Scrap tire recycling – The next generation!

Scrap tire recycling

Source: “scrap tire situation Steiermark” 2004
Actually there are different ways for scrap tire recycling:

- Production of rubber granulates
- Energy recovery by production of diesel-like condensates for electric power production
- Thermolysis for production of secondary raw materials

Due to emission regulations and economic reasons a granulation nor simply energy recovery will be more and more uneconomic.

The data sheet shows the prices for electric power in Germany.
The scrap tire market in Europe changes dramatically. DGE is calculating with prime costs for scrap tires!
Sample mass balance

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- **Anlieferung**: Altreifen: 3500 kg/h
- **Mechanische Aufbereitung**: Gummi: 2180 kg/h, Metall: 420 kg/h, Gummmehl: 900 kg/h, Russ: 900 kg/h
- **Drehrohr-Thermolyse**: Prozessgas: 1280 kg/h
- **BHKW**: Restgas: 98 kg/h, Rohgas: 100 kg/h
- **Gasreinigung**: Kondensate: 1180 kg/h, Schwefel: 2 kg/h
- **Versand**: Gummi: 2180 kg/h, Metall: 420 kg/h, Gummmehl: 900 kg/h, Russ: 900 kg/h

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Preparation - overview

- Truck tires → Rotor cutter
- Car tires → Granulator
- Metal appr. 10-15% → Separator
- Condensate oil → Thermolysis
- Carbon black → Thermolysis

Granulate
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Preparation – truck tires

Preparation Limassol

→ Rotor cutter
→ Screen
→ Refeeding
→ Granulator
→ Metal separator

Appropriate for truck tires up to 1,6m

Throughput 2 -3 t/h

Energy demand (actual)
< 800 kWel. For 2 – 3 t/h
< 0,40 kWh/kg
**Specification for the granulator:**

→ car tires (quartered)

or

→ pre-shredded to 250 x 250 mm
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Preparation - granulation

Energy demand
330 kWel. for
3 – 5 t/h
< 0,10 kWh/kg
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Preparation - granulate

**Specification:**

→ Metal-free
→ <20 mm
Due to the kiln rotation
Wire balls will be built...
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Rotary kiln thermolysis plants

Energy demand

< 210 kWel. for 600 kg/h
< 0.35 kWh/kg

Please note: The needed process heat will be produced by a burning chamber.
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Efficiency

Vergleich Bruttoenergiebedarf

Typ MIDI mit Attreifen

Leistung [kW]

0 500 1000 1500 2000

Beheizungsart [°C]

Heizstabe 1200 Gas 800 Gas 1000 Gas 1200 Gas 1500 Induktion Elektrisch+Wind

- Heizstrom aus BHKW 42%eff
- Gaswärme aus Prozessgas
- Anlagenstrom aus BHKW 42%eff
- Strom aus Windenergie
**Pyrolysis**

Complete thermal decomposition of educt with target of destruction of educt.

Thermal decomposition in oxygen-poor / (nearly) oxygen-free atmosphere.

---

**DGE-Thermolysis**

Thermal decomposition with selective and controlled generating of new products.

Thermal decomposition in a definitely oxygen-free atmosphere.
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Thermolysis – balance variation

Source: CalRecovery-Report Nr. 1364 Kalifornien 1995
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Product carbon black

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>CBp</th>
<th>N330</th>
<th>N375</th>
<th>N550</th>
<th>N660</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTAB surface area</td>
<td>m²/g</td>
<td>58,2</td>
<td>82</td>
<td>96</td>
<td>42</td>
<td>36</td>
<td>Our CBp has a higher surface area than that of N500 or N600 series, but not reach N300 series.</td>
</tr>
<tr>
<td>BET surface area</td>
<td>m²/g</td>
<td>67,8</td>
<td>76</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil absorption number (OAN)</td>
<td>ml/100g</td>
<td>95,9</td>
<td>102</td>
<td>114</td>
<td>121</td>
<td>90</td>
<td>Indication of carbon structure (high value, high structure-&gt; high viscosity)</td>
</tr>
<tr>
<td>Iodine absorption number</td>
<td>mg/g</td>
<td>154</td>
<td>82</td>
<td>90</td>
<td>43</td>
<td>36</td>
<td>A measure of surface area and micropore content.</td>
</tr>
<tr>
<td>Sieve Residue (45 µm)</td>
<td>%</td>
<td>82</td>
<td>100ppm</td>
<td>100ppm</td>
<td>50ppm</td>
<td>100ppm</td>
<td>Aggregate/agglomerate size as well as metal impurities</td>
</tr>
<tr>
<td>Ash content</td>
<td>%</td>
<td>11,7</td>
<td>0,3</td>
<td>0,3</td>
<td>0,4</td>
<td>0,4</td>
<td>Inorganic impurities (not dispose at 550°C)</td>
</tr>
<tr>
<td>Water content/ Heating loss at packing</td>
<td>%</td>
<td>1,8</td>
<td>0,4</td>
<td>0,4</td>
<td>0,3</td>
<td>0,3</td>
<td>Important factor for packing and storage.</td>
</tr>
</tbody>
</table>

CBp = Carbon Black pyrolized

Please note: The Carbon black quality depends highly due to the kind of process and its parameters!
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Product carbon black

Source: TARR-Magazin 21 - 2014

Please note: The Carbon black quality depends highly due to the kind of process and its parameters!
The raw condensate oil can be used in multifuel diesel engines or heating oil burners. But: An application as a chemical raw material is economically even more interesting!

Remarks:
The condensate oil is already filtered and distilled during DGE-process to clean the oil from larger particles.
### Analysis of scrap tire condensate oil

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>Weight %</td>
<td>9.6 – 12</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>Weight %</td>
<td>0.7 – 0.9</td>
</tr>
<tr>
<td>Ash</td>
<td>Weight %</td>
<td>&lt;0.01 – &lt;0.01</td>
</tr>
<tr>
<td>Sulphur</td>
<td>Weight %</td>
<td>0.74 – 1.0</td>
</tr>
<tr>
<td>PCB</td>
<td>mg/kg</td>
<td>1 – 8</td>
</tr>
<tr>
<td>Water content</td>
<td>Weight %</td>
<td>0.06 – 0.09</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Weight %</td>
<td>0.08 – 0.1</td>
</tr>
<tr>
<td>Burning point</td>
<td>°C</td>
<td>&lt; 21 – 19 – 25</td>
</tr>
<tr>
<td>Viscosity at 40°C</td>
<td>mm²/s</td>
<td>2.81 – 2.6 – 3.1</td>
</tr>
<tr>
<td>Calorific value</td>
<td>MJ/kg</td>
<td>39.72 – 37 – 41</td>
</tr>
<tr>
<td>Silicium</td>
<td>mg/kg</td>
<td>36.7 – 32 – 42</td>
</tr>
<tr>
<td>Carbon</td>
<td>Gew. %</td>
<td>87.7 – 82 – 91</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/kg</td>
<td>7.1 – 6 – 8.5</td>
</tr>
<tr>
<td>Acid content</td>
<td>mg KOH/g</td>
<td>0.81 – 0.4 – 0.9</td>
</tr>
<tr>
<td>Density at 15°C</td>
<td>kg/m³</td>
<td>946 – 880 – 970</td>
</tr>
</tbody>
</table>

Please note: The Carbon black quality depends highly due to the kind of process and its parameters!
Advantages:
- Automatic operation
- Production of carbon black and oil
- Product result ok
- Condensation ok
- Autothermic operation
- Remote Control used

Potential for development:
- Long warm-up time (8 hours)
- Smoke gas-cleaning with waste
- Linked control circuits → due to safety critical!
- No adjustable heating zones
- No emergency flare
**Enhancements:**

- Fully automatically operation
- Short warm-up time
- Variable heating zone control
- Self-sustaining operation
- Remote Control
- Comprehensive safety concept

**Products:**

- Coke
- Condensate oil similar to diesel
- Permanent gas
- Optional: liquid gas
- Elementary precipitated sulphur
- Power for own usage
- Waste heat (steam, warm water)
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DGE-Prozess 2015

1 Hopper
2 Input sluice
3 Thermolysis coke hot
4 Thermolysis coke cold
5 Thermolysis raw gas
6 Permanent gas
7 Permanent gas, cleaned
8 GPL / natural gas
10 Rotary kiln unit

20 Condensation
21 Cooler
22 Bypass filter
31 Activated Carbon Filter
32 Emergency Flare
33 Gasometer
34 CHP
35 Raw oil storage
39 Thermolysis raw oil
40 Desulphuring
60 Condensation
67 Super fraction
68 Light oil fraction
69 Heavy oil fraction

*Optional:
40 Desulphuring
50 Oil CHP (own power+ external peak power)
70 Wind generator / photovoltaic

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Performance data MIDI

<table>
<thead>
<tr>
<th>Product input</th>
<th>Mass-%</th>
<th>MIDI</th>
</tr>
</thead>
<tbody>
<tr>
<td>scrap tires</td>
<td>600°C</td>
<td>600,00 kg/h</td>
</tr>
<tr>
<td>Carbon 83%</td>
<td>40,0%</td>
<td>240,00 kg/h</td>
</tr>
<tr>
<td>condensate</td>
<td>49,0%</td>
<td>294,00 kg/h</td>
</tr>
<tr>
<td>gas</td>
<td>11,00%</td>
<td>66,00 kg/h</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product input</th>
<th>Mass-%</th>
<th>MIDI-Duo</th>
</tr>
</thead>
<tbody>
<tr>
<td>scrap tires</td>
<td>600°C</td>
<td>1,200,00 kg/h</td>
</tr>
<tr>
<td>Carbon 83%</td>
<td>40,0%</td>
<td>480,00 kg/h</td>
</tr>
<tr>
<td>condensate</td>
<td>49,0%</td>
<td>588,00 kg/h</td>
</tr>
<tr>
<td>gas</td>
<td>11,00%</td>
<td>132,00 kg/h</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product input</th>
<th>Mass-%</th>
<th>MIDI-Quad</th>
</tr>
</thead>
<tbody>
<tr>
<td>scrap tires</td>
<td>600°C</td>
<td>2,400,00 kg/h</td>
</tr>
<tr>
<td>Carbon 83%</td>
<td>40,0%</td>
<td>960,00 kg/h</td>
</tr>
<tr>
<td>condensate</td>
<td>49,0%</td>
<td>1,176,00 kg/h</td>
</tr>
<tr>
<td>gas</td>
<td>11,00%</td>
<td>264,00 kg/h</td>
</tr>
</tbody>
</table>

Please note: Special customer's designs are possible!
Influences on the process

Throughput

The kiln diameter limits the volume of product in the reactor. By shortening the residence time the throughput can be increased.

Water content

"The drier the better!"
The highest efficiency is with a completely dry product.

Feeding quality

All hydrocarbons are thermolysed. Included minerals and heavy metals remain unchanged.

process-parameters:

- temperature
- atmosphere
- rotation speed

Ratio

gas - oil - coke

Higher processing temperatures produce a higher gas / oil content. Lower temperatures increase the solids output.

Product quality

The product obtained has, process-related, a higher percentage of minerals and heavy metals, as the product contained in the task.
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Using of permanent gas

Due to safety reasons the permanent gas must be depolluted.

In worst case this gas can be simply burnt.
In standard case a power generation is much more senseful.

The following points are advantages of this technology:

➔ No lubricating oils that need to be replaced regularly
➔ Air bearings for wear-free, long life
➔ No pistons or abrasive components
➔ High control range from 10 – 100%
  which allows an energy generation on demand
➔ High off gas temperature (280°C),
  can be used for generating steam and drying

**Specification C1000 (5x C200)**

- Manufacturer: Capstone
- Type: Gas turbine
- Nominal power: 5x 200 kWel.
- Full load speed: 61,000 rpm (Nominal speed)
- Cooling type: air
- Off-gas temperature: 280°C
- Cooling liquid: -
- Consumption ca. 300g/KW at full load ca. 300 kg/h
- Electrical effectiveness ca. 33%
### Off-gas from the turbine

**Heating oil extra light scrap tire oil scrap tire scrap tire oiling oil extra light limit value**

<table>
<thead>
<tr>
<th></th>
<th>Power, el. kW</th>
<th>T-air °C</th>
<th>T-Off-gas °C</th>
<th>CO ppm</th>
<th>CO mg/Nm³</th>
<th>NO ppm</th>
<th>NO2 ppm</th>
<th>NOx Cal. mg/Nm³</th>
<th>NOx ppm</th>
<th>SO2 ppm</th>
<th>SO2 mg/Nm³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25,0</td>
<td>21,0</td>
<td>77,2</td>
<td>213</td>
<td>266</td>
<td>21</td>
<td>4</td>
<td>51</td>
<td>25</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>30,0</td>
<td>22,1</td>
<td>231,6</td>
<td>29</td>
<td>36</td>
<td>111</td>
<td>0</td>
<td>228</td>
<td>111</td>
<td>98</td>
<td>280</td>
</tr>
<tr>
<td></td>
<td>25,0</td>
<td>23,1</td>
<td>269,0</td>
<td>8</td>
<td>10</td>
<td>104</td>
<td>0</td>
<td>213</td>
<td>104</td>
<td>105</td>
<td>300</td>
</tr>
</tbody>
</table>

**Notes:**

The shown values have been measured with a standard diesel turbine.

The high SO2-content results from a high sulphur content within the oil. A reduction of the oil sulphur will decrease the SO2-values.

The NOx depends on the combustion parameters and can be reduced with appropriate adjustment.
Emergency power generation

Multi-fuel engines can use condensate oils of (almost) every quality.

**Specification MTU 837 BA 500**
- Manufacturer: MTU Mercedes Benz Manufacture
- Design: V-shape 90 Type
- Mode of operation: Four stroke precombustion chamber with mechanical charging
- Number of cylinders: 8
- Total cylinder capacity: 29900 ccm
- Nominal power: 460 bis 485 kW according to DIN at 2200/ min
- Max. torque: 2206 Nm at 1750/ min
- Idle-running speed: 600 bis 630 / min (motor at operating temperature )
- Full load speed: 2200/ min (nominal speed)
- Cooling type: water circulation cooling
- Cooling liquid: 115 liter up to -20 °C frost-proof
- Engine oil pressure at operating temperature 6 bis 8 bar at 2200/ min
- Consumption 240g/KW at full load ca. 108 kg/h
- electrical effectiveness ca. 39%
A safe process?

Not this way!
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Process control system

The AutomationX is an industrially successful management and control system.

The plants are operated usually by local staff.

For optimizing or troubleshooting a remote access via a secure VPN-line via Internet.
Only by using **comprehensive sensor technology** the process control system can react appropriate on possible changes and incidents.

Only by **redundancy of measurement points**, especially of the relevant measurements, according to SIL-concept, the control system receives reliable data.

Only by thorough **FME-analysis** the control system gets routine to guarantee safe handling of malfunctions.

Only by comprehensive **Log-functions** of all parameters a correct operation is traceable and the QS-system reliable.

Only by **comprehensive connecting of the complex measurement results** regulation of the process is possible at all.
Prejudice: dioxines + furans

Polychlorinated dibenzodioxines

Polychlorinated dibenzofurans
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Prejudice: emissions

### Fine dust

<table>
<thead>
<tr>
<th>Limit value for this facility according to 17. BlmSchV</th>
<th>Measured value MPA Burgau (LUA Bayern)</th>
<th>Bagatelle mass flow TA-Luft</th>
<th>Limit value for stoves 1. BlmSchV</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 mg/m³</td>
<td>1,3 mg/m³</td>
<td>1,000,000 mg/h (1,000 m³/h * 1 g/m³)</td>
<td>60 mg/m³ 100 mg/m³</td>
</tr>
</tbody>
</table>

### Dioxine

<table>
<thead>
<tr>
<th>Limit value Daily average value for this plant according to 17. BlmSchV</th>
<th>Measured value Annual average value MPA Burgau (LUA Bayern)</th>
<th>Bagatelle mass flow Technical instructions on air quality control</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,1 ng/m³</td>
<td>0,0013 ng/m³ (unsorted waste + combustion chamber)</td>
<td>-- mg/m³</td>
</tr>
</tbody>
</table>

### Mercury

<table>
<thead>
<tr>
<th>Limit value Daily average value for this plant according to 17. BlmSchV</th>
<th>Measured value Annual average value MPA Burgau (LUA Bayern)</th>
<th>Bagatelle mass flow According to technical instructions on air quality control</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,03 mg/m³</td>
<td>0,00089 mg/m³ (unsorted waste + combustion chamber)</td>
<td>2,500 mg/h (1,000 m³/h * 2,5 mg/m³)</td>
</tr>
</tbody>
</table>
New at DGE:
Equal consideration of all three products:

- Solid (coke / carbon black / fertilizer)
- Condensate (chemical raw material)
- Gas

... additionally:

- Combination with re-newable energies
- Possibility of power network stabilization

Source & Thanks to Dr. Rüdiger Schmidt (Babcock & environmental auditor)

Source & Thanks to Werner Schütze
DGE-plants – The universal rotary kiln for (almost) every application®!

*= for the thermolysis of carbon-hydrogen products...
Further product applications

- Wood
  - Wood chips
  - Wood pellets
- Straw pellets
- Bamboo
- Miscanthus
- Animal manure
- Camel dung
- Hazelnut shells
- Coconut shells
- Palm oil shell
- Waste wood
- Plastic chips
- Sewage sludge
- Oil sludge (for cleaning of contaminated soil)
- Tetra pack fluff (creates aluminum chips)

Mixing of the products is generally possible, but economical not recommendable!
## Tires - Ingredients

<table>
<thead>
<tr>
<th>Element</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubber</td>
<td>47 %</td>
</tr>
<tr>
<td>Carbon Black + fillers</td>
<td>21,5 %</td>
</tr>
<tr>
<td>Mesh</td>
<td>5,5 %</td>
</tr>
<tr>
<td>Ferrum</td>
<td>16,5 %</td>
</tr>
<tr>
<td>Oils</td>
<td>9,5 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Element</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc oxide</td>
<td>1 %</td>
</tr>
<tr>
<td>Sulphur</td>
<td>1,5 %</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0,5 %</td>
</tr>
<tr>
<td>Stearic acid</td>
<td>0,3 %</td>
</tr>
<tr>
<td>Halogenes</td>
<td>0,1 %</td>
</tr>
<tr>
<td>Copper compounds</td>
<td>450 mg/kg</td>
</tr>
<tr>
<td>Lead</td>
<td>410 mg/kg</td>
</tr>
<tr>
<td>Cobalt</td>
<td>250 mg/kg</td>
</tr>
<tr>
<td>Chrome</td>
<td>97 mg/kg</td>
</tr>
<tr>
<td>Nickel</td>
<td>77 mg/kg</td>
</tr>
<tr>
<td>Arsis</td>
<td>20 mg/kg</td>
</tr>
<tr>
<td>Cadmium</td>
<td>8 mg/kg</td>
</tr>
<tr>
<td>Quicksilver</td>
<td>0,177 mg/kg</td>
</tr>
</tbody>
</table>

Source: Newsletter Bavarian State office for environment June 2011
Minimum distance

Scrap tires are declared as **non hazardous waste** (waste classification key 160103)

According to the 4\textsuperscript{th} BlmSchV such a plant is classified (in accordance with 8.1(1)a)) as:
Facilities for removal or recycling of solid, liquid or gaseous materials by means of thermal treatment (pyrolysis facilities) up to 3 t/h.

In agreement with appendix 2 distance decree "Immission relevant facilities which are not included in the distance list", valid for this type of facility is: **No minimum distance!**

Requirements for sites

For such a facility (in Germany) a commercial-industrial site or a special site is required