

Application for Industrial Permit: Pilot Waste Pilot Plant
Testing



1. Introduction

Inrigo As hereby applies for a temporary permit for a shredded waste tyre conversion by pyrolysis pilot plant for production of recyclable pyrolysis oil and carbon black. Plant will be located within the Industrial premises. The main raw material used are from Norwegian waste. The planned start-up of the plant is Q3 2024 . Permission is requested for 3 months of operation of the pilot plant.

2. Information about the company

The pilot plant will be located at Inrigo As, Trondheim. The exact location has not yet been determined.

Table 1 Company information

Navn	Inrigo As
Beliggenhet/gateadresse	Industriveien 43 B, 7080 Heimdal
Offisiell e-postadresse	reza@inrigo.no
Org.nummer	921 474 431
Gårds-og bruksnummer	
UTM-korordinator	
NACE-Kode og bransje	74.101
Kategori for virksomheten	
Normal driftstid for anlegget	
Antall ansatte	29
Navn	Reza Hezari
Tittel	CEO
Telefonnr	90977446
e-post	reza@inrigo.no

3. Goal for increases sustainability for waste recycling sector

It is estimated that each year approximately 1.2 Billion used tires are added to the pile of 7 billion already landfilled worldwide. These piles of tires pose an environmental hazard due to the toxic effect on the environment. This project will focus on providing a solution for the problem of rubber from waste tires generated in Norwegian condition. Add to that the fact that decomposing of tires takes centuries to millennia, if at all, used tires are proving to be a huge environmental problem for safe disposal when they contaminate soil and ground water.

Ragn-Sells approached Inrigo to develop a cost-effective technical solution for recycling discarded tires. Ragn-Sells Dekkgjenvinning AS, commissioned by Norsk Dekkretur (NDR), is responsible for collecting and recycling discarded tires in Norway. The cost of collection and recycling is covered by the recycling fee charged by manufacturers and importers when selling new tires. Ragn-Sells collects discarded tires from customers and rubber workshops upon request, transporting them to their facilities where they are sorted and recycled. Norway's tire recycling program, managed by Norsk Dekkreturn (NDR), recycles over 2 million tires annually. However, there are growing health concerns associated with products derived from recycled tires, such as artificial turf and rubber mats for playgrounds. In response, Ragn-Sells and Inrigo have been in continuous dialogue to find innovative solutions for recovering high-value products from recycled tires. Inrigo aims to convert shredded tire particles into high-value carbon black for new tire production and pyrolysis oil as a supplement for

asphalt industry to replace bitumen. This represents a promising new technology to address this issue. Consequently, Ragn-Sells has entered into an agreement to receive clean crumbed rubber from Inrigo, enabling them to operate at full scale free of charge.

4. Description of the process

The pilot facility will handle crumbed rubber supplied by a tire recycling agency. The shredded crumbed rubber will arrive in large bags and be stored in dry storage until needed. Approximately 1-3 days' worth of crumbed rubber will be kept inside the building. The crumbed rubber will then be deposited into a feeding container equipped with a moving auger at the bottom, which will transport the crumbs to an inclined auger conveyor. This conveyor will deliver the crumbed rubber to a feeder for pyrolysis reactor system (pyrolysis). Within the pyrolysis, the crumbed rubber will pass through a triple auger continuous reactor utilizing screw technology. This triple auger reactor technology facilitates the decomposition/breakdown of the tire crumb particles in the absence of air at a specified pyrolysis temperature. The system will break down the crumbed rubber into pyrolysis syngas and Carbon Black.

The pyrolysis gas will be condensed to Pyrolysis oil and not condensable syngas will be used as a fuel for heating up the system. See figure under:

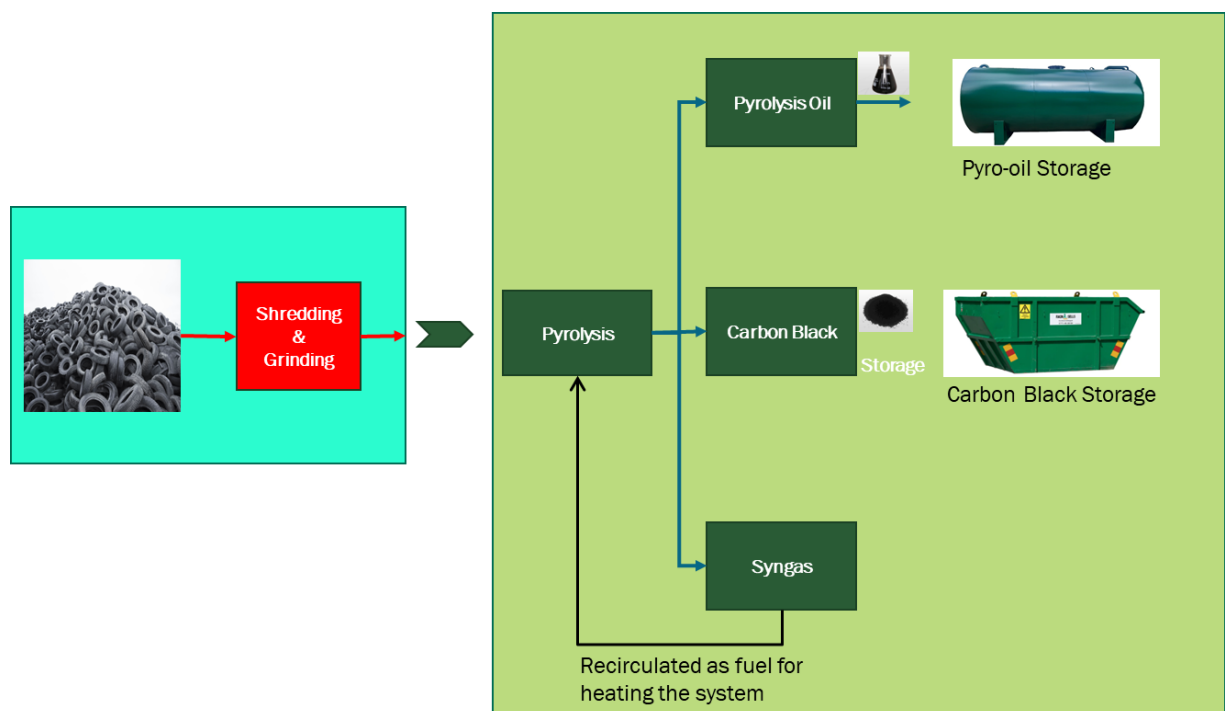


Figure 1 Schematic of Tyre pyrolysis

5. Description of facility

The size of the facility is within the confines of the building for the actual handling and processing of the crumb rubber. Outside of the building there will be a covered area to store the crumb tire, pyro-

oil tank & carbon black container. All loading and unloading activities will be confined to the fenced in area, which is more than large enough for all activities related to the operation of the facility. The

The proposed facility will operate within the boundaries of the property. The operation of facility will take place inside the building during the trail period of 3-6 months.

Required built area around 200-250 m². The property is within industrial zone premises as per the rules and regulations local municipal authority.

Capacity of the facility is approximately 400 kg of crumb tire per hour, producing approximately 150-170 kg of pyro-oil oil, 150-170 kg of carbon black, and approximately 70kg of syngas per hour. The project will be planned to be located in industrial approved facility. This project is set up in close cooperation with Innovation Norway, Ragn-Sells AS and Norsk Dekkretur AS. The stakeholders looking for fulfilling visions of circular economy and new economic and industrial development, and this activity is directly in line with national & local plans.

Currently, waste rubber is stocked in large piles, representing an existing, urgent environmental hazard. The facility is a new, alternative technology and we are working closely with Norwegian research institute SINTEF Energy to identify relevant technology benchmarks to see to what extent this technology can provide a significantly more environmentally sound way of dealing with crumb rubber. Inrigo performed literature research to provide a baseline environmental assessment of the technology for Phase 1.

6. Product quality assessment

The focus of the work at the pilot plant will be to develop a continuous performance test of pyrolysis plant for shredded tyre material and document its stability and performance well on a larger scale.

The proposed plant for crumb rubber thermally decomposed in 3 fractions: carbon black, pyro-oil and pyro-gas. These final products are carbon black and pyro-oil; the intermediate product is pyro-gas which is combusted to produce heat through Pyro-Gas Burner and the resultant heat of the combustion is used in the thermolysis process resulting in the major (estimated) emissions summarized in **Feil! Fant ikke referansekilden..**

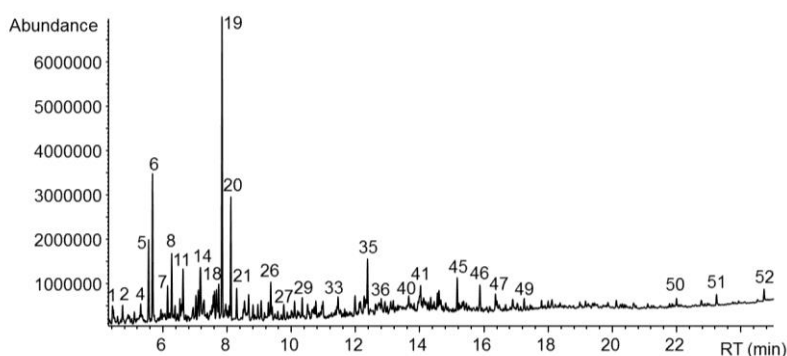
Table 2 Mass-balance

Products	Production Rate	
	(kg/hr)	(kg/day)
Black Carbon	165	3960
Pyro-Oil	167	4008
Non condensate Pyro-Gas	68	1632

Carbon black produced from tire plants holds significant value for recycling as a filler material in the tire production industry. The pilot test aims to establish various quality specifications based on variations in the input raw materials. The current system does not yet include the phase 2 proposition of flue gas cleaning and system integration. Flue gas cleaning systems will be proposed after confirmation of testing for 3 months and based on the results obtained regarding flue gas composition, further technology screening and adaptation will be proposed. In phase 1, testing of the pilot pyrolysis system will be conducted to verify emissions.

7. Analysis of liquid product at SINTEF Lab

The SINTEF laboratory was utilized for analyzing Ragn-Sells' crumb rubber materials with a particle size of 3 mm. Pyrolysis was conducted in a lab-scale reactor to benchmark the quality of the oil. The following figure illustrates that the majority of the components in the condensate from the rubber pyrolysis are aliphatic (mostly terpenes), aromatic, and polyaromatic hydrocarbons. The most prominent peak (15% area) is limonene, a cyclic dimer of the terpene monomer. Limonene can be further extracted as a potential solvent from the recycling of End-of-Life Tires (ELT), valorizing this waste stream. The condensate likely contains isoprene as well, although it was not detected due to its retention time falling within the solvent delay period of the mass spectrometer. Styrene, ethyl benzene, and various alkyl-substituted aromatic compounds originate from the aromatic polymer constituents of the rubber. Polyaromatic compounds were also detected in the condensate, along with some heteroatom-containing components. Benzothiazol (peak 35), an aromatic compound containing both sulfur and nitrogen, was identified in significant amounts (3.3% peak area). Additionally, N-(1,3-Dimethylbutyl)-N'-phenyl-1,4-benzenediamine (peak 52), a widely used antioxidant in the rubber industry, was identified. Further research will be conducted by Inrigo AS using the pilot plant with a capacity of 10 tons per day, which is designed and established based on Inrigo's patented technology. The test results conducted in the laboratory show potential recyclable solvents and chemicals. The pilot test will assess the effect of particle size on the quality and yield of the pyrolysis oil for potential scalable recyclable solvents. Inrigo is also in discussions with major refineries for the buy-back of pyrolysis oil as a supplement for process chemical recycling products. Additionally, pyrolysis oil can be further used in the asphalt industry to replace bitumen. Numbered peak identities are given in appendix 3



GC/MS chromatogram of the *condensate* sample.. (Ref..)

8. Storage of products, residues

The storage yard serves for both raw material and product storage. During the pilot test, crumb rubber will be delivered to site in 1-tonne bags. These bags will be stored in the designated storage area, ensuring dry conditions.

- Carbon Black Storage

The carbon black produced will be packed and stored in a clean and dry area in closed containers in the building before shipping to end users for testing.

- Pyro-Oil

The produced Pyro-oil will be stored in certified oil Tank. The oil will be shipped to end users for testing.

- Pyro-Gas (Syngas)

The produced Syngas will be recirculated in the pyrolysis system as a fuel for heating up the crumb rubber. The emission gases after combustion will be CO₂, NO₂ & SO₂.

- **Waste water**

There is no contaminated wastewater in the pilot plant facility. Water only will be used for cooling and will not be in contact with produced material.

9. Environmental risk assessment

Proposed pyrolysis technology undertakes substantial “purification” steps to maximise the combustible content of its syngas; the fact that its burners work equivalently with fossil fuel (LPG) on startup as syngas is evidence that syngas is “similar to a fossil fuel”. According to the EU’s clarification Pyrolysis plant proposed likely to not fall under the definition of a “waste incineration plant” or a “waste co-incineration plant”. The company examined the Environmental Impact Assessment (EIA) requirements under the Environmental Protection and Enhancement Act (EPEA) (https://www.regjeringen.no/globalassets/upload/kilde/md/bro/2003/0001/ddd/pdfv/182783-t-1428_e.pdf). However, since this is a pilot project aiming to establish emission benchmarks for patented technology, a comprehensive monitoring plan will be implemented. This plan will include monitoring activities for air pollution.

Further potential environmental risks expanded and the type risk and mitigation strategies are explained in following table:

Potential Environmental Risks	Risk Description	Mitigation Strategies
Air Pollution	Emission of pollutants such as NO _x , SO ₂ , CO ₂ , and particulate matter.	Syngas burnt in pyrolysis plant in the pilot project a continuous emission monitoring systems will be implemented to identify emissions data. Based on the emissions data and local regulatory measured gas cleaning equipment such as advanced filtration systems and scrubbers will be implemented
Water Pollution	There is no-risk related discharge of wastewater as such	Not-required
Greenhouse Gas Emissions	Contribution to climate change through the release of CO ₂ and other greenhouse gases.	Implementation of carbon capture and storage (CCS) technologies and Optimization of process efficiency to reduce emissions
Odor Emissions	Release of unpleasant odors from the pyrolysis process.	Odor control systems such as filters and Regular odor monitoring
Operational risks	Accidentally exceeding oil-levels, accidental screw-jamming	Oil-level sensors are in place PLC-controls and emergency stops are in place and emergency stack evacuation with fire-safety measures

Chemical Spills	Accidental release of chemicals into the environment.	Emergency spill response plans and Training for handling hazardous materials
-----------------	---	--

10. Environmental aspects of the plant and its limitations

The proposed use of synthetic iso- or poly-chloroprene rubber (CR) is extensively applied across various industries, notably in tire manufacturing. The transformation of hazardous substances such as nitrogen, sulfur, and chlorine through the pyrolysis of waste tires is detailed in Figure 2. This process is adapted for the current plant setup, which utilizes the complete combustion of pyrolytic gases for self-heating. During this combustion process, hazardous materials are fully oxidized, resulting in the emission of gases such as CO_2 , SO_2 , NO_2 . Most of the chlorine present in the tyre have tendency to condense into oil and carbon black.

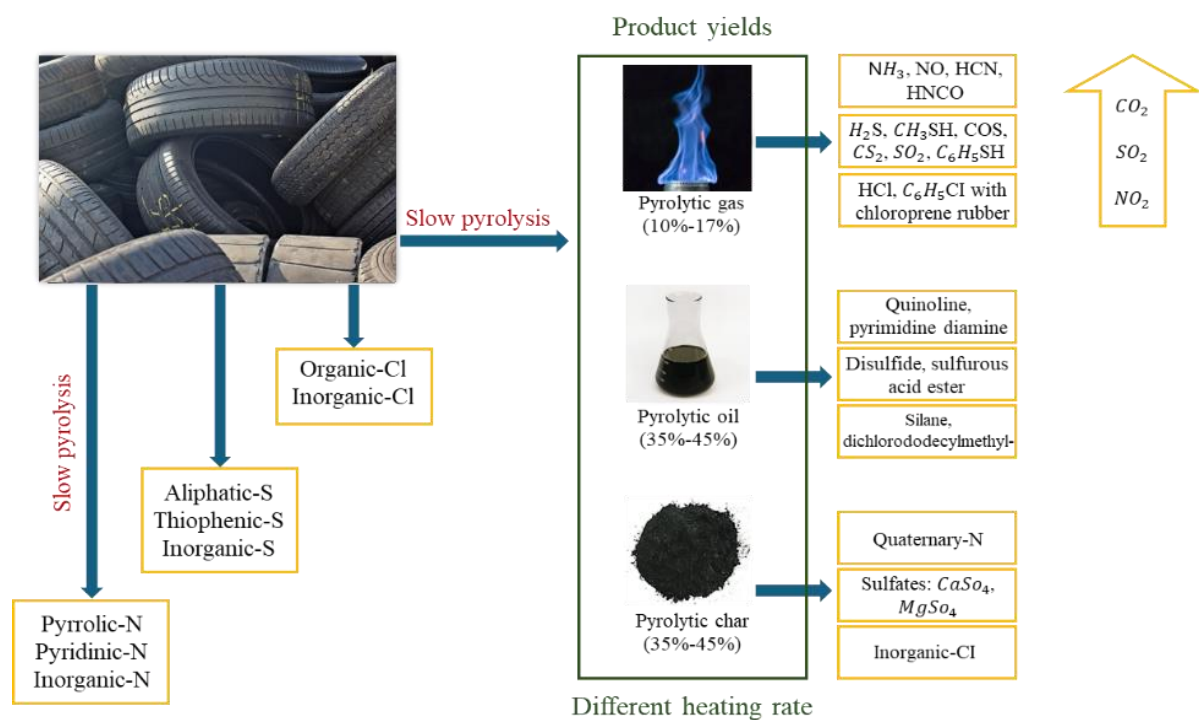


Figure 2 : pollutants.

Table presented below, outlines the air quality standards for specific pollutants and their permissible emission levels in alignment with the European guidelines on air pollution. These regulations consider varying health impacts based on exposure duration versus estimated pilot plant emissions.

Table 3 Regulation and Limit for emission

Pollutant	Pilot plant estimated emissions	Concentration Limit	Averaging Time	Regulation Source
CO_2	2.54 vol%	NA	NA	NA
SO_2	$62.7 \mu g/m^3$	$350 \mu g/m^3$ $125 \mu g/m^3$	Hourly Daily	EU Regulation XYZ
NO_2	$19.5 \mu g/m^3$	$200 \mu g/m^3$ $40 \mu g/m^3$	Hourly Annual	EU Regulation XYZ

In the context of the pilot plant in question, the stipulation is that pyrolysis testing runs are restricted to a maximum hourly, if emissions of NO₂ or SO₂ exceed 200 µg/m³ or 350 µg/m³, respectively. On the contrary, the plant may operate continuously if the emissions are within the lower thresholds of 40 µg/m³ for NO₂ or 125 µg/m³ for SO₂.