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Permalink

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ISBN

9780857096555

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Publication Date

2014

DOI

10.1533/9780857096678.2.112

Peer reviewed

Life cycle assessment of engineered nanomaterials

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DOI: 10.1533/9780857096678.2.112

Abstract: Life cycle assessment (LCA) is used for the comprehensive environmental assessment of engineered nanomaterials (ENMs) and ENM-enabled products. A complete LCA can highlight a possible shifting of burden where reduction of environmental impacts at one stage may come at the expense of another. The objective of this chapter is to familiarize the reader with LCA as a methodology in the context of ENMs. This is done by first presenting a basic LCA framework, followed by peer-reviewed LCAs on ENMs. We conclude with a brief on evolving approaches that address ENM-specific challenges for LCAs.

Key words: life cycle assessment, engineered nanomaterial, nanotechnology, emerging technologies, environmental assessment.

6.1 Introduction

Conventionally defined as a manufactured material with at least one physical dimension below 100nm, engineered nanomaterials (ENMs) are projected to reach a production volume of 4 million tons by the year 2016 (LUX, 2007). While nanotechnology, or ENMs, is considered to be one of the 'key technologies' of the twenty-first century with high expectations for innovative products and new market potentials (Klöpffer *et al.*, 2007), the exposure to nanoparticles may also lead to environmental risks and adverse health effects (DEFRA, 2007). At the heart of the environmental assessment literature on ENMs is the concern that ENMs, with their size and unique functionality, may exhibit unconventional behaviour leading to different fate, transport and toxicity mechanisms compared with their bulk counterpart (Thomas *et al.*, 2011). The potentially high embodied energy of ENMs is also a concern (Theis *et al.*, 2011). Therefore, comprehensive environmental assessment of nano-enabled products has been called for (DEFRA, 2007; Klöpffer *et al.*, 2007).

To that end, life cycle assessment (LCA) has been proposed as a system-level evaluation of ENMs and ENM-enabled products by a joint workshop of the Woodrow Wilson International Center for Scholars, The Pew Charitable Trusts, and the European Commission (Klöpffer *et al.*, 2007). Life cycle assessment provides a framework for quantifying environmental impacts, and for comparing