

Towards Standardising Methods for Reporting the Embodied Energy Content of Aerospace Products

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ABSTRACT

Within the aerospace industry there is a growing interest in evaluating and reducing the environmental impacts of products and related risks to business. Consequently, requests from governments, customers, manufacturers, and other interested stakeholders, for environmental information about aerospace products are becoming widespread. Presently, requests are inconsistent and this limits the ability of the aerospace industry to meet the informational needs of various stakeholders and reduce the environmental impacts of their products in a cost-effective manner. Energy consumption is a significant business cost, risk, and a simple proxy value for overall environmental impact. This paper presents the initial research carried out by an academic and industry consortium to develop standardised methods for calculating and reporting the embodied manufacturing energy content of aerospace products. Following an action research approach, three potential methods are identified and applied in a real manufacturing environment. Suitability for use across the aerospace value chain is assessed. The benefits, implementations issues, areas of data uncertainty, and differences in results are outlined. Results show companies could be over/under reporting the embodied manufacturing energy content of parts by a factor of 10. The subsequent business and EU policy implications for industry reporting and evaluating product risks are discussed. The paper concludes the novel research outcomes will be valuable to businesses and other interested stakeholders seeking to report or understand the embodied energy content of aerospace products and associated data uncertainty, as well as inform the development of future industry standards.

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1. INTRODUCTION

Within the aerospace industry there is a growing interest in understanding, measuring, evaluating, and reducing business risks and the environmental impacts of products [1]. As business and environmental impacts centre on the management of products across the whole life cycle, product-level environmental information can provide greater insight into the environmental aspect of product sustainability. Consequently, requests from governments, customers, Original Equipment Manufacturers (OEMs), and other stakeholders, for environmental information about aerospace products have become widespread [2, 3, 4]. Presently, these requests lack consistency which limits the aerospace industries' ability to meet the informational needs of various stakeholders in a cost-effective manner.

In an attempt to standardise this type of information exchange, the Aerospace, Defence, Space, and Security (ADS) industries trade association's "Design for Environment" working group established a set of six product-based environmental indicators (PBEIs) identified as forming a useful core of environmental information [5]:

- Energy consumption
- Water consumption
- Waste production
- Hazardous substance use
- Recyclability potential
- Access to resources

To ensure consistency and industry relevance, a collaborative research project between the University of Surrey and several aerospace companies (ADS Group, Airbus Group, BAE Systems, Bombardier Aerospace, Granta Design, and Rolls-Royce) was established and aims to develop suitable methodologies for measuring the pre-selected set of product-based environmental indicators for use within the ADS industries, and test the methodologies for their data collation.

The "energy consumption" Product-based environmental indicator (PBEI) was initially selected to focus research activity as it is a significant business cost, and a growing data requirement for evaluating environmental impacts and business risks. Currently, although energy is widely measured within the aerospace industry, there is no consistency in calculating and reporting the embodied energy content of aerospace products. This paper presents the outcomes of the research designed to:

1. Develop a methodology for measuring the "energy consumption" PBEI
2. Test methodology for measuring the "energy consumption" PBEI in a real manufacturing environment and assess suitability for use across the aerospace value chain

The paper takes the following structure. [Section 2](#) presents the literature review, split into two parts: [\(2.1\)](#) examines product sustainability within the aerospace industry, and [\(2.2\)](#) reviews

available standards and guidelines for measuring and communicating the embodied energy content of aerospace products, alongside overall environmental footprint.

[Section 3](#) then describes the research approach used to develop the indicator measurement methods and to test them in a factory environment. [Section 4](#) provides a summary of the work undertaken to develop a methodology for measuring the energy consumption indicator. Three potential methods for use as an industry standard are identified and described.

[Section 5](#) presents the case study designed to apply the developed methods in a manufacturing environment to assess overall suitability for use across the aerospace value chain. Commentary on benefits, implementation issues, areas of data uncertainty, and differences in results are given. Finally, [Section 6](#) reflects on the overall results and implications for advancing the development of methods for reporting the embodied manufacturing energy content of aerospace products.

2. LITERATURE REVIEW

2.1. Product Sustainability within the Aerospace Industry

Over the last 15 years, there has been increasing attention within the aerospace industry to deliver more sustainable products and services as part of reducing business risks, costs, and environmental impacts [6]. Activities have mainly focused on reducing the environmental impacts of products through eco-design (e.g. [7]), sustainable manufacturing (e.g. [8, 9]), use of bio fuels and other alternative fuels (e.g. [10, 11]), and improving end of life treatment and recovery of aircraft [12, 13].

In recent years, a total life cycle view to product management, e.g. via Life Cycle Analysis (LCA)/eco-design, is gaining popularity amongst OEMs and suppliers to identify environmental impacts and costs reduction opportunities (e.g. [14]). Some notable activities are attempting to standardise the use of LCA for two particular contexts: (1) eco-design through the EU Clean Sky 1 project, and (2) making environmental product declarations (EPDs) through establishing a product category rule (PCR) for "Passenger Commercial Aeroplanes". Additionally, there is increasing EU regulation and policy attention on product manufacturers to standardise reporting and labelling of the whole life environmental impacts of products (e.g. EU Product Environmental Footprint (PEF) scheme).

However, current industry LCA standards and developing policy proliferate the use of mixed methods and incomparable information as they do not strictly specify how raw environmental information (e.g. product manufacturing waste, water, and energy use) is collected and collated from the supply chain. There is no dominant method(s) emerging to allow for a consistent provision of this information. As such, there is an urgent need for the development of standardised and cost-effective PBEIs suitable for use within the aerospace industry.

Table 2.1. Review and overview of product standard and guidelines (Adapted source: [15])

Name	PEF Guide	ISO 14040/14044	PAS 2050	ISO 14067: Carbon footprint of products	GHG Protocol Product Standard	ISO 14025 (Type 3 label)
Description	Published by the EU commission, guide for calculating the environmental footprint of products and aims to harmonise existing methods for product groups	Leading international standards for Life Cycle Assessments (LCA)	UK carbon footprint standard published by BSI	Based on ISO 14040/44 and ISO 14025, but focuses on climate change only	Similar to ISO 14067 and focuses on greenhouse gas accounting	Based on ISO 14040/44, introduces PCR and EPD for products
Does the standard provide a means for potentially measuring any of the ADS pre-selected product-based environmental indicators (Y/N)?	No, but provides guidance on setting system boundaries, use of primary and secondary data, and potential sources of data to consult	No, but provides guidance on setting system boundaries and use of primary and secondary data	No, but provides guidance on setting system boundaries and use of primary and secondary data	Yes: 1.direct measurement 2.activity data (i.e. inputs/outputs of processes) 3.secondary data	Yes: 1. Directly measuring 2.collecting activity data (e.g. production hours, kg) 3.modelling processes (e.g. mass balance, stoichiometric calculations, etc.) 4.Use of secondary data	No, but provides guidance on setting system boundaries and use of primary and secondary data

2.2. Review of Available Standards and Guidelines for Reporting Product-Based Environmental Information

Several pertinent standards for calculating and declaring product-based environmental information are potentially available (See [Table 2.1](#)). These standards vary in their scope, use, and environmental topics covered. To understand suitability for the aerospace industry, the selected standards were reviewed to identify “methods” that manufacturers/suppliers could use to measure the pre-selected product-based environmental indicators.

The review of product standards and guidelines identified several key learnings. Most product standards and environmental accounting methods are LCA based and draw on international standards as their basis, such as ISO 14040/44. Generally, 3 methods for collating/calculating product-based environmental data are inferable from the standards: (1) direct measurement, (2) modelling/theoretical calculations, and (3) generic calculations. However, there is little prescriptive guidance on how to implement these methods/calculations for measuring the pre-selected PBEIs. Two types of product-based data are used: (1) primary/specific, and (2) secondary/generic, though there is little prescriptive guidance on how to calculate this data. The reviewed standards provide guidance on setting system boundaries and how to report information, but provide little description from a manufacturers' perspective on how to calculate, for example, the embodied manufacturing energy content of their products. Most of the reviewed standards provide guidance on assessing uncertainty and data quality. Although several product-standards are available for calculating and declaring product-based environmental information, none of them are directly useable for measuring the pre-selected environmental indicators. This raises the need to explore existing approaches adopted by aerospace companies to develop appropriate methods. Thus based on these learnings, the project identified the need to engage the industry partners and carry out primary research to achieve the following objectives:

- **Objective 1:** Develop a methodology for measuring the energy consumption PBEI
- **Objective 2:** Test methodology for measuring the energy consumption PBEI in a real manufacturing environment and assess suitability for use across the aerospace value chain

3. METHODOLOGY

Overall, an action research approach was adopted to meet the research objectives. Following [Koshy et al. \(2011\)](#) guidelines for carrying out action research, [Figure 3.1](#) illustrates the generic action research cycle developed and applied within the context of this research. Input into the planning and implementation of each stage from the research consortium is sought to ensure the collaborative nature of the work is maintained.

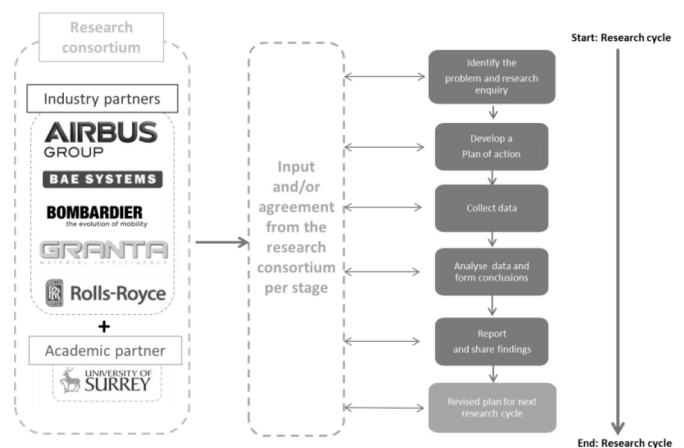


Figure 3.1. Action research cycle model developed and adopted for the project's context