Energy Balance for the Recycling of Butyl Rubber Bicycle Inner Tubes

Is the manufacture of new bicycle inner tubes out of used butyl rubber inner tubes environmentally friendly, in comparison to the production of new tubes made from crude oil?

In order to answer such questions, one usually carries out a comparative environmental balance. What is that? An environmental balance takes into account all the environmental effects that the manufacturing process of a product or a material have. This includes, for example, the mining of ores or the extraction of oil from the Earth's crust; the consumption of water resources; the pollution of the environment with waste materials, wastewater and gaseous emissions; and the toxic effects of these, as well as their relevance to climate change. These endpoints will be summarized in a standardized form. This will allow products with different manufacturing processes to be compared with each other regarding the relevance of their environmental impact.

A detailed environmental balance requires a large amount of data, which are not always available for complex processes. In such cases, one often limits oneself to a comparative energy balance, as the energy data are almost always available. In any case, the energy use is, from experience, a good indicator of the total impact on the environment. EPEA Internationale Umweltforschung GmbH performed such an energy balance for Ralf Bohle GmbH in 2015, for the recycling of bicycle inner tubes.

In the case of bicycle inner tubes, two production routes ("Scenario A" and "Scenario B") for the manufacture of butyl rubber are compared; namely, the recycling of old butyl rubber inner tubes, and the new production of butyl rubber from crude oil. The comparison is limited to the part of the inner tube production that is different, namely the production of the pre-vulcanisation rubber mixture.

The inner tubes are manufactured in Jakarta, Indonesia. Therefore, the used inner tubes for recycling must be collected from the dealers in Germany, sent by packet post to Reichshof, then transported by lorry to Antwerp, and finally shipped by container to Jakarta. The valves are cut out of the inner tubes in a factory near Jakarta, and the rubber is devulcanised in a special plant. The resulting devulcanisate, can, after the addition of vulcanization chemicals, be used instead of fresh rubber mixture in the production of new inner tubes. The energy balance for this is:

A. Scenario Inner Tube Recycling

1. Transport of old inner tubes to Reichshof by packet post (DHL)[1]	1.5 MJ/kg
2. Transport Reichshof to Antwerp Harbour by lorry (distance 260 km)[2]	1.1 MJ/kg
3. Transport Antwerp to Jakarta by container ship (distance 15,800 km)[2]	2.4 MJ/kg
4. Devulcanisation by R&R near Jakarta (energy use 0.72 kWh_{el}/kg)[3]	7.8 MJ/kg
Total energy use (crude oil)	**12.8 MJ/kg**

If the inner tube is made exclusively from new material, i.e. from crude oil, then the following picture emerges:

B. Scenario New Material[4]

1. Synthesis of butyl rubber (70% x 55.8 MJ/kg)[4]	39.1 MJ/kg
2. Synthesis of carbon black (30% x 126.5 MJ/kg)[4]	37.9 MJ/kg
3. Energy recovered by incineration of old inner tubes in MWI plant	- 13.0 MJ/kg
Total energy use (crude oil)	**64.0 MJ/kg**

In order to put the energy use into perspective, the combustion of one litre of crude oil results in approximately 40 MJ of energy released as heat.

The comparison of Scenarios A and B shows that, for an inner tube made exclusively from devulcanisate (recyclate), only a fifth of the energy used in production of inner tubes from new material is required. Currently, only around 20% recyclate is used in the inner tube production. The actual energy and crude oil savings in the production of a new inner tube is therefore currently around 15%. An increase in the proportion of recyclate being used is aimed for.

It is also notable that the production of the carbon black used as a filler is even more energy intensive than the butyl rubber production itself. As the carbon black stays in the rubber after devulcanisation, it is also reused in the new production using recyclate.

The energy use for rubber synthesis given in the literature is widely variable. The reasons for this cannot be clarified without further research. They are probably related to different frame conditions being set for the different calculations. As the values given in several sources[4] are significantly higher than the in Scenario B, line 1 mentioned 55.8 MJ/kg, the energetic advantage of recycling compared to the new production from crude oil is probably even more than a factor 5.

Annotations:

1. The energy balance for the transport by DHL packet post is based on information from DHL (personal communication with GoGreen/DHL on 13th July 2015). According to this information, the transportation of a 4.4 kg packet with a volume of 27 litres over a distance of 380 km, would require 7.5 MJ total energy ("well to wheel"). As the distances between the bicycle dealers and the logistics hub in Reichshof are variable, the average distance between Reichshof and all big German towns (more than 500,000 inhabitants; weighted by the number of inhabitants) was calculated. This calculation gave a distance of 370 km. An average packet size of 21 kg and 90 litres was assumed (with a density of 0.23 kg/l of rubber inner tubes). The average energy use, arrived at through calculation based on volume, and calculation based on weight, is 1.5 MJ/kg.

2. Data taken from "Primärenergiefaktoren von Transportsystemen" by ESU-Services, commissioned by the Bundesamt für Energie der Schweiz (http://www.esu-services.ch/fileadmin/download/Transportsysteme_v2.2_2011.pdf; downloaded on 22.10.2014).

3. Submission by the operators of the R&R devulcanisation plant in Indonesia. For the conversion of kWh (electrical) to MJ (oil), a heat transfer efficiency from thermal to electrical energy of 33% was assumed.

4. Assuming a simplified formulation of 70% butyl rubber and 30% carbon black. As the LCA data for pure butyl rubber were not available, the data for the synthetic elastomer SBR were used. Source: T.Amari. Resource recovery from used rubber tires. Resources Policy, Volume 25, Issue 3, 1999, 179–188.
In another calculation, data for polyisobutylene were used, as this is chemically very similar to butyl rubber, although it is not vulcanised. This calculation gave a value of 73.7 MJ/kg (in comparison with 55.8 MJ/kg for SBR). With this higher value, recycling of butyl rubber inner tubes would be 6 times more energy-efficient than the new production from crude oil. Source:
http://bau-umwelt.de/download/CY3ebc0060X14455318d36X73be/EPD_MON_20130274_IBA1_DE.pdf downloaded on 28.10.2015).

5. In Scenario B, the bicycle inner tubes are not collected and recycled after use. In most cases they will be thrown away in the household rubbish. In Germany, this will be taken to a Municipal Waste Incinerator with thermal and electrical energy recovery. This energy is returned to the system, and must therefore be taken away from the total energy used in the original manufacture of the rubber inner tubes. For various reasons, the energy transfer efficiency of Municipal Waste Incinerators is very low. On average, it is 32.5% (combined thermal and electrical energy). Therefore, only a small part of the material's caloric value of 40 MJ/kg is used. Source: IAA Dresden und INTECUS. Nutzung der Potenziale des biogenen Anteils im Abfall zur Energieerzeugung. Study commissioned by Umweltbundesamt (2010), p.70 (http://tu-dresden.de/die_tu_dresden/fakultaeten/fakultaet_forst_geo_und_hydrowissenschaften/fachrichtung_wasserwesen/iaa/publikationen/Endbericht_19072010.pdf; downloaded on 18.2.2015)

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