quality recovered carbon black from tyre pyrolysis?**

**4: Limonene**

- Solvent and fragrance used in consumer products
- Inefficient distillation production process = high price (\$2000+/tonne)



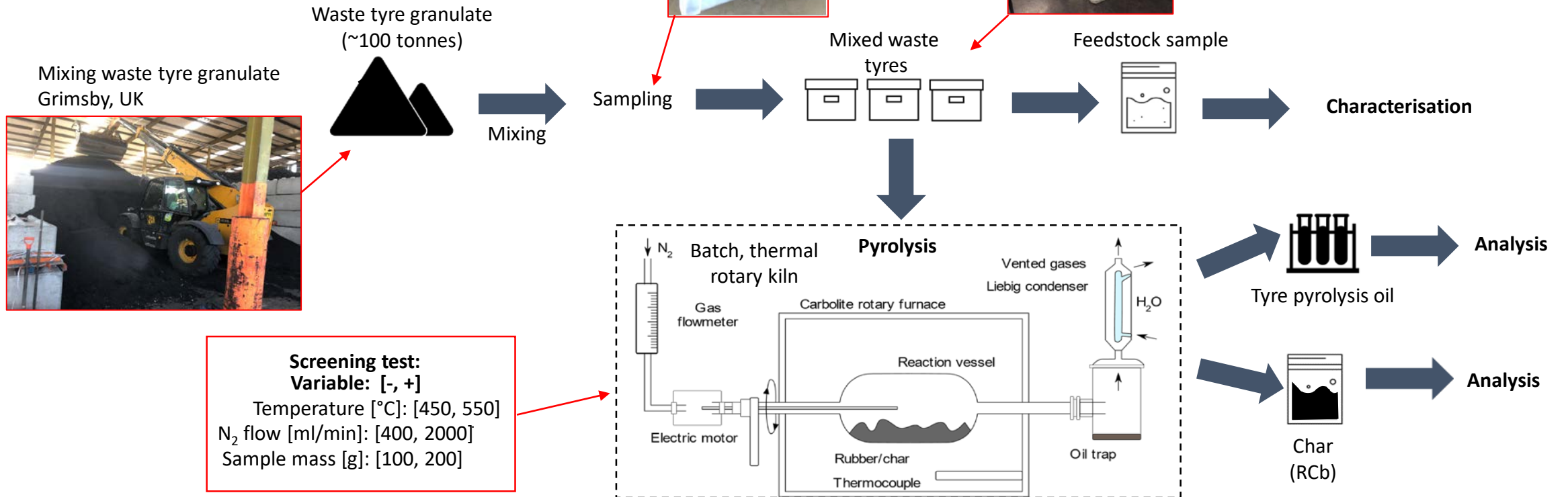
**Question #2: Can we produce limonene at a substantial quantity to valorise waste tyres?**

## 5: Experimental methodology

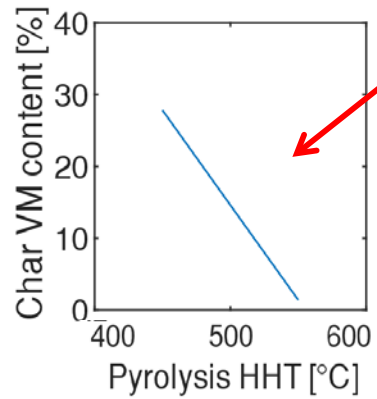
**Q1 & 2: Can we produce RCB & Limonene from waste tyre pyrolysis?**

To answer these, we need to understand:

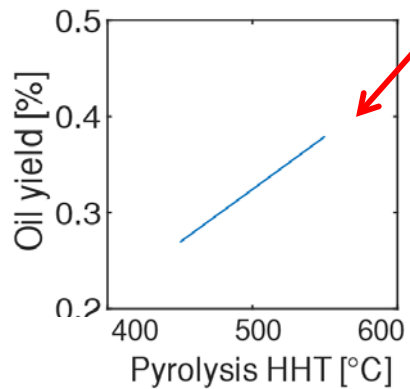
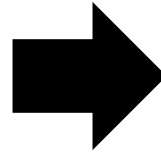
- Feedstock properties
- Tyre pyrolysis influencing variables



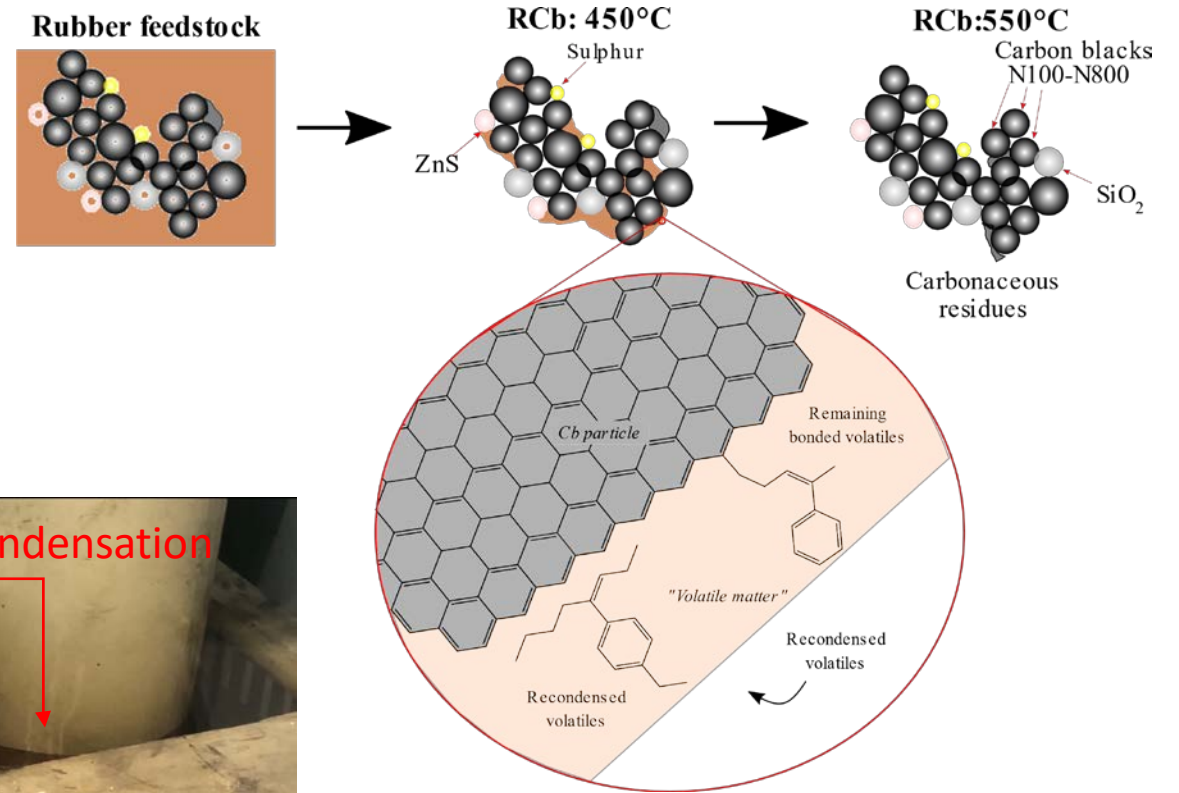
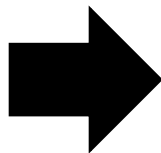
## 6: Effect of temperature



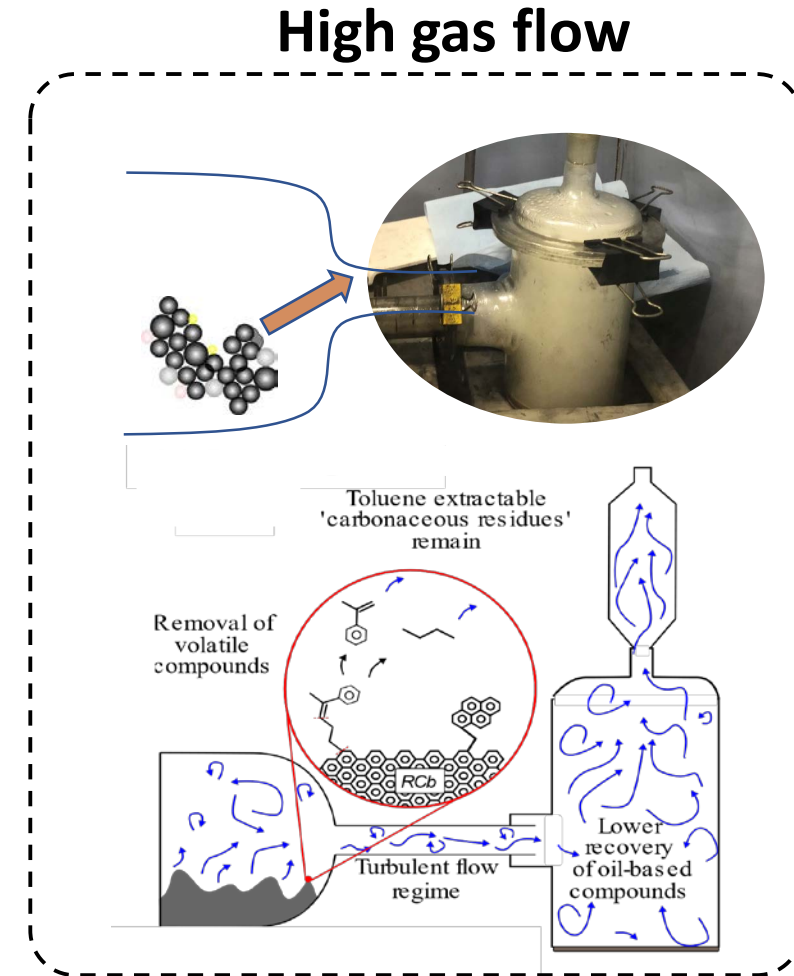
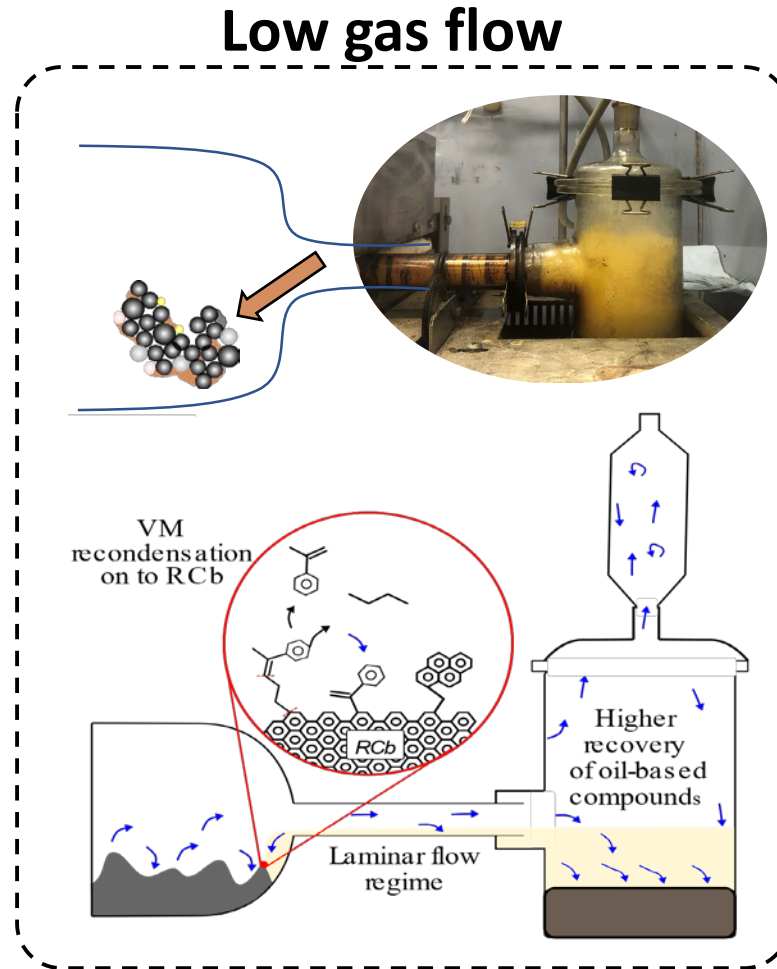
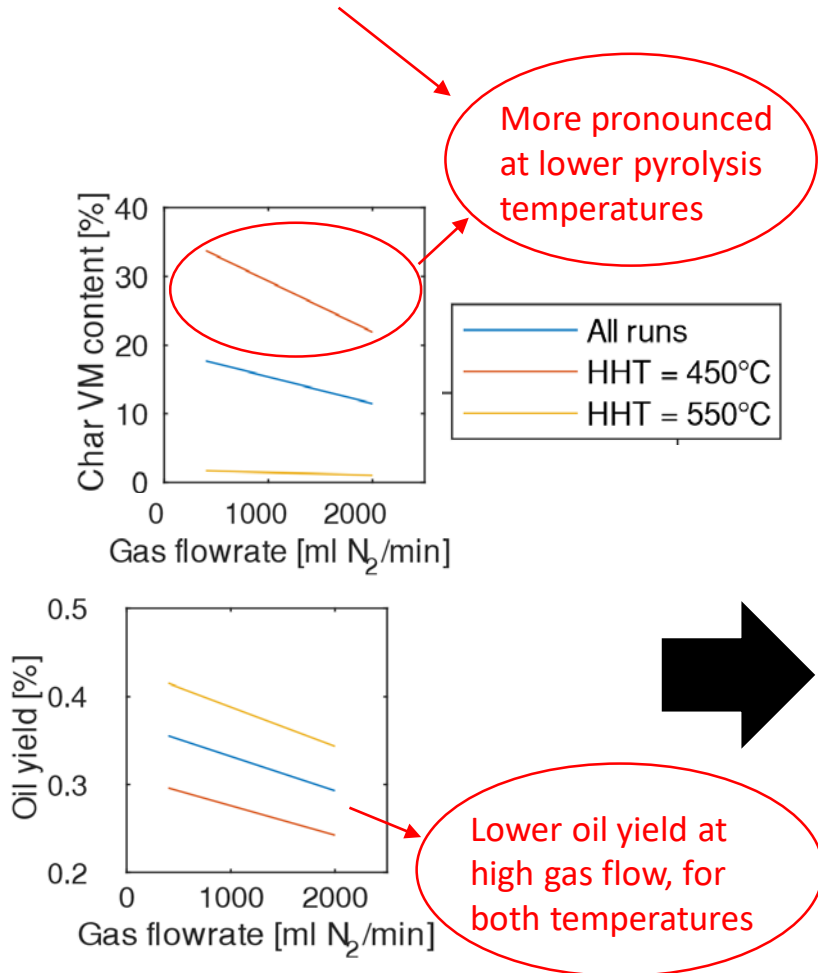
Higher temperature increased volatilisation



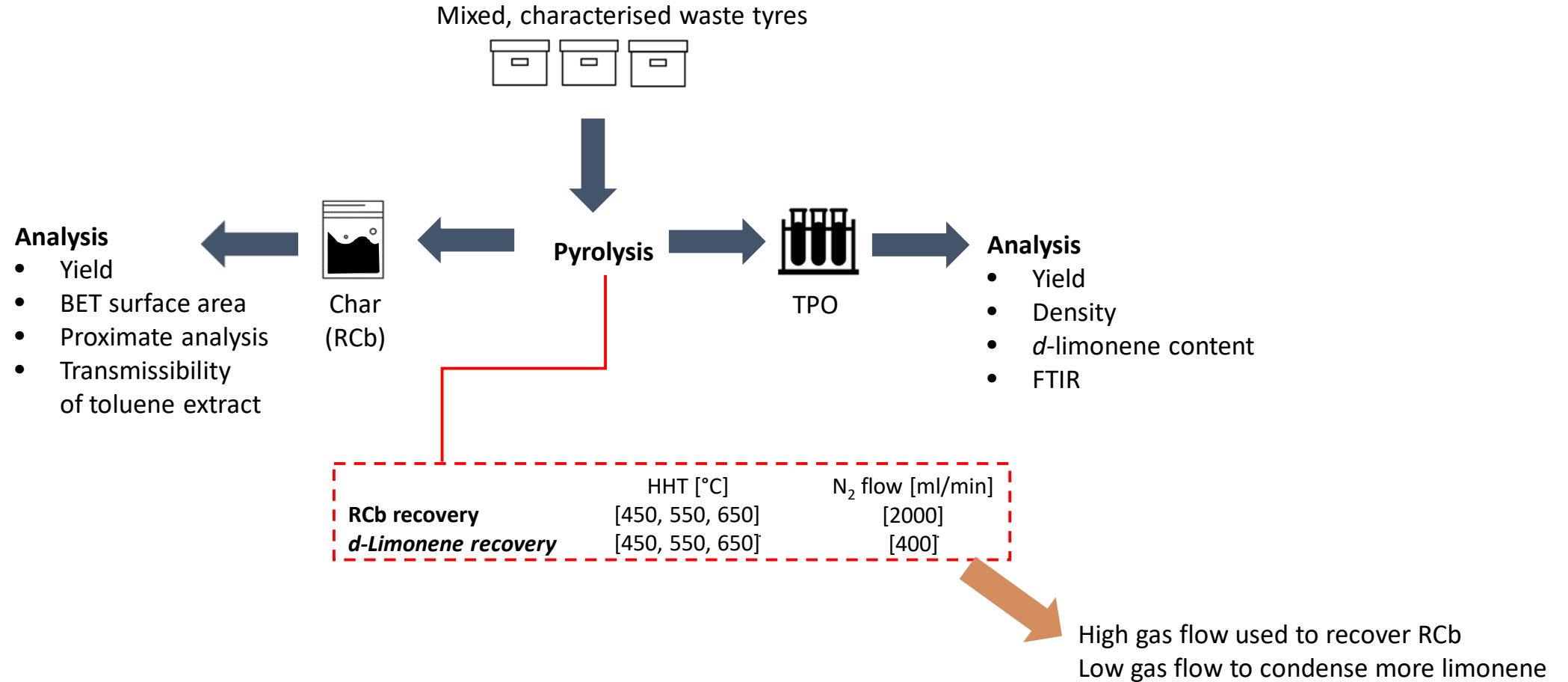
Higher oil yield produced from condensed volatiles



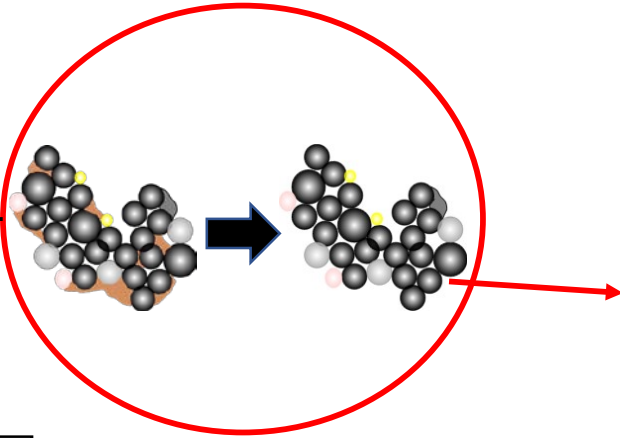
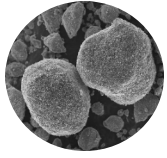
**7: Effect of gas flow**



## 8: Experimental methodology II

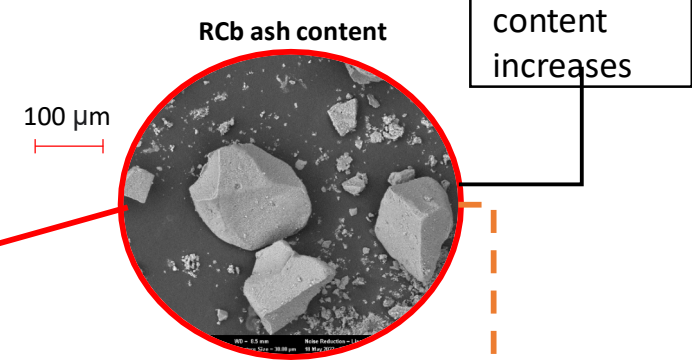
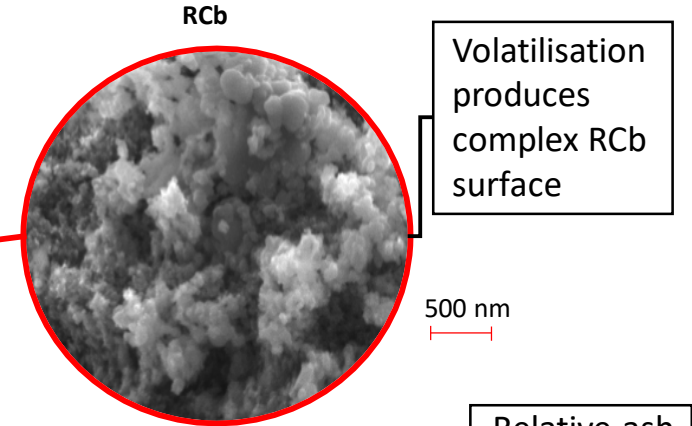
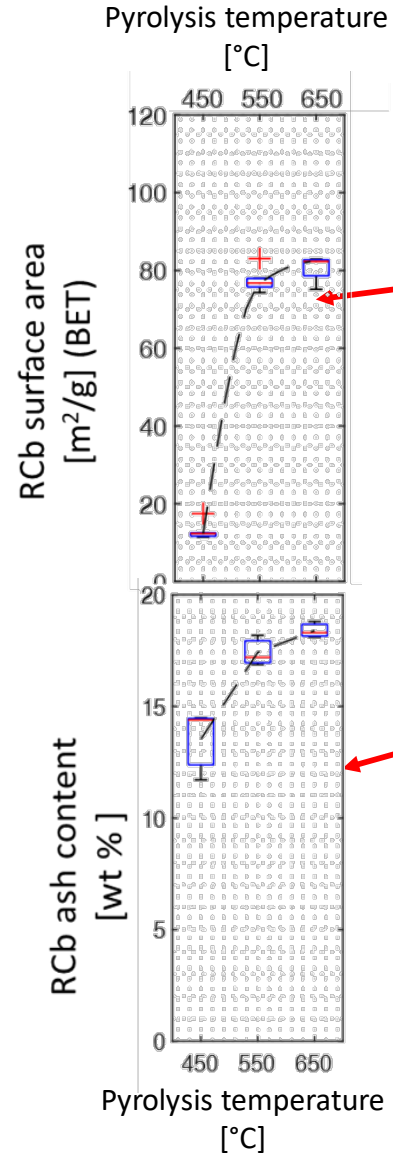
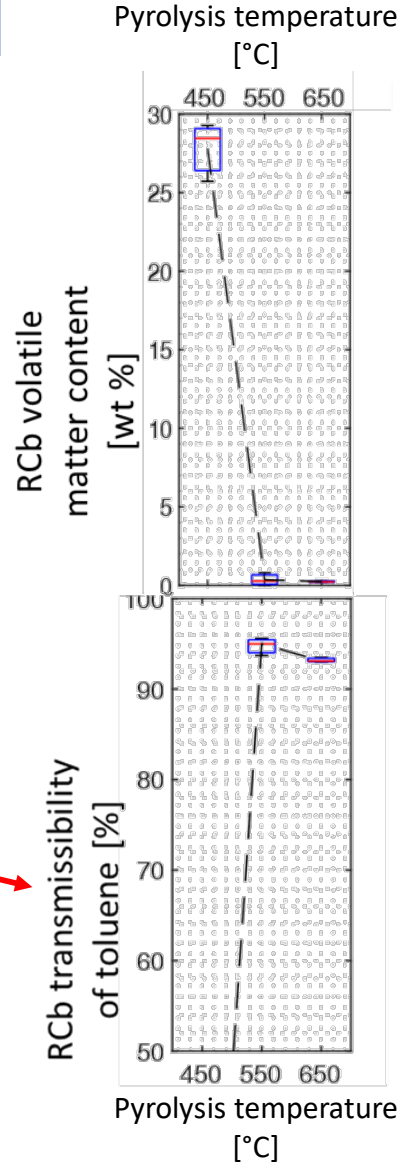
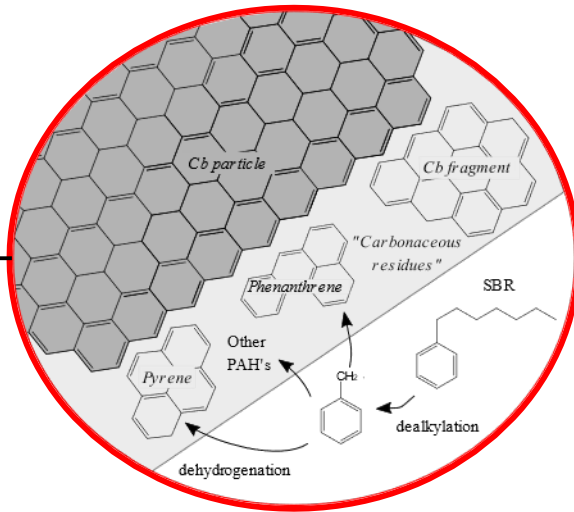


**9: RCb properties**

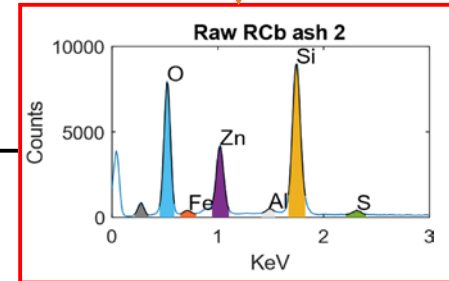


>550°C required to volatilise VM

<99% suggests cyclisation and PAH deposition on RCb

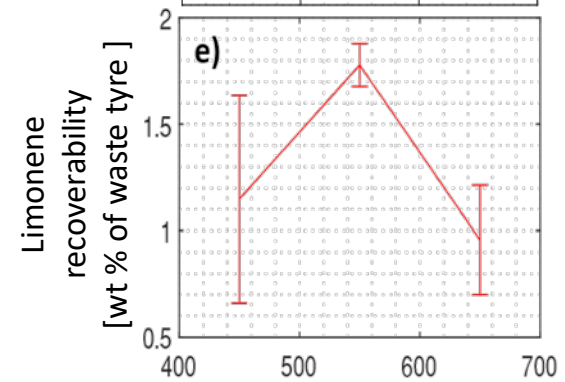
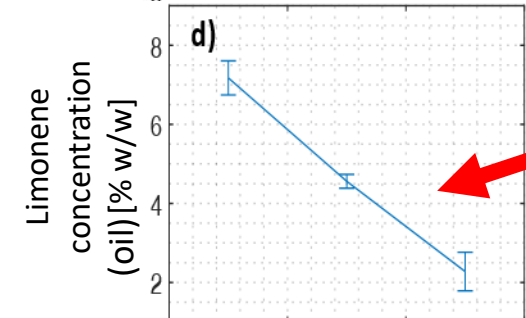
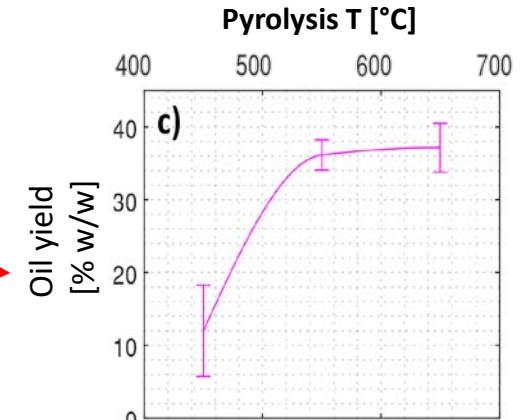
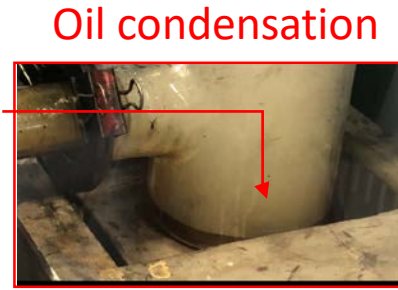
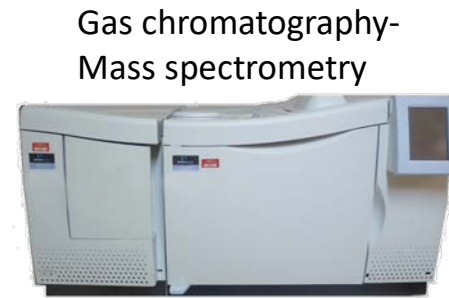
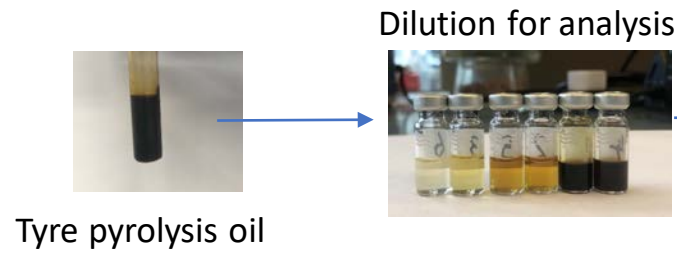


EDS showed elemental heterogeneity of ash

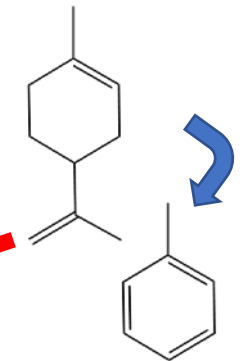




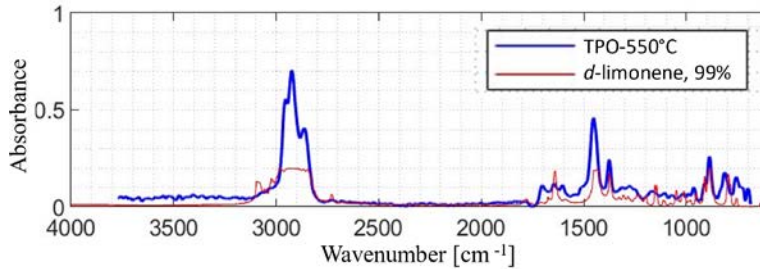
**10: Limonene properties**



Thermal degradation to smaller hydrocarbons with increasing temperature

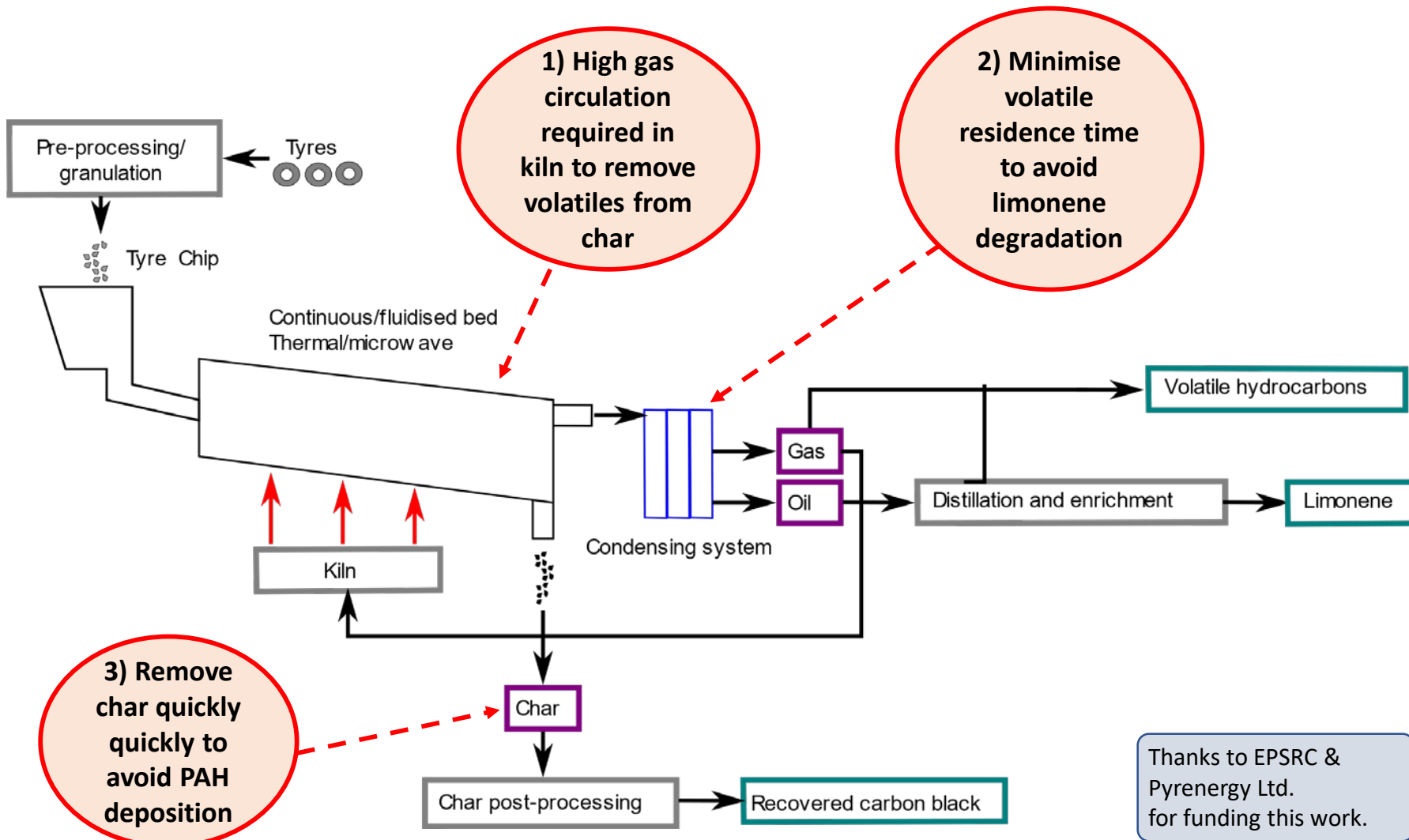


FTIR also confirmed presence of limonene.



Oil Y \* Limonene conc =

11: Conclusions and further work



At 550°C,  
 1) Limonene yield = 1.8% wt of tyre  
 2) Recovered carbon black yield = 36.6% wt of tyre

assuming RCb = \$600/tonne  
 & limonene = \$2000/tonne...

These two products can increase the value of waste tyres by **\$250/tonne**

Further work:  
 1) **Extraction** of limonene from TPO.  
 2) **Incorporation** of RCb to recycled products.

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Thank you

Questions?  
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