PUBLISHABLE SUMMARY

The Sulfree project sets out to convert low-value rubber crumb into high value products, including activated carbon and low-sulphur pyrolysis oils. Sulfree is a novel end of life tyre recycling process that employs microwave pyrolysis technology. Pyrolysis is thermal decomposition of organic materials in the absence of oxygen. Tyres due to their high carbon content are ideal candidates. Pyrolysis of end of life tyres results in a gas, a liquid (oil) and a solid carbon char (carbon black) fraction.

The major novelty of the project is the development of a complete desulphurisation process that reduces the sulphur content of the pyrolysis oils and gas, with sulphur recovery. This enables the sale of the pyrolysis oils as light sweet crude oil, currently sold at $90/bbl and estimated to reach by 2020 $125/bbl.

A working Sulfree rig was produced (Figure 1) this was then used for optimising the process.

Figure 1: The working Sulfree rig

During the process oil is continually condensing from the vapours produced during the pyrolysis process and is collected.

Figure 2: Oil condensed and flowing

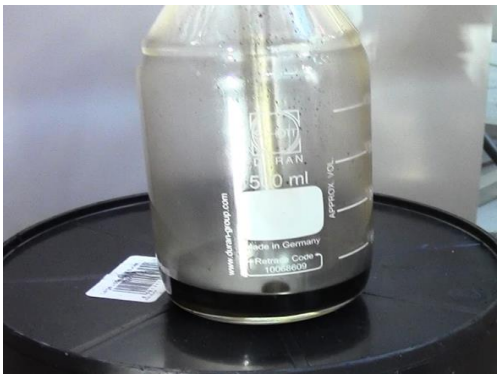

Figure 3: Oil being collected in collection bottle

After five dispenses the excess hot carbon is ejected from the pyrolysis chamber and via a screw conveyor and is cooled and collected ready for dispensing. This screw conveyor and carbon cooling process is computer controlled via a dedicated computer programme (Figure 4).

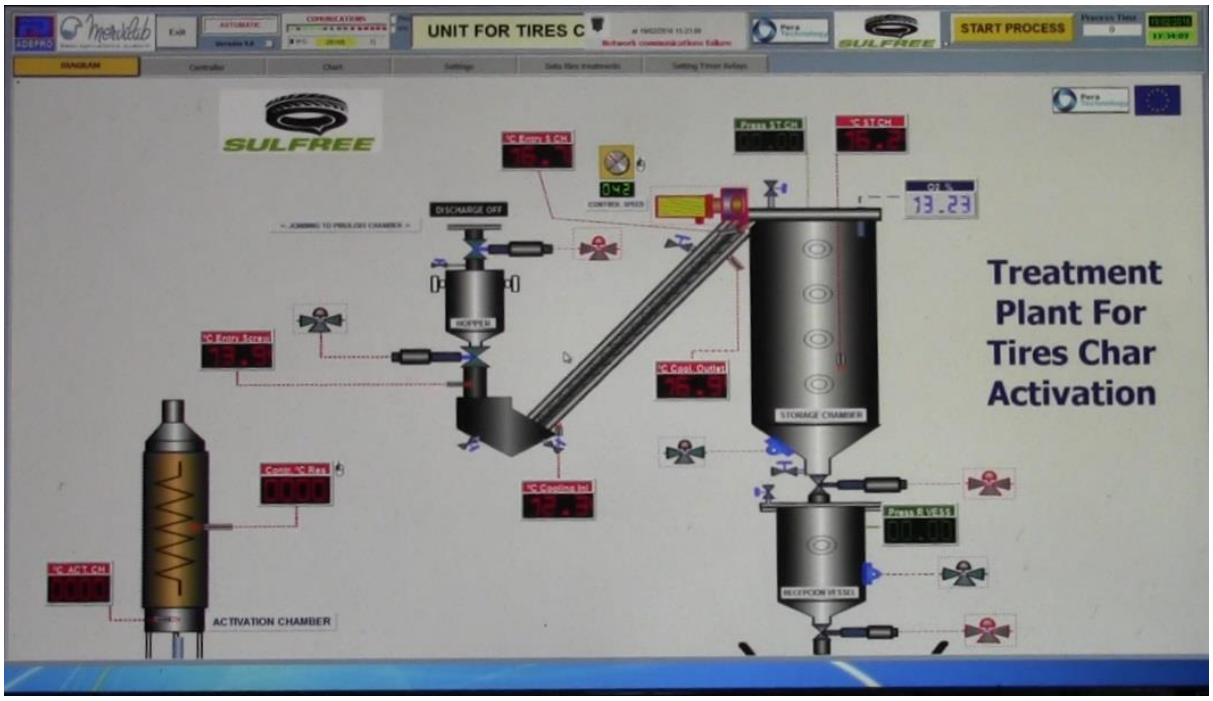

Figure 4: Computer control process for screw conveyor and carbon cooling process.

The key measures of pyrolysis success are production of 'dry' carbon (i.e. fully-pyrolysed solid material that does not contain any pyrolysis oil) and recovery of the maximum yield of condensable pyrolysis oil. Both of these outputs are strongly affected by the pyrolysis temperature and the residence time in the pyrolysis chamber, along with the inertness of the atmosphere inside the pyrolysis zone, the mixing regime adopted and how the carbon and oil are cooled outside of the pyrolysis chamber.

The optimum temperature to achieve full pyrolysis of rubber crumb without unnecessary 'over-heating' was previously determined using thermogravimetric analysis (TGA, Figure 5) and found to be 450 °C. This was therefore set as the target temperature for the reactor.

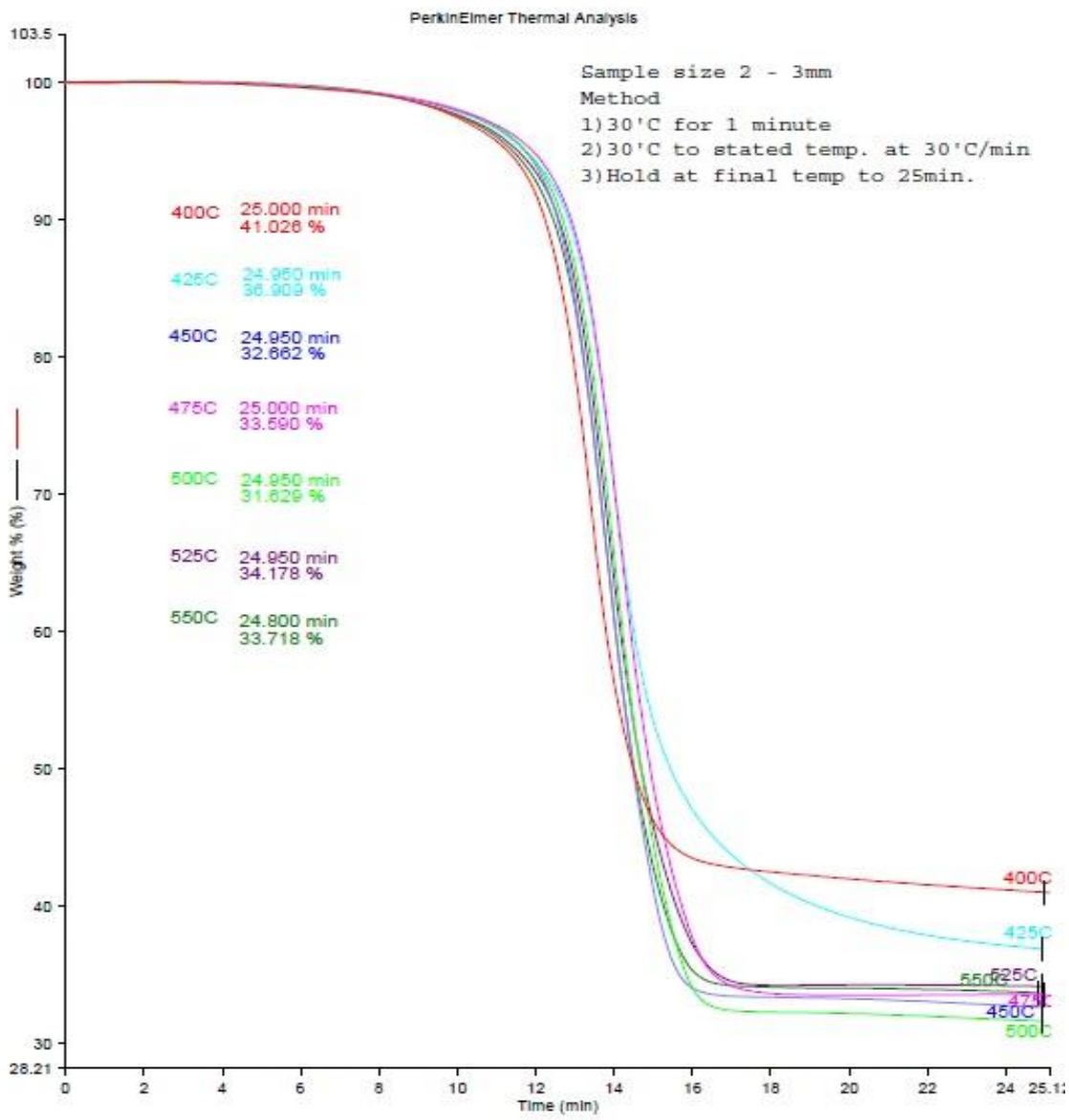

Figure 5: TGA trace for pyrolysis of rubber crumb at various temperatures

After each trial, the pyrolysis oil was recovered and the total volume determined. It was found that, for our system, the relationship between oil volume produced and degree of pyrolysis was almost linear (e.g. 85% pyrolysis of the crumb generated 85% of the theoretical maximum of pyrolysis oil) Changing operating parameters inside our chamber had very little impact on oil production and, as the most valuable component of our system is the carbon and not the pyrolysis oil, this production rate was not optimised further.

The design of the mixing blades ensures the walls of the chamber are kept clean, as the constant movement of the blades inside the chamber stops material building up on the walls. This is a significant advantage over many typical pyrolysis units. A second significant advantage of the Sulfree system is the lack of formation of waxes, which is a common problem in wholly thermal pyrolysis systems. It appears that microwave pyrolysis of rubber crumb significantly reduces the production of waxes, although the reason for this is unclear.

Energy and mass balance calculations have been carried out and the calculations estimate that the total cost of pyrolysis and oil treatment for 1 kilogram of crumb at steady state would therefore be 1 kilogram of crumb at steady state could be €1.62 (worst case scenario) or €0.17 at 90% efficiency of energy recovery from hydrogen.

During the project the following successes were achieved:

- Successful pyrolysis of rubber crumb using microwave technology
- One step “carbon black” production
- Modular design.
- Overall system designs for all sub-units to allow scale-up and installation at commercial end-user sites
- High efficiency process.
- Instant heating
- Internal reactor conveyance system
- Self cleaning
- Stop/start – semi continuous
- Low odour (clean process), low tar production
- Fine carbon black particle size
- Production of “carbon black” and “low sulphur oil” with significant resale value to make the system commercially viable
- Identification of a suitable HDS catalyst to remove sulphur from pyrolysis oil
- Optimised HDS process for the recovery of sulphur-rich gas and low-sulphur oil

The proof of concept for the Sulfree project has proved that this technology is now ready for progressing to the commercialisation of the process.

A video of the working plant has is available for viewing on the Sulfree project website at www.sulfree.eu

The main contacts of the consortium members who worked on this exciting project are:

- The UK Health & Environment Research Institute. (Coordinator)

  Contact: Simon Fawcett s.fawcett@pertechnology.com

- Autico Ltd

  Contact: Kevin Poole kevin.poole@autico.co.uk

- Crumb Rubber Ireland Ltd

  Contact: Leo Kerley leo@crumbrubber.ie

- Fricke und Mallah Microwave Technology GMBH

  Contact: Brais Vila b.vila@microwaveheating.net

- WLB LIMITED

  Contact: Marianna Vari mvari@wlbltd.eu

- Innora Proigmena Technologika Systimata Kai Ypiresies Anonymi Etaireia

  Contact: Vasilis Papadimitriou papadimitriou@innora.gr

- Azienda Speciale Innovhub - Stazioni Sperimentali Per L'Industria

  Contact: Gabriela Migliavacca migliavacca@ssc.it

- Material Y Equipos De Vidrio De Laboratorio SA

  Contact: Andres Del Alamo andres@mervilab.com