OVERVIEW OF LCI DATA FOR CARBON FIBER

The Japan Carbon Fiber Manufacturers Association, October 2022

In 1999, the Japan Carbon Fiber Manufacturers Association (JCMA) has published for the first time "life cycle inventory" (LCI) data for carbon fibers. In the following years, several revisions have been published (2004, 2006 and 2012). Since 2006, these LCI data have been based on underline actual production data, in contrast with many other published data which are based on model calculations and/or lab scale or pilot scale experimental data.

As the assessment of the environmental impact of materials and processes has gained importance in the past decades, an international standard (ISO 14044) has been established *(and has been followed in this survey)*. A full LCA (life cycle assessment) comprises, next to the definition of the goal and scope of the exercise, three main parts: inventory analysis, impact assessment and interpretation. This study is limited to the life cycle inventory (LCI), but analysis of the inventory results provides information on some relevant impact categories like cumulative energy demand (CED), CO_2, NO_X and SO_X emissions, and hence allows comparison with other published LCA data.

The object of this study ("subsystem" in LCA terminology) is the manufacturing of 1 kilogram of PAN-based, high strength carbon fibers, in the form of 12k (800tex) to 24k (1600tex) tows, having an elastic modulus in the range of 230 to 250 GPa. The survey was conducted under a contract between JCMA and the Industry Information Collaboration Research Center (WIC), which has conducted numerous inventory analyses for the materials industry. The input data for this survey *(later called foreground data)* are provided to WIC by the three Japanese carbon fiber manufacturing companies (Toray, Mitsubishi Chemical, Teijin), and have been measured during the production, in 2017, of **6994 tons** of carbon fibers, representing about 40% of the annual domestic production of this type of carbon fibers in Japan. The data is considered to be representative enough for the major markets for CF, such as aerospace equipment and automobiles.

The system boundary is presented in Figure 1. A "cradle to gate" type of calculation has been applied. The foreground data collection has been carried out for the unit process itself, namely the manufacturing of 1 kg of carbon fibers, which consists of three parts: PAN polymerization, fiber spinning and carbonization. For the input of raw materials (acrylonitrile, solvents, …), electricity and steam, retrospective calculations have been carried out *(partially based on background data)*. This finally results in an inventory of cumulative data traced back to natural resources. Further analysis and grouping of these cumulative data allows then to summarize the results of this survey in four relevant inventory categories: CED (cumulative energy demand), CO_2, NO_X and SO_X emissions.

- The CED or total primary energy consumption of all raw materials and fuels (electricity, steam, and directly consumed fuels) input for the production of 1 kg of CF, calculated back to the mining and extraction of resources, is **318.2 MJ**. In addition, in this survey **32.1 MJ** of feedstock energy has been included, which together makes a total of **350.2 MJ**.
- The CO_2 (**19.849 kg/kg-CF**), NO_X (**0.0353 kg/kg-CF**) and SO_X (**0.0161 kg/kg-CF**) emissions are in line with the 2012 survey.

It is believed that this new survey has a unique value for the industrial and scientific community involved in the use and study of carbon fibers (and their composites), because it is based on underline actual production data. This report should provide sufficient detail for allowing a well-documented comparison with other published LCI (and LCA) data for carbon fibers.
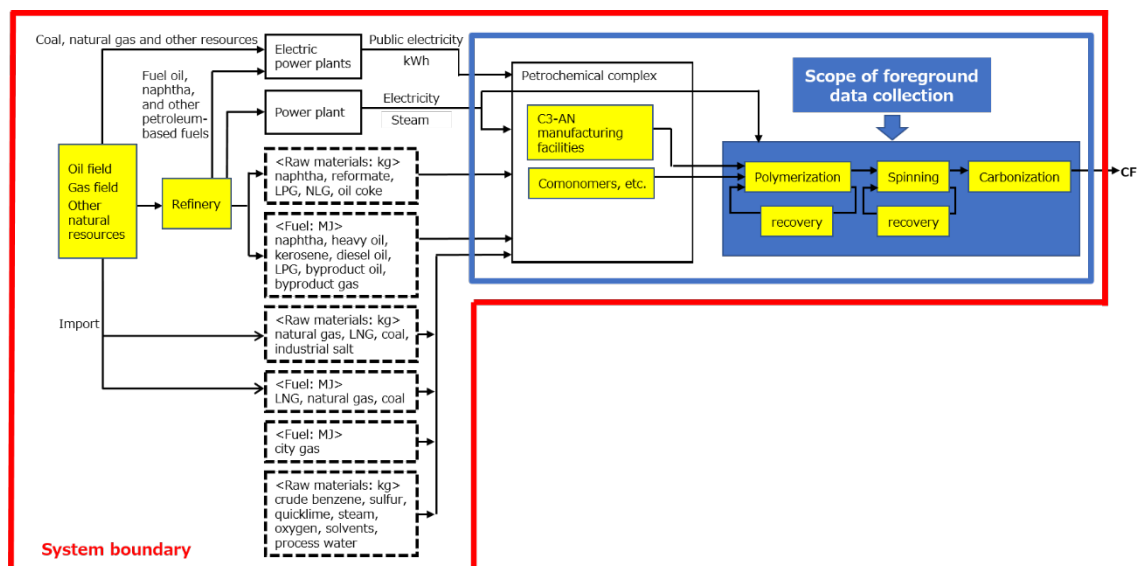
Figure 1 Computational scope of inventory data and system boundaries of PAN-based CF.

Note: *Data was collected for each process (polymerization, spinning, and carbonization), and an inventory analysis was conducted for each process. After weighting and averaging the results of each company's inventory analysis for each of the three processes by the ratio of each production volume, LCI data for the three processes were calculated as a single unit.*

The full report of this survey can be found on
      https://www.carbonfiber.gr.jp/english/tech/pdf/lci2022_en.pdf

For further information, please contact JCMA.
      https://www.carbonfiber.gr.jp/english/contact/index.html