External note

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Confidential

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Department	Biomass & Energy Efficiency
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Subject Physical/Chemical analyses and general combustion behaviour characterisation of alternative fuels for Van Eck Power Station - Proponent METRECO

Introduction

Within the framework of the NamPower Van Eck Power Plant Alternative Fuels Programme, the Energy research Centre of the Netherlands (ECN) was commissioned (through NamPower tender NP/EOI/2015/01) to deliver broadly-scoped technical assistance in the assessment and implementation of alternative fuels at the Van Eck Power Station. This project envisages ultimately repowering of the Van Eck PS with a biomass-based fuel, to replace (a part of the) currently used hard coal.

A number of fuels have been received for testing from several proponents. In the course of 2016 and 2017, extensive analytical and dynamic combustion testing has been undertaken, which is in full described in a separate report (ECN-BEE-2016-130). This note describes the findings of the physical and chemical characterisation of the delivered fuel of Proponent METRECO providing a brief evaluation of the results. For confidentiality reasons no other proponents data are shown, nor used for comparison purposes.

Physical characterisation

General description/visual description

METRECO (Tyre shred)
A small-sized (< 5 kg) sample of the end-of-life-rubber tyre shred was received as one of the materials. A photograph of this material is shown in Figure 1.

The material obtained from the Proponent METRECO has a typical appearance for whole-tyre shred. It includes chunks of material, irregular in shape and ranging in diameters from < 1 cm to large particles with the longest dimension > 5 cm.

Figure 1: METRECO - photograph of the final product received at ECN for physical/chemical analyses and combustion testing.

The material features clearly recognisable layers of typical tyre composite, i.e. white nylon cords (ply), metal-wire carcass and rubber inner-liner as well as thread. All of the layers are still highly fused with each other and impossible to separate mechanically.

The metal wires stick out of the particles at all cutting faces, sometimes to a length exceeding the dimensions of the chips itself. This causes the chips to get entangled whenever they are drop-loaded, and making it very difficult to separate the particles from each other, which might be critical for the gravity-driven transport into the under-thrower feeder, as well as the feeding process itself.

(Bulk) Density

Bulk density was due to be determined by using the prescribed 10L measurement volume. Since there was not enough material delivered in this preliminary shipment, this volume had to be limited to 5L container.

METRECO (Tyre shred)
The density of the shredded tyres was determined to be around 440-450 kg/m^3. However, also here the measurement should be considered less reliable due to the low volume of the material available. Also, the tendency of the chips to become entangled, and hence compress less during drop in filling of the vessel, might be of much influence for the accuracy of this measurement.

Durability/dust formation testing

The tyres shred material was not found to form any measurable dust in handling, hence no physical testing was performed.

METRECO (Tyre shred)
This material was not tested due to limitations described earlier.

Dust explosivity testing

METRECO (Tyre shred)
This material was not tested for reasons explained earlier.

Self-heating and spontaneous ignition testing

METRECO (Tyre shred)
This material has not been tested for self-ignition behaviour.

Chemical composition characterisation

Proximate/ultimate analyses

A summary of the proximate/ultimate analyses of the batches received for testing is show next in Figure 2.

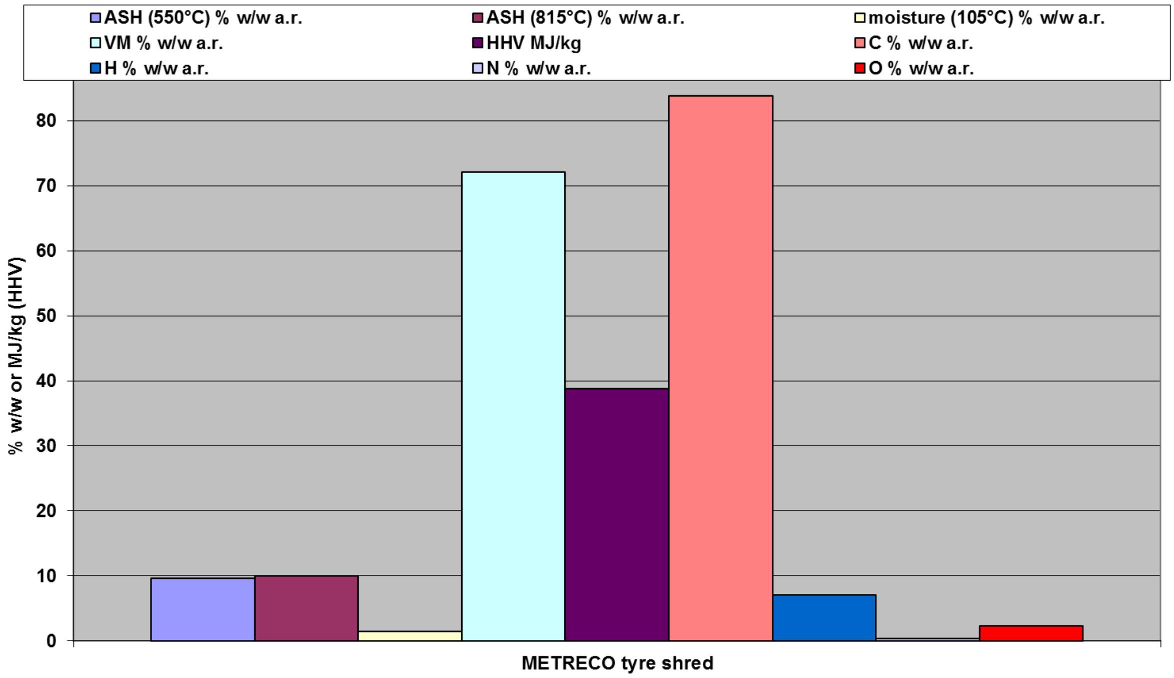

Figure 2: Graphical summary of proximate/ultimate analyses.

METRECO (Tyre shred)
The METRECO material is low in oxygen. This is well in line with the expected composition for rubber-based materials. Both natural as well as synthetic rubber hardly contains any oxygen. Also, the carbon black, used as the filler/heat resistant material is primarily composed of this element. At the same time it is quite volatile (72% d.a.f.) and calorific material (HHV of >38 MJ/kg).

The ash level is relatively low at just under 10 % at 550°C. It can be concluded that, likely the material delivered for testing was de-beaded. The increase in the ash content at the higher ashing temperature is caused by the partial oxidation of the main ash constituent - iron (vide infra).

Elemental analyses - main ash forming elements

A summary of the main, ash forming elements analyses of the batches received for testing is show next in Figure 2.

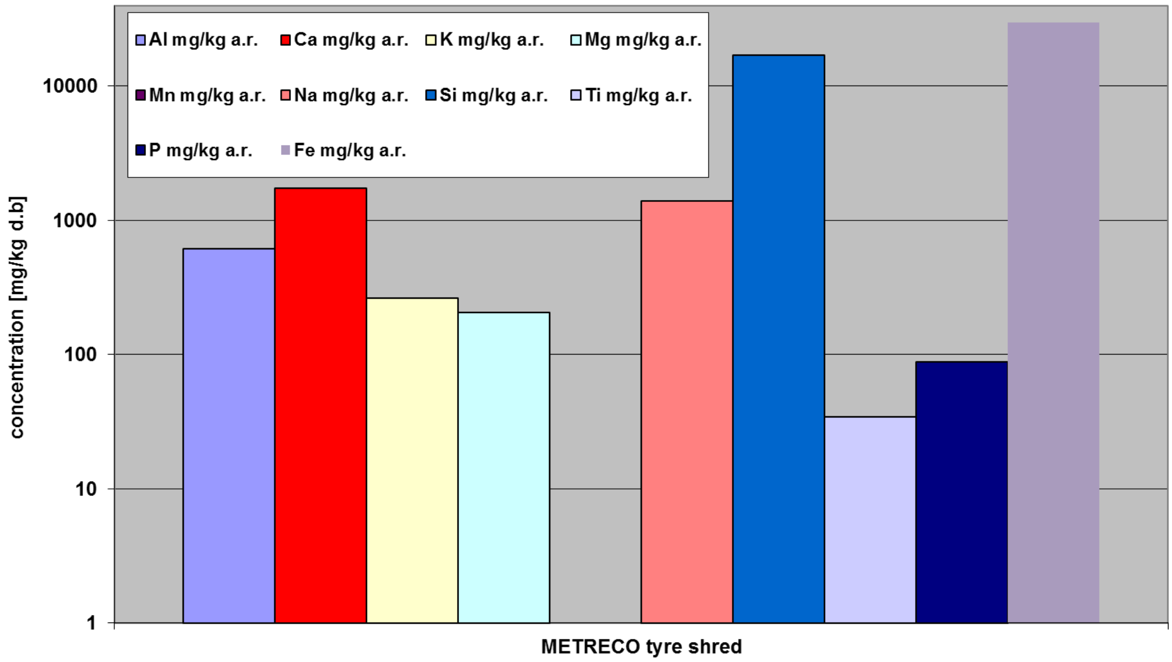

Figure 3: Graphical summary of main, ash forming elements analyses.

METRECO (Tyre shred)
The composition of the tyre shred ash is also well in line with the general material composition of tyres. The dominant element in the ash is iron (from steel wire used in the beading/carcass), making up almost 2/3 of the total ash load. The next major element present is silicon - most likely due to the use of (micro) silica as the friction-increasing material in the rubber. Next to these two elements, only sodium and calcium are present in noticeable amounts, but their concentrations are minor. At this point it is worthwhile considering the fate and the actual morphology of the ash freeing itself from the rubber matrix. A photograph of the raw tyre shred ash obtained from slow ashing of this material (pre-ground on a coarse cutter mill with a sieve size of 6 mm) at 550°C is shown next.

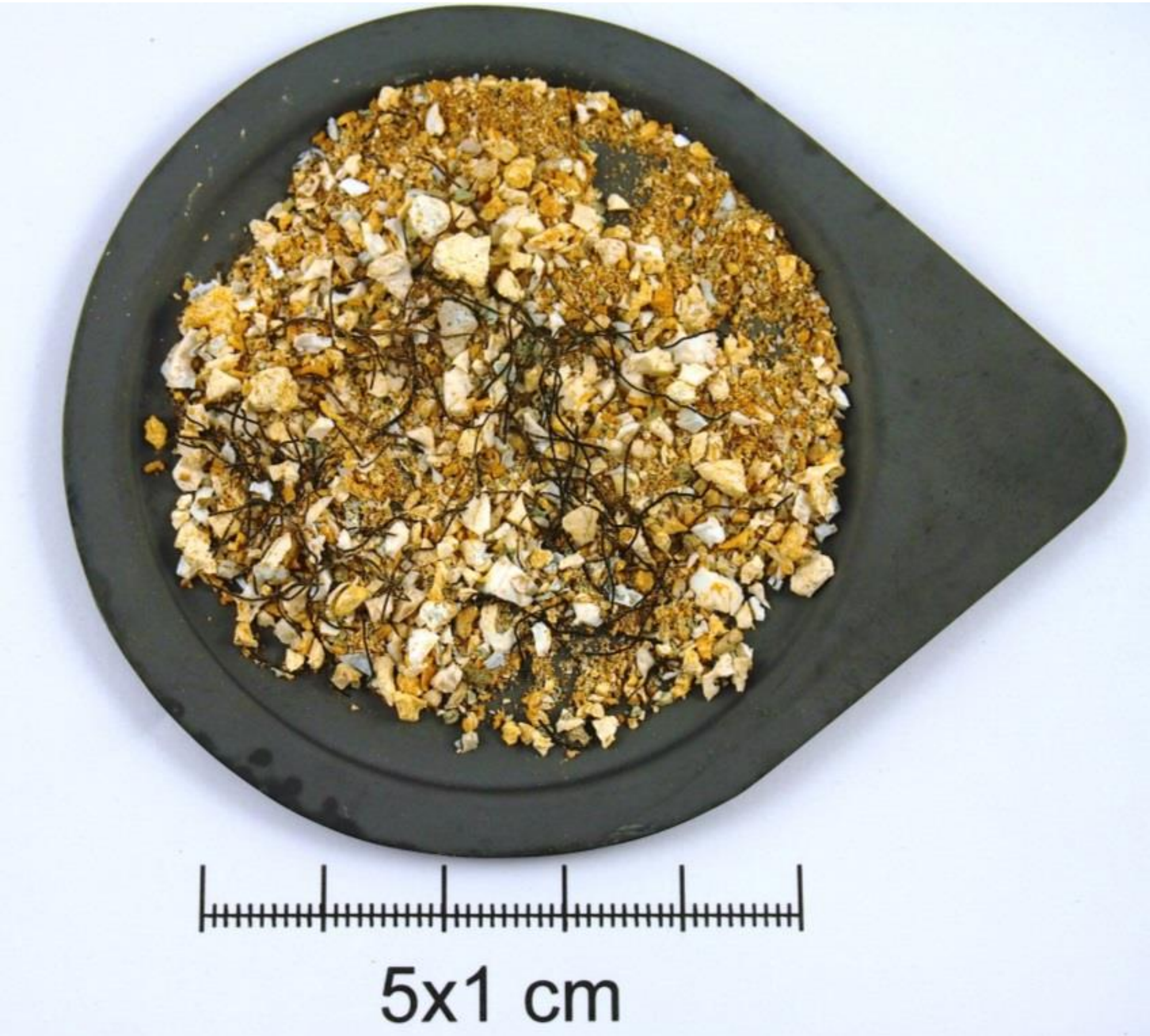

Figure 4: METRECO - photograph of the raw tyre shred ash, obtained after slow ashing at 550°C.

As can be seen in Figure 4, the ash is very inhomogeneous in nature, consisting of large (soft) lumps of material (presumably silica-based matrix from the rubber tyre components, note the size of the large entities close to the size of the pre-ground material) and more or less intact steel wires. Also, since the two main ash constituents actually are very poorly mixed in the process of combustion (since they are present in distinctive components of the tyre), their behaviour should also be considered as separate entities. In such case the silica-based matrix is likely to get entrained into the flue gas and may cause melting at relatively low temperatures above the grate, while the steel wires will only oxidise and break apart at high temperatures and extended residence times on the grate. The said wires can be problematic on the grate system, as they can cluster together and obstruct the air jet inlets of the grate or otherwise get entangled in the chain-like grid joints.

Ash behaviour - Ash fusion testing

The preliminary testing of the in-boiler ash behaviour, a standard ASTM Ash Fusion Test was undertaken. However, different from the coal-based standard, the biomass-based materials were ashed at 550°C, in order to avoid evaporation of the volatile components. Also, the ashing was done with thoroughly pre-ground fuels (integrally, to avoid loss of components) and very gradually, i.e. by slowly increasing the material temperature, degasifying under starved air conditions and only later exposing the degasified matrix to air. Result of the AFT performed with thus prepared ashes is shown in **Figure 5**.

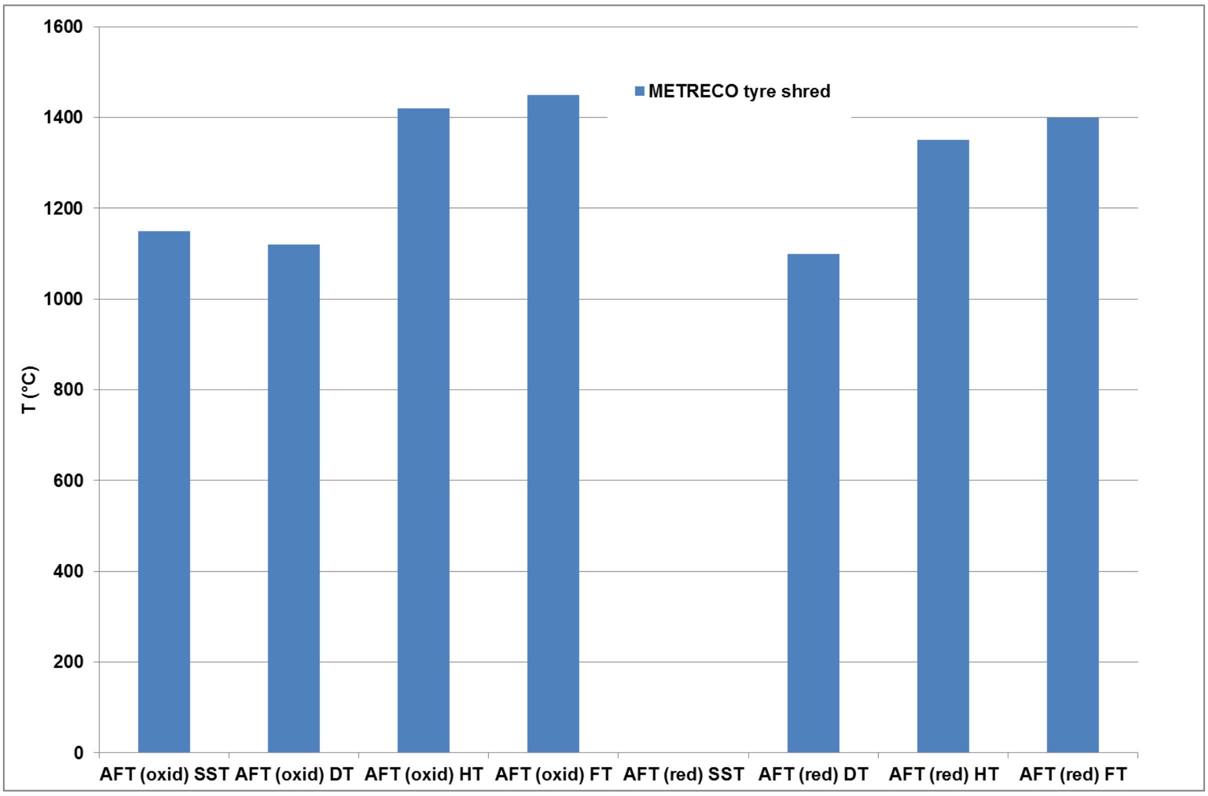

Figure 5: Graphical summary of Ash Fusion Test.

METRECO (Tyre shred)

The AFT results of the tyre shred are indicating some slagging risk. This material (besides the aluminium melting reported for RDF) shows the lowest softening and deformation temperature, in the range of 1100-1150°C. This is likely due to the presence of the silica. However it should be noted that also here, the dynamic behaviour might be vastly different from the "static" homogenised ash behaviour.

Conclusions/General evaluation of the potential fuels based on the evidence thus far.

METRECO (Tyre shred)
As of January 2017, this proponent is the least advanced of the current RFP, as it has not convincingly demonstrated the most basic aspects of the production and delivery scheme. Neither the feedstock collection scheme, nor the actual mechanical processing exist at the moment in Namibia. The delivered material, possibly also from South-African origin, shows some promising qualities, however many aspects disqualify this material as a viable alternative fuel for Van Eck PS site, at least in the current form.

The compliant aspects include:

- high calorific value with low oxygen content
- acceptable ash levels
- low native dust levels

The non-compliant/challenging aspects include:

- high volatile matter content
- very challenging mechanical properties of the chips, due to the steel wires entangling/clustering, posing likely problems with drop-feeding the material into the under-throwers and injecting the material into the boiler
- similar issues with the steel wires on the grate and ash disposal system
- possibly a challenging ash behaviour

Most of the challenging mechanical properties are due to the very poor quality of shredding/comminution, causing the wires of the tyre carcass to stick out of all cut surfaces.

NB: the main application of end-of-life tyres in Europe and North America, is whole-tyre combustion in cement kilns. This makes the energy-consuming shredding procedure completely unnecessary for the application of tyres as fuel. Furthermore, the cement production process can much more easily accommodate all of the tyre's inorganic components, without the need to remove the bead wiring.