Tyre Recycling

350PPM

Capitalist Solutions to Climate Change

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Introduction

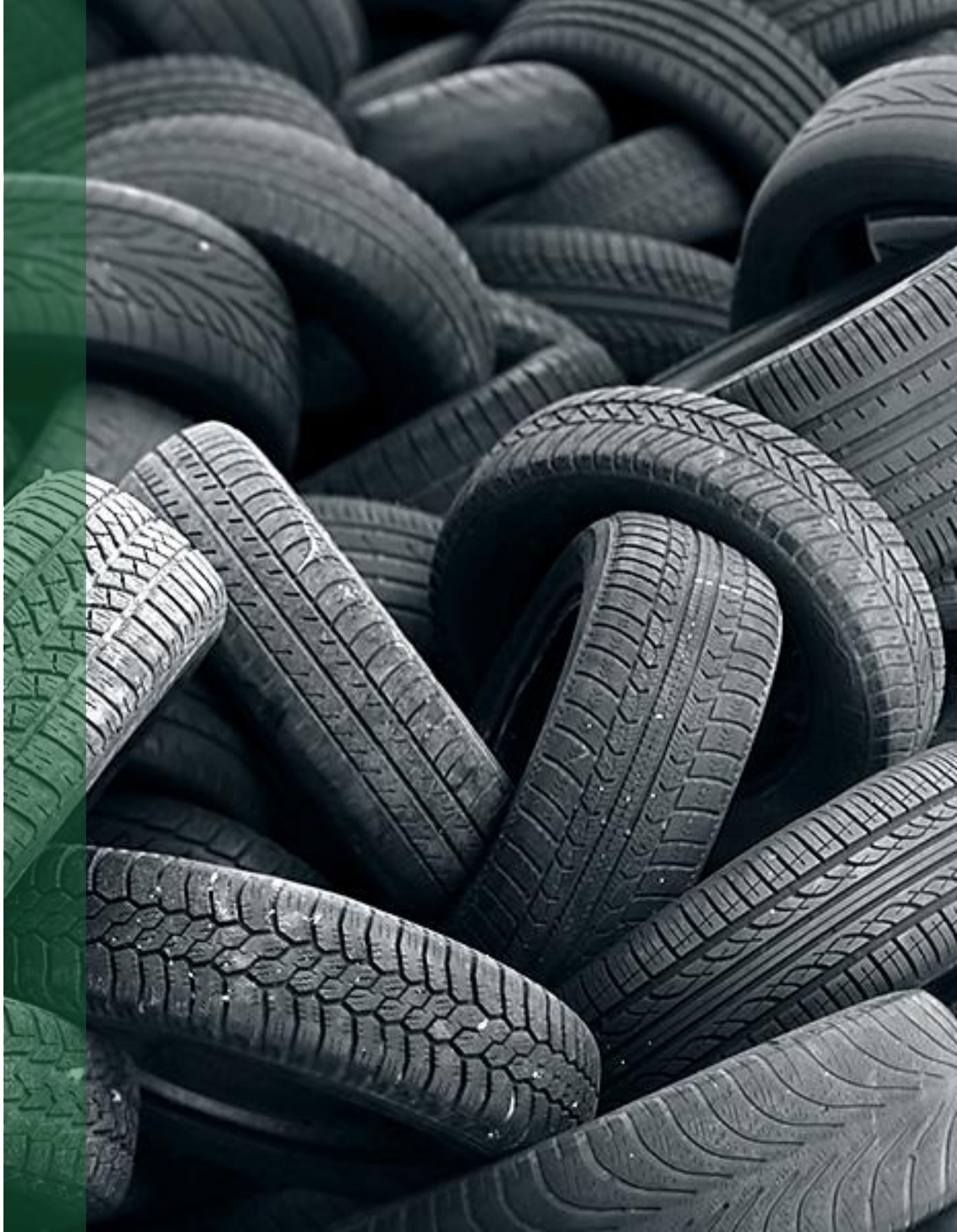
End-of-life tyres – henceforth ELTs - are a significant waste problem. Billions are generated worldwide each year, with billions more currently stockpiled. ELTs have a complex construction, meaning they do not naturally decompose (for decades) and are not easily recycled.

In this report we first examine what is currently done with ELTs. Typically they are combusted to reclaim their energy content, physically broken up for reuse in rubber products, or dumped in landfill.

Next we look at how ELTs might be dealt with more effectively - from both commercial and environmental perspectives - in the future. Our focus in on recycling using pyrolysis, the thermal decomposition of materials in the absence of oxygen.

The outputs of this process are oil – with ~40-50% renewable content – recovered Carbon Black (rCB) and steel, all major global markets. Use of these recycled outputs avoids the manufacture and associated environmental impact of the virgin materials they replace.

Although tyre pyrolysis has been slow to emerge as a commercially viable solution in developed countries, there are signs the industry is now finding its feet. This therefore represents the perfect time for investors to explore the sector. Even at just 10% of its current worldwide market potential, pyrolysis could potentially transform ELTs into over a billion pounds of yearly revenue.



Contents

Background

Tyre Composition

Pneumatic tyres have a complex construction – see **Figure 1** – which is built from a surprisingly large number of materials (one example tyre has ~90 distinct constituents). The details vary slightly by tyre type and manufacturer.

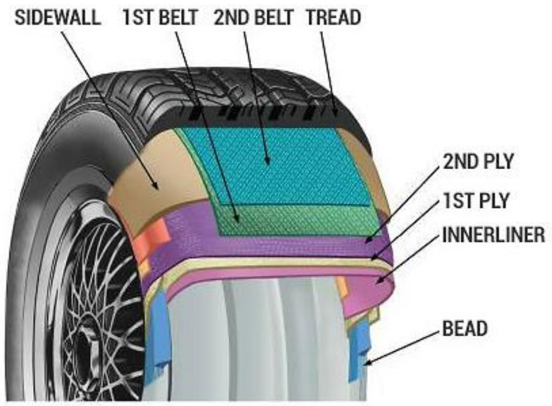


Figure 1 – example tyre construction. Source.

Tyres are typically made from:

- **Rubber**, both natural (from rubber plants, with associated impact on land use, water consumption, etc.) and synthetic (from oil or natural gas).
- **Fillers**, mainly **carbon black** - a form of powdered carbon, highly polluting in its traditional production, covered in detail later - or silica. These reinforce the rubber, improving its physical properties.
- **Steel wire**. This provides structural support.
- **Textile**, such as polyester, rayon or nylon. In lighter vehicles, textile provides structural support, reducing the need for steel wire.
- Other minor ingredients include **zinc oxide** and **sulphur**, both used in the hardening of rubber, and numerous additives (our example tyre has 40 different chemicals, waxes, oils, pigments, silicas & clays).

Figure 2 shows the relative composition of a typical new truck tyre. At end-of-life, relative rubber content is lower. Tyres for lighter vehicles have ~5% textile, reduced steel and natural rubber contents, and higher synthetic rubber content.

Though only one aspect of a much broader environmental impact, creation of one car tyre is estimated to produce 31 kg-CO_2e; truck tyres considerably more.

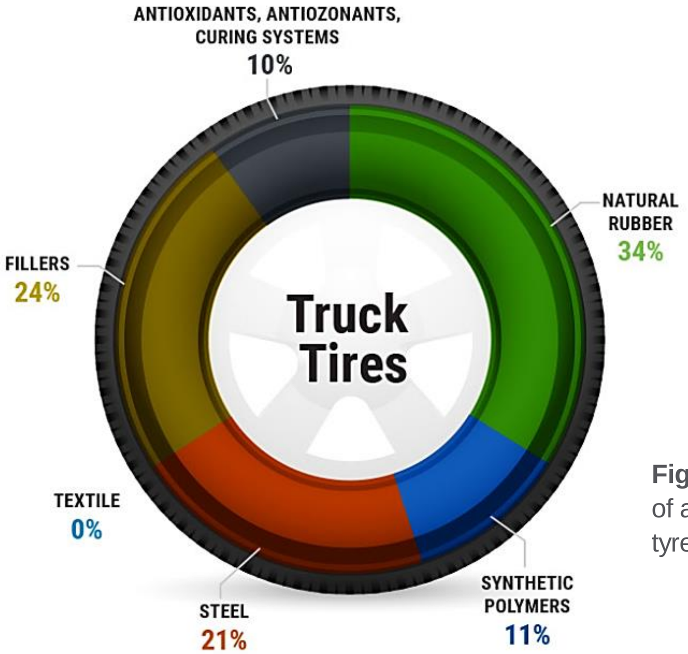


Figure 2 – composition of a typical new truck tyre. Source.

Scale of The Problem

This year it is estimated that 1.8 billion ELTs will be generated worldwide, up ~30% since 2014, see **Figure 3**. Approximately 4 billion more ELTs are estimated to be sitting in stockpiles around the world (these are just the ones we know about). Together, these two sources of ELTs present a monumental and growing waste problem.

As the world population and middle class fraction of this expands – both well established trends - demand for both personal and goods transport is likely to grow. This implies increased future demand for new tyres and therefore increased generation of ELTs a few years later. So, what do we do with them all?

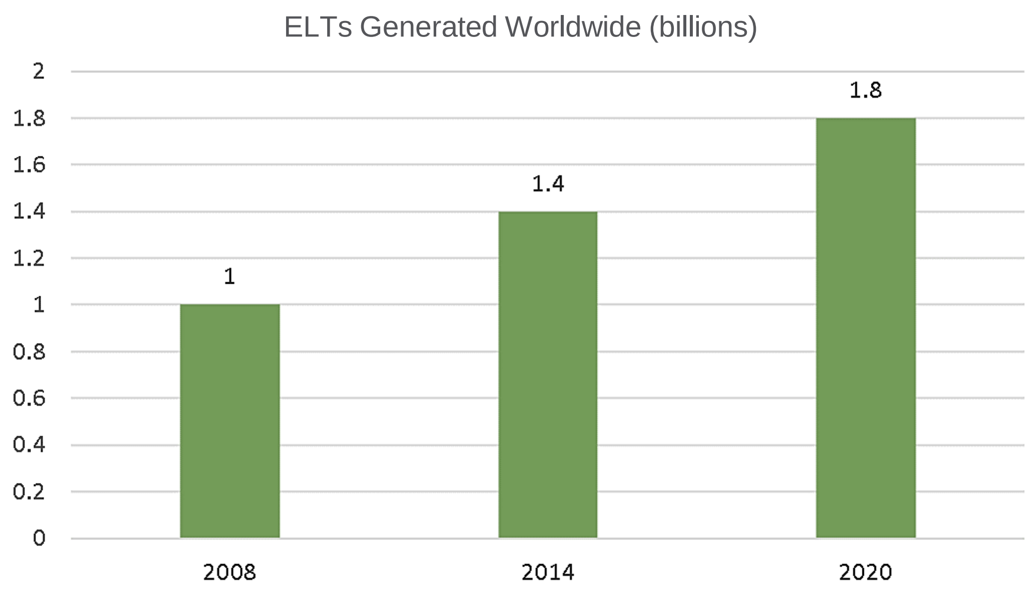


Figure 3 - billions of ELTs generated worldwide in given years. 2020 figure is estimate based on 2016 market forecasts and assumed four year lag from new tyre to ELT. Source.

Dealing with ELTs

When a tyre becomes worn to the point of being dangerous and illegal there are several options - retread, dump in landfill, use as fuel, reuse whole, or recycle by physically or thermally breaking up the tyre.

Retread

Before considering some form of disposal, there may be the option of having a tyre retread. Tyres are designed to allow for this possibility. This delays the manufacture of a replacement tyre and associated environmental impact. Retreading involves replacing just the outer part of the tyre, see picture below - most of the tyre remains sound and is untouched during the process. It is estimated that 50% of truck and bus tyres in the UK have been retreaded and that 90% of aircraft tyres are retreads. Retreading car tyres is also possible, though less common.

Unfortunately, the retreading process can only be performed a limited number of times before the tyre becomes truly end-of-life. Whilst aircraft tyres are typically retreaded many times, commercial vehicle tyres are retreaded only two or three times, and a car tyre once, if at all.

Dump in Landfill

Once tyres reach end-of-life the simplest thing to do is simply to dump them in landfill, if there is space.

Reasons why this is not a sound option include:

- The lack of circularity - the material and energy content of the tyre is lost, rather than reclaimed.
- The practice is not sustainable. Tyres take up a large volume of space, with 75% of that space simply empty air. And, as tyres do not naturally break down for decades - they are designed to last - the volume of space needed to hold dumped tyres will grow inexorably.
- There are concerns that tyres - when they do eventually break down - will leach toxins into the soil, surface water and groundwater. This may be true to some extent, but one literature review concluded 'human health concerns are minimal'.
- There are concerns about tyres trapping water and acting as a breeding ground for pests. Mosquitoes are a particular worry in certain climates.
- Though they do not start spontaneously, tyre fires are highly polluting and hard-to-extinguish. A 1998 Welsh tyre fire burnt for 'at least 15 years'.

For these and other reasons, dumping tyres in landfill is banned in many countries, including the UK and EU, where both whole and shredded tyres are included in the ban since 2006. In these locations tyres are therefore forced into an energy or material recovery process, or some combination.

Use as Fuel (Energy Recovery)

A potentially more sustainable strategy than landfilling is to combust tyres in a controlled manner to reclaim their energy content. This energy content is high, approximately 20% more than coal by weight. Usually in a shredded form known as ‘Tyre Derived Fuel’ (TDF), tyres can be mixed with coal or other fuels to be burnt in cement kilns, power plants, district heating systems and pulp and paper mills, to name a few examples. Emissions from the combustion of ELTs are an obvious environmental problem, though these are similar to conventional fossil fuel emissions (other than zinc content) if combustion is properly designed and controlled, according to the US EPA (Environmental Protection Agency).

As we quantify later, use as a fuel is one of the most common endings for ELTs. In the case of cement production, ELTs act as more than simply a fuel - roughly 25% of the inorganic material in the tyre is incorporated into the cement as well. This leads us onto the concept at the heart of this report – recycling.

Recycle (Material Recovery)

Given the flaws with the above methods, it would be neat if ELTs could be recycled directly back into new tyres. And, this is feasible to some extent - ELTs *are* recycled back into solid rubber tyres, such as those used on supermarket trollies, if on a small scale. However, wholescale recycling of ELTs back into standard pneumatic tyres is not practical, with the inferiority of tyres containing recycled rubber the apparently fatal flaw. Our options are therefore limited to:

- Finding another purpose for the whole tyre (strictly repurposing not recycling).
- Physically breaking up the tyre, at sizes ranging from paper-sized all the way down to a fine powder.
- Thermally breaking up the tyre into a range of chemicals. This is our focus.

The output of the physical or thermal decomposition process may have a direct use, or act as an input for the production of secondary products - even tyres in the case of thermal decomposition - see **Figure 4**. **Figure 5** summarises recycling options.

Figure 4 - diagram illustrating the circularity in the life cycle of a tyre. Percentages are 2017 European figures. Source. Higher resolution version can be found at the source.

Civil Engineering

Civil engineering applications provide common examples of repurposing and physical breakdown of ELTs.

Whole tyres are repurposed in civil engineering applications as diverse as coastal protection, erosion barriers, artificial reefs, breakwaters, avalanche shelters, slope stabilisation, road embankments, landfill construction operations, sound barriers and insulation.

Shredded tyres intended for use in civil engineering applications are called 'Tyre Derived Aggregate' (TDA). TDA is used as a replacement for some materials commonly used in construction. These include soil, clean fill, drainage aggregate, and lightweight fill materials such as expanded shale and polystyrene insulation blocks. TDA is therefore used in filling, insulation, vibration attenuation and drainage applications.

Ground Rubber

ELTs are most often recycled by being physically broken down into rubber chips, crumb or powder, depending on the application (the steel is removed). See **Figure 5**. Applications include use in moulded rubber products, playground mulch, sport surfaces and rubber modified asphalt. This type of asphalt is not widely used but is claimed to have desirable properties such as increased life span, reduced noise pollution and increased safety in wet road conditions.

To address a widely aired concern, Health Protection Scotland concluded that 'there is a clear consensus…which does not support the hypothesis that exposure to tyre crumb used in artificial surfaces poses a significant risk to human health.' Despite this, the perception remains, and some recycling companies feel the need to distance themselves from this use of ELTs.

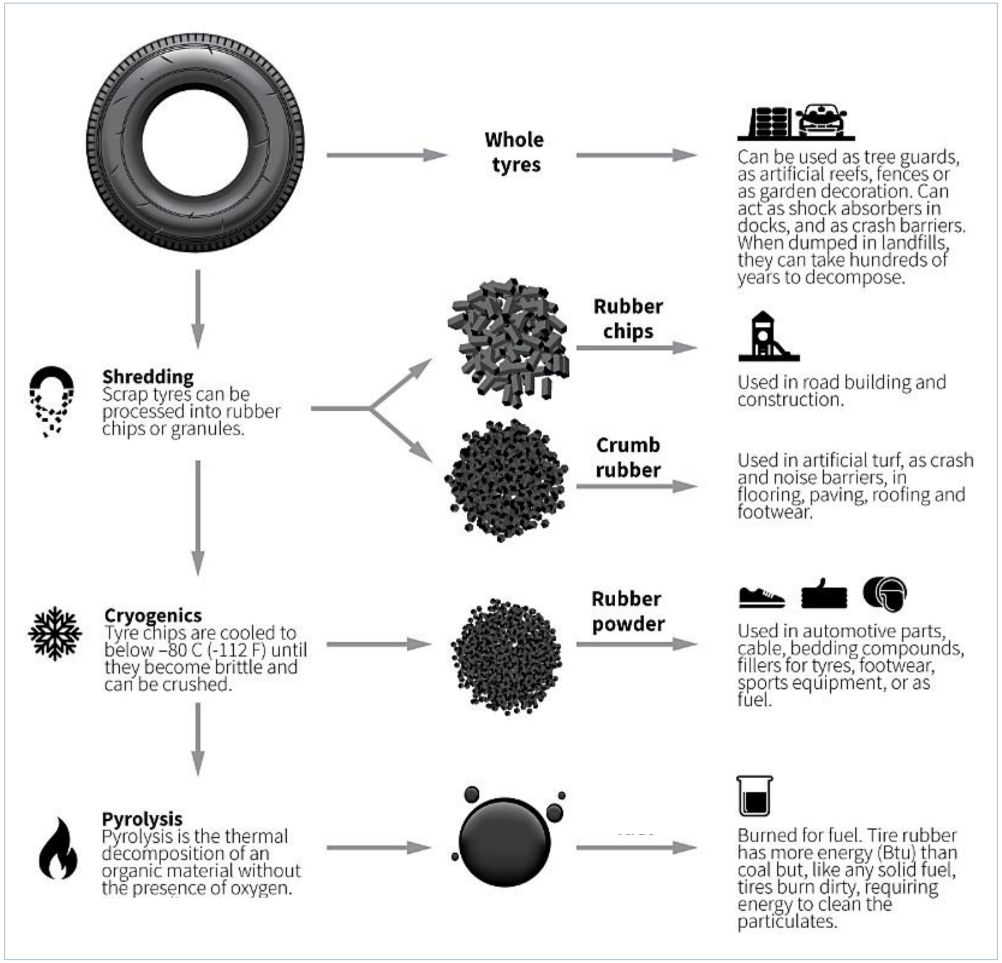


Figure 5 – material recycling options for ELTs. Source: European Tyre Recycling Association.

Thermal Recycling

The recovery options discussed so far have historically been the only ways of diverting ELTs from landfill. Looked at from a commercial angle these options have their disadvantages, including, in some cases, niche end-markets with limited scale-up potential.

Compared to these, the recycling of ELTs by thermal decomposition is a less established recycling route but with promising scale-up potential. Tyres possess technical qualities that make them an ideal feedstock for thermal decomposition processes such as pyrolysis, gasification or liquefaction (PGL). These processes use heat to break up ELTs but do not involve combustion. Other feedstocks can be used but tyres provide a widely available and consistent feedstock, with valuable outputs.

According to one journal review article, when compared to operations that utilise combustion of ELTs, it is 'generally accepted that these {PGL} technologies yield equal or lower environmental risks in most cases'; specifically, the exhaust gases require less cleaning, making the control of air emissions less costly and complex. Nevertheless, running clean thermal recycling plants is non-trivial, with the extent of environmental regulation an important factor in commercial viability.

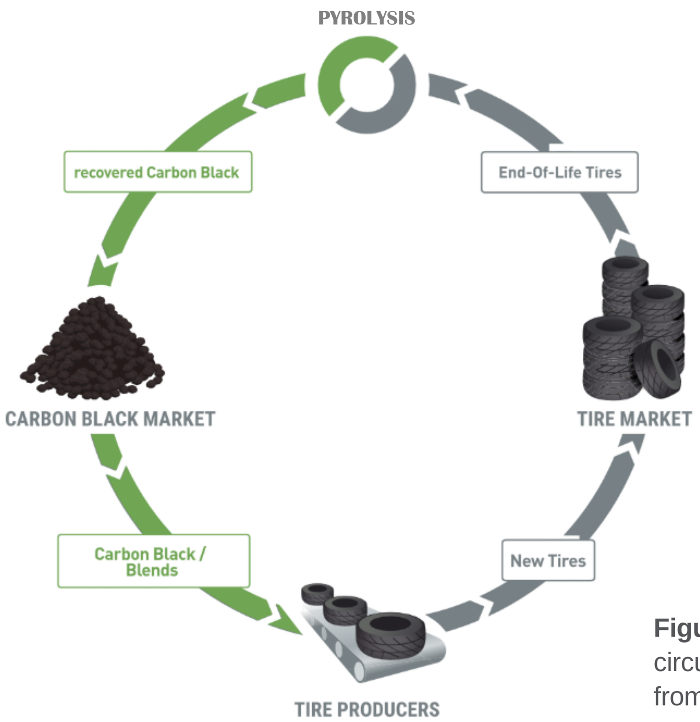


Figure 6 – diagram illustrating how pyrolysis introduces circularity into the life cycle of a tyre. Source (adapted from).

Pyrolysis

Our focus is on the pyrolysis of ELTs, the thermal recycling method whose commercialisation is being most visibly pursued. As a very rough rule of thumb, pyrolysis can extract products with a value tens times that of TDF (Tyre Derived Fuel, mentioned earlier). For more on gasification and liquefaction, and a comparison with pyrolysis, see the Appendix and the above journal article. Pyrolysis and gasification were also covered in our Recycling Plastics report.

Pyrolysis is the thermal decomposition of (organic) materials in the absence of oxygen. As we explore later, the main outputs with ELTs as the input are oil, recovered Carbon Black (rCB) and steel, all valuable products with global markets. Although it has many applications, rCB can be used in the production of new tyres as a sustainable, low cost substitute for virgin Carbon Black, see **Figure 6**. If we can't recycle whole old tyres back into to whole new tyres, then this is the next best thing.

Skip to section on pyrolysis

Tour A Pyrolysis Plant…

Link to company videos:
ReOil
Scandinavian Enviro Systems
Black Bear Carbon

What Currently Happens with ELTs?

Having outlined the processing options for ELTs in the preceding section, we now quantify the current situation. **Figure 7** shows figures for ELT destination in the USA. Note that shredded tyres still go to landfill in 40 states, with whole tyres allowed in 10. This presents a good opportunity for the tyre recycling sector if and when regulations fall into line with other parts of the developed world.

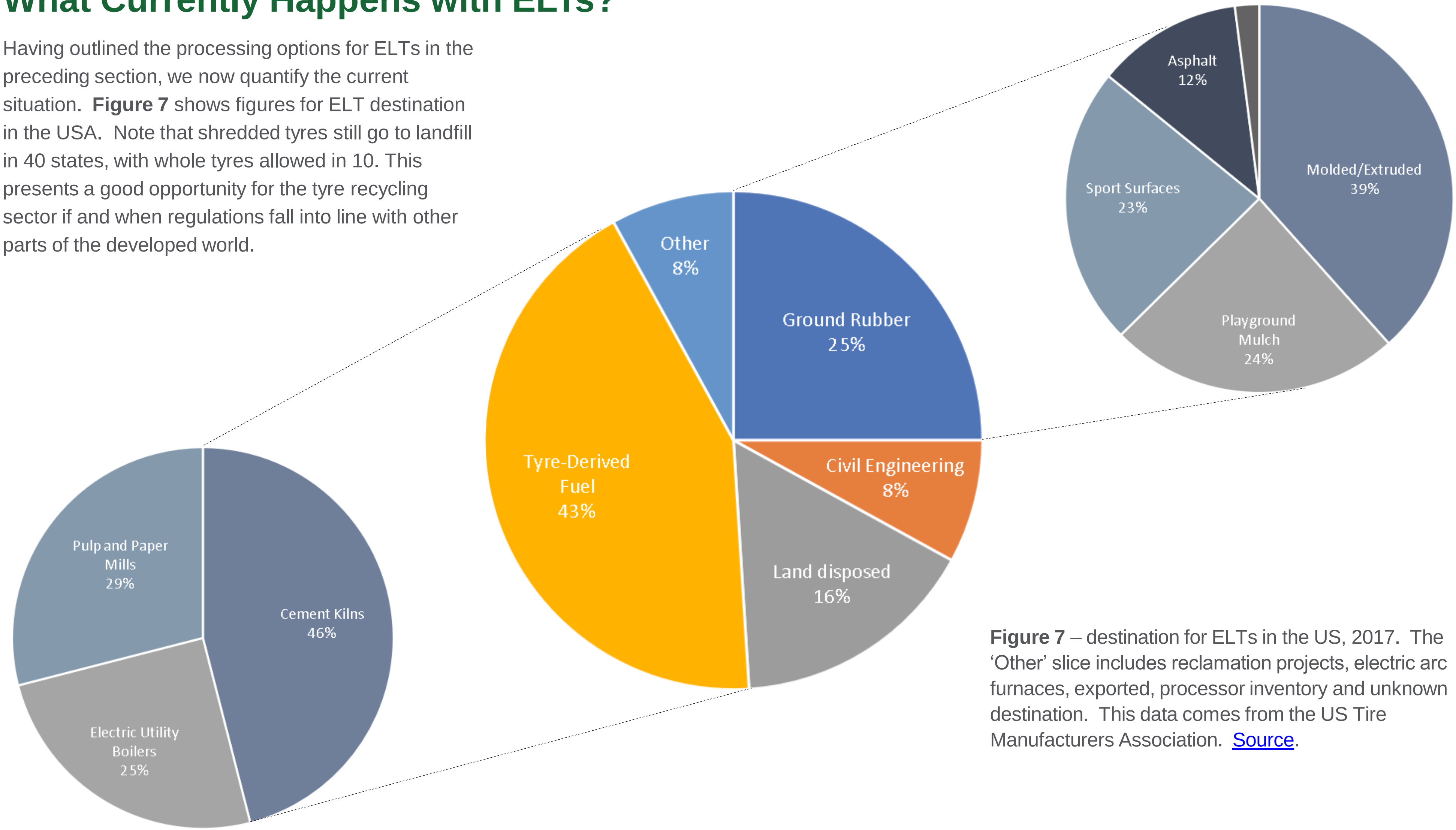


Figure 7 – destination for ELTs in the US, 2017. The 'Other' slice includes reclamation projects, electric arc furnaces, exported, processor inventory and unknown destination. This data comes from the US Tire Manufacturers Association. Source.

As mentioned previously, tyres in any form cannot legally go to landfill in the UK or the EU. This means that a significantly larger fraction of tyres are recycled than in the US, with ~50% of all EU ELTs ending up as ground rubber (double the US figure). **Figure 8** shows figures for the UK. These are similar to the EU figures; see the source for more detail.

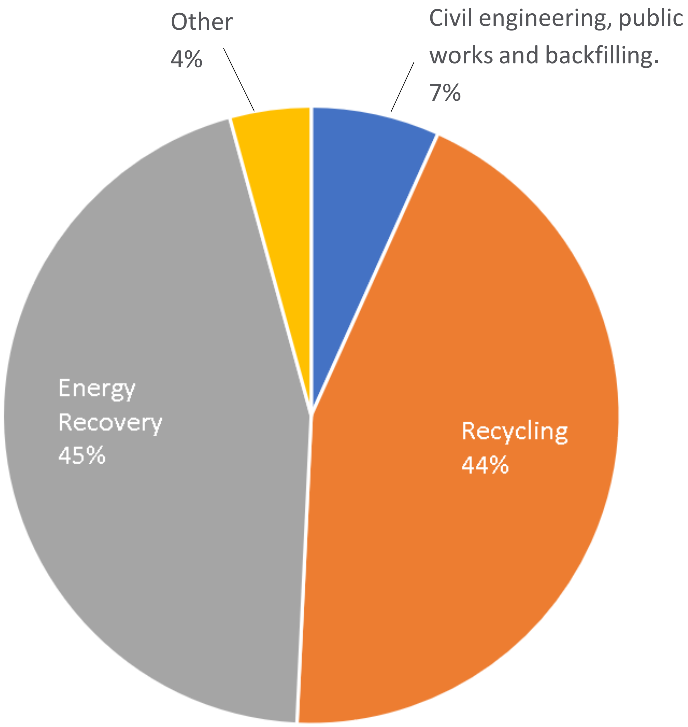


Figure 8 – destination for ELTs in the UK, 2017. The 'Other' slice consists of 'unknown destination' plus 'waiting to be processed'. This data comes from the European Tyre & Rubber Manufacturers' Association. Source.

Although **Figures 7** and **8** do not mention pyrolysis, the statistics on which **Figure 8** is based show that 0.4% of EU tyres were processed by pyrolysis in 2017. Additional capacity has come online since. Other parts of the world – chiefly China, India and Africa - use pyrolysis much more widely. However, these tend to be small, low-tech plants, often with low environmental standards.

Three different regulatory systems exist for managing ELTs in the EU/UK:

- **Extended Producer Responsibility (EPR)** – this obliges producers to ensure that products it has created are disposed of in an environmentally sound manner. The majority of Europe uses this system.
- **Free market system** – this works by legislating what must happen but does not designate those responsible. All operators in the recovery chain must together act in compliance with the law. The UK has a 'managed free market system' in which ELT collectors and treatment operators must report to national authorities. However, there are plans to shift to a producer responsibility system.
- **Tax system** – a tax is levied on tyre producers, with the proceeds used by the government to fund ELT disposal.

Overall, these systems work - most ELTs are known to have been treated in some manner (93% for EU 28). However, there is an international trade in ELTs, with the UK 'the largest exporter'. This can lead to tyres ending up in countries with lower environmental standards and would present a problem if currently receptive countries – such as India - were to stop accepting ELTs.

As we cover later, the UK is actively supporting the use of sustainable fuels made from ELTs. However, aside from such initiatives, the policy environment is not ideal. For example, in the EU and UK there is some complexity and potential financial burden associated with pyrolysis derived products being classified as 'end-of-waste' (or not). In general though, regulations and markets are moving in a supportive direction. This is likely to continue in the future, in our opinion.

Carbon Black

A recycled form of Carbon Black (CB) is one of the outputs of tyre pyrolysis. As some may have no knowledge of this material we provide a short introduction in this section.

CB is a ubiquitous filler, added to materials such as rubber and plastic to reduce cost without compromising on quality. CB bestows desirable qualities into products including strength and abrasiveness (for tyres), conductivity (for cable coating) and colour properties (for inks and paints).

CB in its pure form is a fine black powder, composed of elemental carbon and small amounts of other elements, referred to as impurities. Different CB applications tolerate and often require the presence of certain impurities.

CBs are categorised into different grades, according to the physical properties of surface area and structure. Different grades are suitable for different applications. Tyres, for example, require several grades of CB for different parts of the tyre, ranging from N110 to N772. Lower grade numbers imply a smaller particle size and a more reinforcing CB. [More details on the technical aspects of CB](#).

Traditional manufacturing of the main CB grades (furnace grades) involves the incomplete combustion of heavy aromatic oils such as residual fuel oil, raw coal tar, or cracked ethylene tar. Typically, producing a single kg of CB requires between 1.5 kg and 2 kg of oil (varies by source).

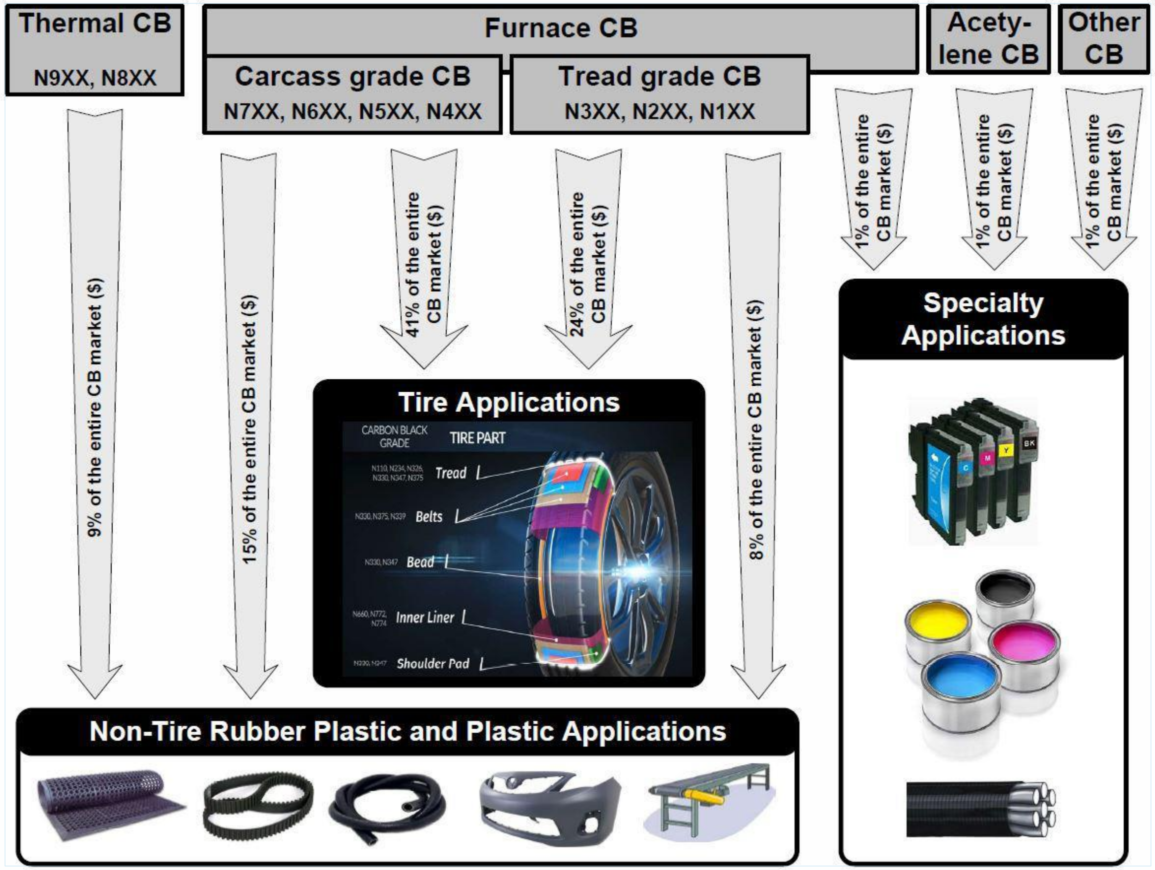


Figure 9 – the carbon black market by production method, grade and application. Source.

Combustion of oil at all is bad for the environment, but incomplete combustion of oil is even worse. Each tonne of virgin CB produced results in approximately 2-2.5 tonnes of CO_2 emissions. NOx, SOx and PAH are also formed. PAH (polycyclic aromatic hydrocarbons) are a group of contaminants that can find their way into food.

Market

To repeat, CB is a ubiquitous material and therefore a highly valuable one. Its price is highly correlated to the price of crude oil. Recent prices range from €1200 - €1400 per tonne, with more reinforcing CBs more expensive.

Figure 9, on the previous page, breaks up the CB market by production method, grade and application. **Figure 10**, right, shows historical and predicted future CB production by application. As obvious from **Figures 9** and **10**, the growth in CB production is closely linked to the automotive industry and to tyre production, given this is its main use.

Pyrolysis company Scandinavian Enviro Systems notes that there is a steady trend toward concentration and consolidation among CB producers; petroleum companies have scaled back their production of CB, and the sector is now dominated by chemical companies whose main product is CB. All the major producers are global players, with Asia dominating production and consumption.

Converting **Figure 10** to an approximate dollar amount, the CB market is conservatively forecast to be worth ~$17 billion this year and ~$20 billion by 2025. A CAGR (Compound Annual Growth Rate) of roughly 4% is implied from 2020-2025. Other forecasts seen by us are in this ballpark.

Despite this rosy picture, increasing environmental costs, especially in the USA, have resulted in the more environmentally inefficient CB plants being closed and prohibited the commissioning of new plants in the USA. This provides a market opportunity for recovered Carbon Black (rCB), one of the outputs of tyre pyrolysis.

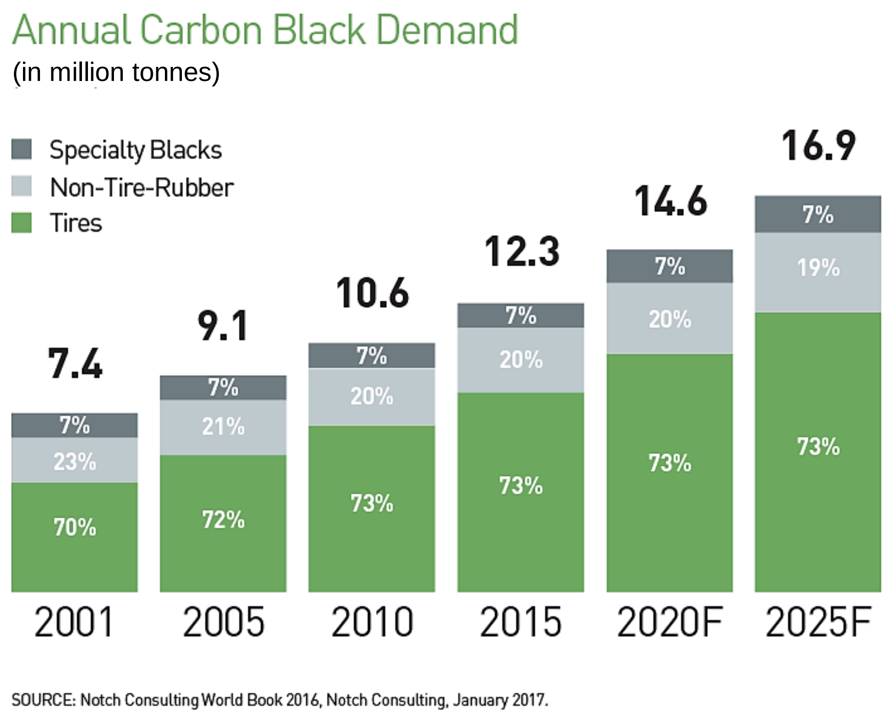
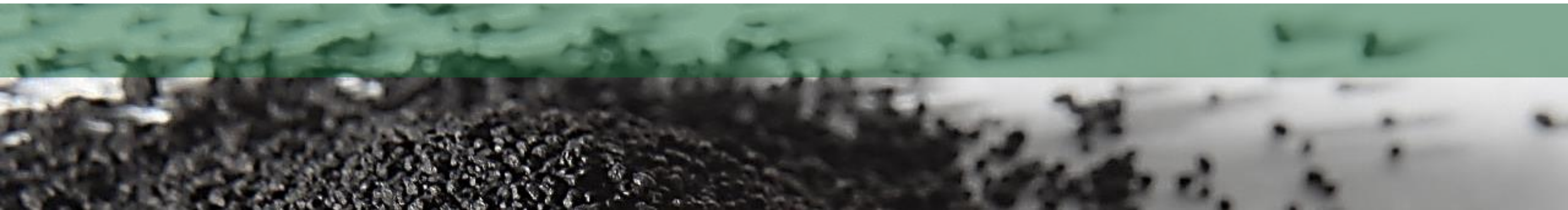


Figure 10 – historical and forecast carbon black demand by application. Source.



Tyre Pyrolysis

Put simplistically, tyre pyrolysis is a process which takes tyres and turns them into three saleable products - steel, oil and recovered Carbon Black (rCB). See **Figure 11**, which shows typical output proportions. These proportions can vary slightly depending on the type of tyre and the technical details of the process, which involves heating to ~600^{O}C for a few hours in the absence of oxygen (see this journal article for more technical detail). A mixture of gases is also output, but this is combustible and is usually fed back into the process to provide heat, so acts as a reduction in operating costs, rather than a saleable output.

A complication to the above picture is that the initial outputs are actually steel, a low value oil and a low value solid. This presents the option to sell these as is – if feasible - or to upgrade to more valuable products, at a cost.

Pyrolysis plants can be categorised by the following properties, at a minimum:

- **Feed process – batch or continuous**. Batch feed entails inserting discrete quantities of tyres into the reactor at fixed intervals. Continuous feed is self-explanatory. Companies claim superiority of both methods.
- **Throughput** - the weight of tyres a plant is designed to process annually. Commercial scale plants are being built in the 20-40k tonnes/annum range.
- **Input/output processing** - the extent to which a plant processes inputs and outputs. Onsite pre-processing can decrease input costs and, as just mentioned, post-processing is used to increase output value.

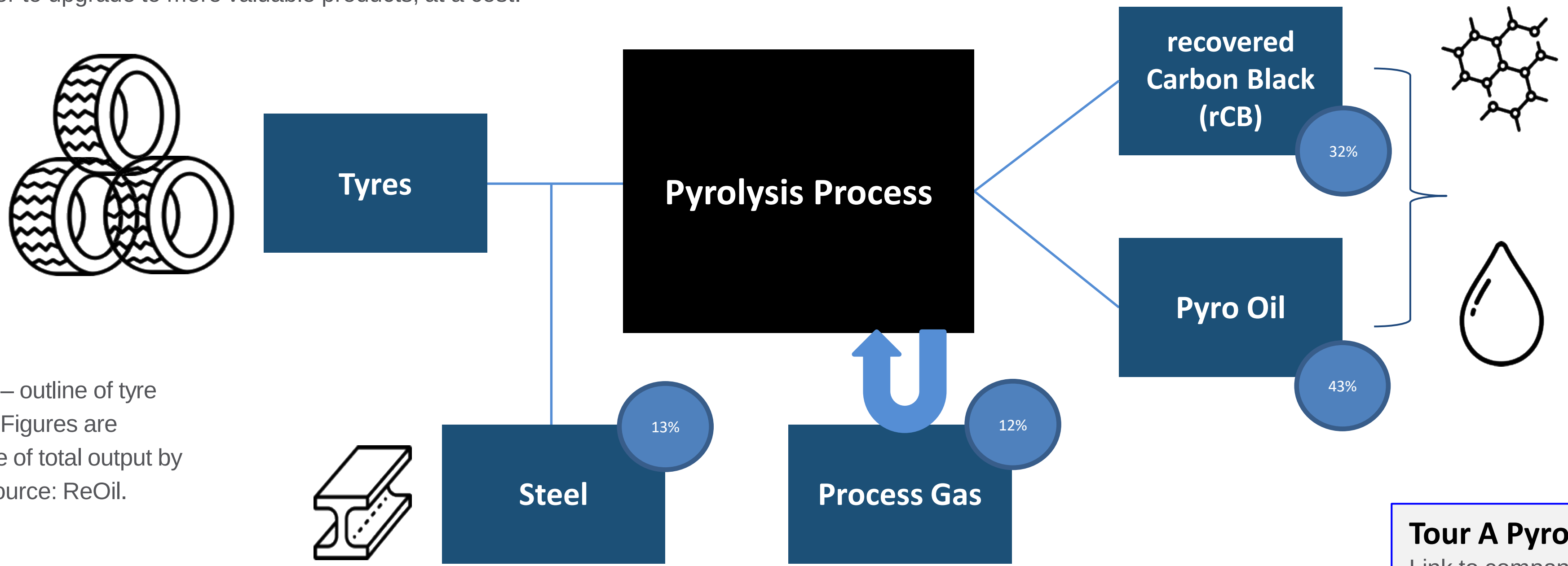


Figure 11 – outline of tyre pyrolysis. Figures are percentage of total output by weight. Source: ReOil.

Tour A Pyrolysis Plant…
Link to company videos:
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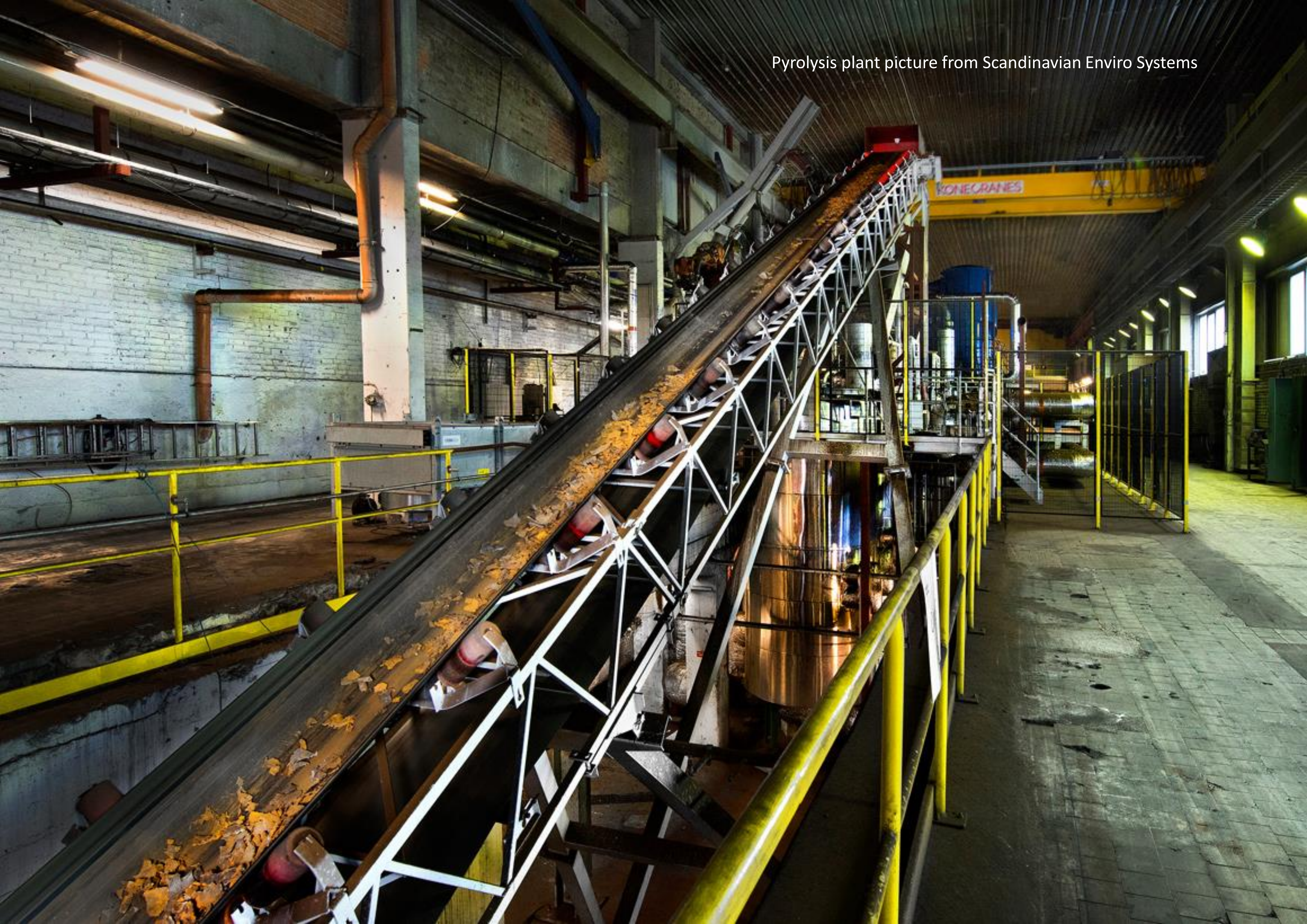


Pyrolysis plant picture from Scandinavian Enviro Systems

Inputs

Tyres

A pyrolysis plant cannot operate without a reliable source of suitable input tyres that matches the plant's throughput. These may be in the form of whole tyres, or as tyre crumb (pieces sized from ~2-10cm, with the steel removed).

If a plant accepts whole tyres, then equipment is needed to break the tyre into tyre crumb and to remove the steel (though not all plants require steel removal). This adds to capital and operating expenses. The big advantage is that it may be possible to charge a gate fee to receive whole tyres, rather than having to pay for the tyre crumb, turning a cost into income. In addition, the extracted steel can be sold, as covered later.

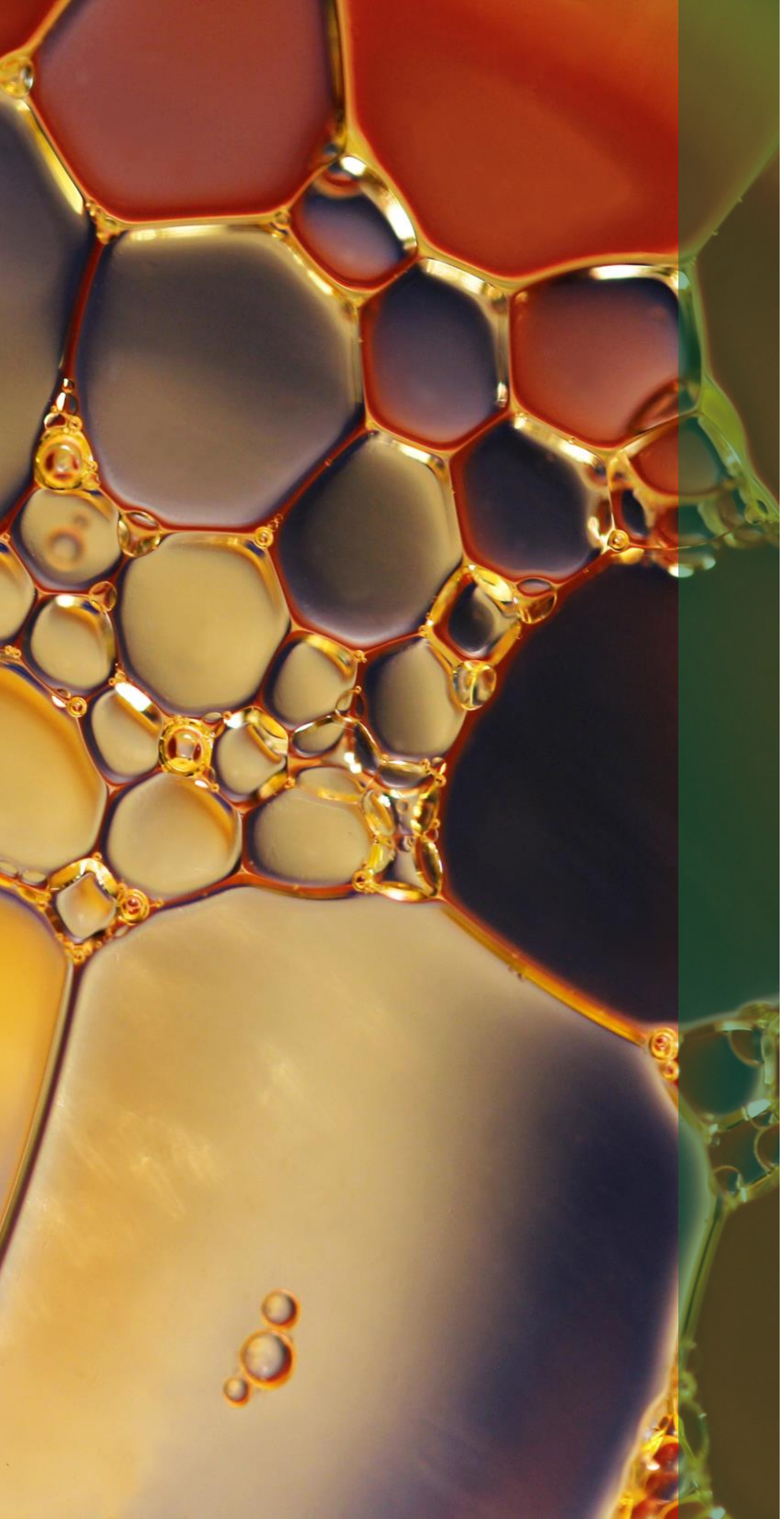
Example Recent Prices (quoted by ReOil)

Tyre crumb *cost*: up to €80/tonne (currently ~£72/tonne).

Gate fee *received* for whole ELTs: €40/tonne. This gate fee will need to be competitively priced to divert existing tyre steams from their current destination.

Other

A pyrolysis plant also requires additional inputs, typically natural gas (to start-up the process), water (for cooling of condensable gases into pyrolysis oil), nitrogen (to empty the reactor of air) and electricity. Post-processing of the oil, if performed on-site, may require additional inputs such as hydrogen and fuel additives.



Outputs

Pyrolysis Oil

Pyrolysis oil is the main output by weight. In its initial from it is a low value mixture of hydrocarbons – paraffins, olefins, and aromatic compounds - with a high energy content. This mixture can be partially used on-site, sold unrefined, or, if the pyrolysis plant has the equipment, can be upgraded to improve its value for use as a fuel or chemical feedstock. There is usually a slight loss of yield by upgrading.

Upgrading to a heating or fuel oil is least complex and costly. Fuel oil is used for industrial combustion, primarily for power generation and as a bunker fuel for ships. A more advanced and costly option is to hydro refine the oil into higher value drop-in fuels such as low sulphur petrol (EN228) or diesel (EN590). According to pyrolysis company ReOil, lifecycle greenhouse gas emissions of these fuels are 94.5% lower than fossil fuel comparators, meaning 1.65 tonnes of CO_2 savings per tonne of ELT capacity.

As a drop-in fuel, pyrolysis oil has value over and above the raw price of the fuel in some countries. This is because it (a) comes from waste (b) contains ~40-50% biogenic material, from the natural rubber. For example, in the UK the Renewable Transport Fuel Obligation (RTFO) is an obligation on suppliers of transport fuels to demonstrate that a proportion of their fuels comes from renewable sources. These proportions ramp up over time, with the obligation lasting till at least 2033. As a waste-derived biofuel, fuel from ELTs is potentially eligible for two Renewable Transport Fuel Certificates (RTFCs), the tradable form of this obligation. Further, a drop-in fuel from ELTs is potentially eligible for status as a 'development fuel', for which there is a separate obligation, and for which the associated certificates are considerably more valuable. More on the RTFO.

Example Recent Prices (quoted by ReOil)

Unrefined pyrolysis oil (stock oil): €0.41/litre

Light heating oil: €0.75/litre

Standard RTFC (Renewable Transport Fuel Certificate) (UK): £0.40/litre (2 certificates)

Development fuel RTFC (UK): £1.40/litre (2 development certificates, quoted by Energy Census)

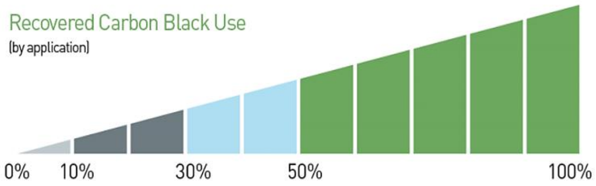
Recovered Carbon Black (rCB)

Monetisation of the solid output has proven one of the trickier aspects in the commercialisation of tyre pyrolysis, and has often been seen as simply a disposal problem, with extracting value from the oil the key focus. The issue is that the initial solid output is a low value product, a mixture of the initial CBs (~80-85%), plus inorganic compounds used in the tyre manufacture such as zinc and sulphur, plus newly formed carbonaceous material. This mixture has a high particle size (compared to the original CBs), and high ash content. The initial solid is therefore not in a commercially ideal form; it usually called char, or carbon black char, at this stage. Although other uses are possible – as a fuel, for conversion to activated carbon - conversion to recovered Carbon Black (rCB) has the potential to create most value.

Going from char to rCB is now understood as a process, but many tyre pyrolysis operations lack the skills and the capital to establish rCB production plants. For these reasons, companies have been set up who focus only on the char to rCB conversion process (for example, Waverly Carbon in the UK). We take such division of labour as a good sign for the sector.

rCB can substitute for some virgin CBs at rates from 10% up to 100%, depending on the application, with the least reinforcing applications most suited to rCB, though ash removal can extend use to the more reinforcing, higher value applications. **Figure 12** shows how pyrolysis company Pryolyx see their rCB being used and in what proportion. Other companies may differ from this.

Figure 12 – potential uses for rCB. Source: Pryolyx.



10-30% rCB

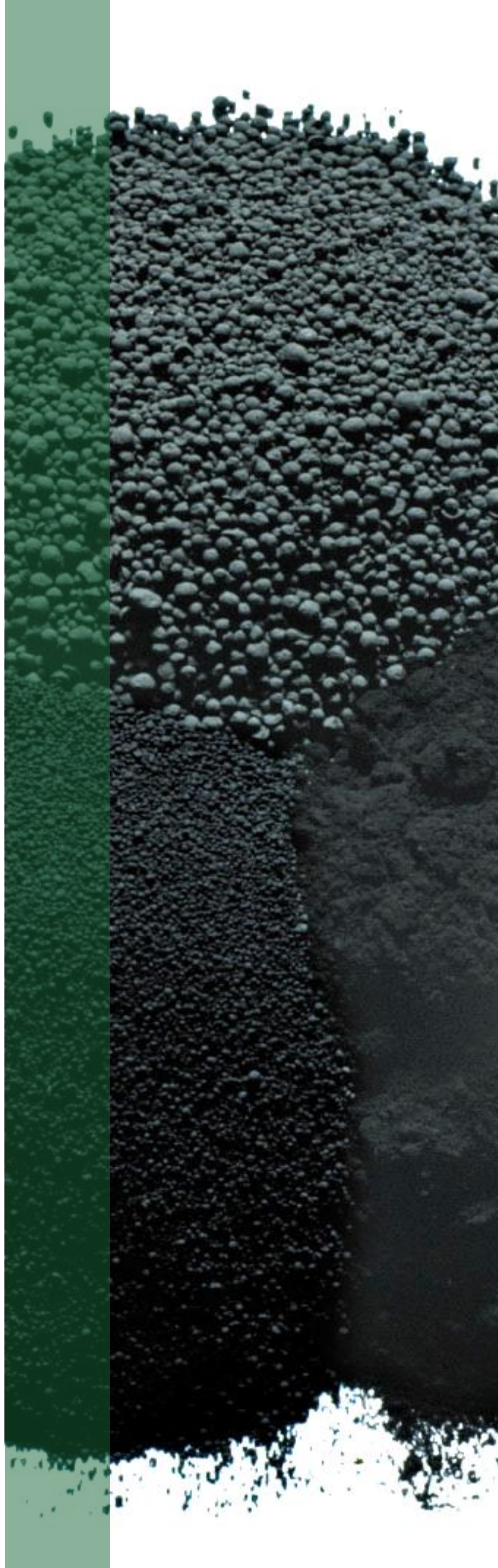
- Passenger car/light truck tyre tread
- Heavy duty conveyor belts (mining, etc.)
- High pressure hoses
- Transmission belts

30-50% rCB

- Passenger car/light truck tyre sidewall, undertread, body and belt plies
- Industrial/agricultural tyre tread and carcass
- Light/moderate duty conveyor belts
- Rubber sheeting/geomembranes
- Wire cable jacketing
- Gaskets and seals
- Rubber roofing

50-100% rCB

- Passenger car/light truck tyre innerliner, bead/apex
- Plastic masterbatch (for general plastic compounds)
- Polyolefin films (trash bags/agricultural film)
- Plastic pipe
- Newspaper inks



Advantages of rCB

Pyrolysis companies are keen to point out the advantages of rCB over virgin CB. These include:

- Cost competitive – rCB is currently priced competitively with virgin CB (partly because it needs to be).
- Environmental benefits
  - Reduced oil consumption by 1.5-2 tonnes per tonne of rCB.
  - Reduced CO_2 emissions by 2-2.5 tonnes per tonne of rCB. No significant SOx, NOx or particulate emissions. Lowered PAH (polycyclic aromatic hydrocarbons, mentioned earlier).
- High quality
  - Has more uniform particle size distribution, essential for high-end applications in coatings, plastics and rubber goods.
  - In certain applications, rCB has been shown to have superior characteristics to virgin CB (for example, better heat and abrasion resistance, improved matt surface finish).

With these qualities, rCB fits perfectly with companies sustainably requirements, which are ramping up almost universally through a combination of regulation, corporate and social responsibility, and customer demands. Major car and tyre manufacturers including Volvo, Continental and Michelin are either already using or exploring the use of rCB. As another example, Semperit AG Holding – the leading listed Austrian rubber company - is aiming to increase the use of rCB from 1% to 10% in its products by 2022. Creation of international standards for rCB could improve its uptake (in progress).

Example Recent Prices (quoted by ReOil)

rCB in basic state: €50-100/tonne.

After further processing by milling and pelletising: over €590/tonne.

Scrap Steel

If a pyrolysis plant extracts steel wire from ELTs on-site, this can be sold as scrap steel. This will get recycled into new steel products. ELT steel has a high carbon content which is a desirable property.

To add a little background, the steel market is vast (~1.8 billion tonnes in 2018, according to the World Steel Association). Scrap steel accounts for a significant fraction of the feedstock used in the production of crude steel, with the amount varying over time, depending on price swings in iron ore. The price of scrap steel correlates with demand for crude steel.

Example Recent Prices (quoted by ReOil)

Scrap steel: €100-140/tonne.

Is it Profitable?

Putting everything together, ReOil figures suggest a pyrolysis plant could turn **1 tonne of tyres into ~€230-580 (currently £200-530)**. For comparison, Scandinavian Enviro Systems puts their figure at ~ €350/tonne ELTs. At one end of this range products are sold in their basic state, at the other as processed rCB and heating oil. Further income is possible by upgrading to a drop-in fuel (and a UK RTFO development fuel). In addition, avoided emissions could potentially have a monetary value if included as part of an emissions trading scheme (such as the EU's ETS).

So, with this scale of revenue, together with operational and financing costs, is it possible to make money from tyre pyrolysis? Well, it is clear from the public accounts of the few listed pyrolysis companies in developed countries that it is not easy to make money. However, the private Polish company ReOil has positive EBITDA and is expected to be profitable this year. So yes, done right tyre pyrolysis *can* be profitable.

Pyrolysis Companies

The following is a non-comprehensive list of tyre pyrolysis companies operating in Europe or the UK. Find more details at each company's website.

ReOil

Private Polish company.

Runs the 'only industrial scale, continuous pyrolysis plant in Europe, perhaps the world'. Throughput of up to 20,000 tonnes per annum.

Positive EBITDA with profitability expected this year.

Although not yet produced at scale, their output drop-in fuel is approved as a 'development fuel' in the UK.

Waverly Carbon

Private UK company.

The 'UK's only producer of rCB'. They just do the conversion from tyre char to rCB, not the pyrolysis.

Can output up to 8000 tonnes of rCB every year, in powdered or pelletised form. This can be used as a partial replacement for grades like N550 or total replacement for the N600, N700 and N900 series.

Pryolyx

German company, listed on the Australian stock exchange.

Batch pyrolysis of ELTs. 'Largest global producer of rCB', with industrial scale facilities in Germany and the USA.

Each 20 oven Pyrolyx plant has a throughput of up to 40,000 tonnes per annum.

Supply agreement with Continental tyres for supply of rCB.

Scandinavian Enviro Systems

Swedish company, listed on Stockholm's NASDAQ OMX First North stock exchange.

Semi-batch pyrolysis of ELTs (the reactors operate independently of each other, but preferably in a sequence). Standard size of 30,000 tonnes per annum.

Their CB is being used at Volvo Cars and Alvenius, among others, where it is replacing 100% of the virgin CB in their rubber products.

Establishing long-term strategic partnership with tyre manufacturer Michelin.

Black Bear Carbon

Private Dutch company.

Previously operated a pyrolysis plant in the Netherlands (production halted due to a 'few commissioning hurdles' and a 'very unfortunate blaze').

Looking to build a new Dutch plant with throughput of 30,000 tonnes per annum, turning on in 2022.

Related Companies

Roll-Gom

Part of public French company Aurea. Creates recycled rubber wheels from ELTs.

Powerhouse Energy

Private UK company. Small scale gasification of waste plastic and ELTs. Process produces hydrogen, electricity and heat.

Market Potential

To conclude this report, we briefly assess the market potential for tyre pyrolysis.

Blue Sky Potential

To provide a rough upper bound on market potential, let's divide the total number of ELTs currently generated per annum by the throughput of an average tyre pyrolysis plant, say 20,000 tonnes/annum. Assuming ELT generation as per sources in the Background section, and that one plant turns 1 tonne of tyres into €580 of output products, this yields the following:

Area	ELT Generation (tonnes/year)	Implied No. Plants	Output Value (million euro/year)
UK	450,000	22	261
EU	3,000,000	150	1740
USA	3,800,000	190	2204
World	23,000,000	1150	13340

The main point is that the amount of ELTs is not a significant constraint on market potential, and the market has the potential to create significant value. This table ignores the existence of large ELT stockpiles.

What about the outputs? Does demand for these provide any constraint on market potential, assuming we can outcompete other suppliers? The simplistic answer is no. The overall steel and oil markets are vast and therefore not a constraint (putting aside the specific products that are output and the size of those sub-markets). As for Carbon Black (CB), its market could support over 2000 typical plants, making the simplifying assumption that rCB is a 100% substitute for all types of CB. And, of course, as we covered earlier, we are expecting both production of ELTs and demand for CB to go up over time.

Summary

Tyre pyrolysis has always seemed like a good idea on paper. However, in developed countries its uptake has been slowed by issues such as an inability to extract sufficient value from the outputs, particularly the solid output. There are encouraging signs though:

- The technology is well proven, with extended operation of multiple industrial scale plants in developed countries, both batch and continuous.
- Sustainability requirements both at a governmental and company level are moving in a direction supportive of the process and output markets.
- There is increased acceptance of, use of, and market for, rCB, with pyrolysis companies forming partnerships with major car and tyre manufacturers.
- There is division of labour in the sector, with, for example, companies specialising in creating high quality rCB from tyre char.

We get the sense that we are at a tipping point. With companies entering profitability, rapid large scale replication is a possibility for which investors could position. The potential rewards certainly justify a closer look.

Appendix – Summary of Thermal Processes

PGL PROCESS SUMMARY

Process	Liquefaction	Gasification	Pyrolysis
Process definition	Liquefaction is the thermochemical conversion of an organic solid into liquids.	Gasification is a sub-stoichiometric oxidation of organic material to maximize waste conversion to high temperature flue gases, mainly CO_2 and H_2.	The thermal degradation of carbonaceous material in an oxygen deprived atmosphere to maximize thermal decomposition of solid into gases and condensed liquid and residual char.
Operating conditions:			
Reaction environment	Oxidizing (oxidant amount larger than that required by stoichiometric combustion)	Reducing (oxidant amount lower than that required by stoichiometric combustion)	Total absence of any oxidant
Reactant gas	none	Air, pure oxygen, oxygen enriched air, steam	None
Temperature	Between 300°C and 450°C	Between 550 – 900 °C (in air)	Between 400 and 800°C
Pressure	Atmospheric	Atmospheric	Slightly above atmospheric pressure
Process output:			
Produced gases	H_2, CO, CO_2, Alkanes Alkenes, H_2S (trace)	CO, H_2, CO_2, H_2O, CH_4	CO, H_2, CH_4 and other hydrocarbons
Produced liquids	Petroleum like liquid, heavy molecular compounds with properties similar to those of petroleum based fuels.	Condensable fraction of tar and soot which is minimal.	Oil is similar to diesel and can be used as a fuel. High aromatic content, thus can serve as a feed stock in the chemical industry
Produced solids		After the combustion process. Bottom ash is often produced as vitreous slag that can be utilized as backfilling material for road construction.	The pyrolysis char residue has a considerable amount of carbon content and can either be utilized as tyre derived fuel for the process or be sold as a carbon-rich material for the manufacture of activated carbon or for other similar industrial purposes
Pollutants	SOx, NO_x, CO,	H_2S, HCl, CO, NH_3, HCN, tar, alkali, particulate.	H_2S, HCl, NH_3, HCN, tar, particulate.

The **pyrolysis** process yields oil, non-condensable gases, and solids, mainly carbon, metal and other inert material.

In contrast, **gasification** is a more reactive thermal process that utilizes air, oxygen, hydrogen, or steam. Gasification happens at a higher temperature range than pyrolysis with products being mainly gaseous.

Liquefaction happens at a lower temperature range compared to both pyrolysis and gasification and produces mainly liquid products.

Source for this page.

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