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Life cycle perspective in environmental strategy development on the industry cluster level: A case study of five chemical companies

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ABSTRACT

The scale of industry clusters and their significant environmental impact make addressing environmental strategies on the cluster level an intriguing task. Although several studies indicate that upstream processes contribute significantly to the total environmental impact of the system, few studies assess how environmental strategy development can be approached from a life cycle perspective. The aim of this paper was to investigate the practical significance of life cycle-based environmental strategy development using a chemical industry cluster in Sweden as the case study. To assess the environmental impact, a cradle-to-gate life cycle assessment (LCA) was chosen as the method, with the total annual production of the cluster in 2011 as the functional unit. To cover the whole value chain, the global warming potential for downstream processes was also estimated. The findings were linked to the cluster vision, which aims to reduce environmental impact by 2030. The results indicate that the cluster must focus on the whole value chain when pursuing the aim of producing sustainable products as environmental impact both upstream and downstream of the cluster accounts for a larger share than on-site processes. The assessment also enables distribution of environmental impact among incoming material streams, thus providing the cluster with decision support when introducing renewable and recycled materials. Additionally, the assessment supports strategy comparison and serves as a base case against which strategy opportunities can be evaluated. This study demonstrates that the life cycle approach has interesting potential to support industry cluster companies in their mutual effort to improve environmental performance.

1. Introduction

Industry clusters exist in large numbers all over the world. The clusters vary in size and comprise one type of industry or a combination of industries. The co-located companies could have several forms of inter-company links. They could exchange materials, water, energy or by-products (Chertow et al., 2008). Such interconnectedness has attracted scientific interest as the features resemble the symbiosis arrangement found in nature. 'Industrial symbiosis' has become a research topic in its own right, the aim being to examine all aspects of symbiotic activities between businesses (Martin et al., 2013). One specific aspect that was investigated is the environmental implications of the interconnectedness. After reviewing case studies from Europe, Asia, Australia and North America, Eckelman and Chertow (2013) came to the conclusion that there are environmental benefits to be gained from symbiotic activities compared with standalone companies. Energy integration, a reduction in transport distances, and availability of secondary materials are just some of the highlighted advantages. These advantages indicate that the interconnectedness and proximity that a cluster arrangement can provide offer a unique opportunity to develop efficient environmental strategies.

One approach that has been used to understand the environmental performance of industry clusters is eco-efficiency, i.e. the ratio between added economic value and added environmental impact. Examples are Salmi (2007), who assessed the eco-efficiency of possible exchanges in a Russian mining complex, and Seppälä et al. (2005), who explored how eco-efficiency indicators can be used in a region in Finland. The latter emphasised the difficulty of including upstream and downstream effects. Since significant

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emissions caused by integrated industry arrangements occur outside the cluster, it is important to include the value chain in environmental assessments (Mattila et al., 2012). A method designed to explore environmental impact from a life cycle perspective is life cycle assessment (LCA). LCA reveals resource demand as well as product and process emissions and waste, and then allocates these to environmental impact categories (ISO, 2006b). In the studies where the method has been applied to industry clusters, the main focus has been on quantifying environmental impact and not on the practical relevance of the method to environmental strategy development. To our knowledge, there are only two articles that use LCA to address strategies for reducing environmental impact in an existing industry cluster: the papers by Dong et al. (2013) and Sokka et al. (2011). Dong et al. (2013) used LCA to reveal the location and scale of CO_2 emissions in a Chinese chemical industry cluster. Electricity and heat consumption were identified as key areas and process integration and cleaner production were proposed as appropriate emission-reduction strategies. Sokka et al. (2011) analysed the environmental impact of a system in Finland where chemical plants, energy plants and a wastewater treatment plant are clustered around an integrated pulp and paper manufacturer. The LCA results show that upstream processes make a significant contribution to the total environmental impact of the system and the authors recommended that strategies focus on extraction and production of raw materials and external energy.

As industry clusters have significant potential for developing large-scale environmental strategies, and previous studies indicate that the value chain should be targeted for environmental impact reduction, we saw a need to investigate the practical significance of life cycle-based environmental strategy development in industry clusters. Although the companies could have mutual interests, they are nevertheless independent businesses with independent economies and goals. A prerequisite for collaboration therefore is that every company realises the benefit. Accordingly, our aim is to investigate and demonstrate what life cycle environmental assessment on the cluster level can contribute. We have used a Swedish chemical industry cluster as a case study for extending current knowledge. Environmental improvements to such an industry cluster are of particular interest since the petrochemical industry is a large consumer of fossil feedstock and fuels (approximately 30% of global industrial energy use) and produces extensive greenhouse gas emissions (2000 Mt $CO_{2\text{-eq}}$ emissions in 2004) (International Energy Agency, 2007). The life cycle environmental impact of the industry cluster was assessed using a cradle-to-gate LCA complemented with a global warming potential estimation for downstream processes. To provide examples of the potential and benefits of the approach, the results have also been linked to the Stenungsund industry cluster 2030 Vision.

2. Description of the industry cluster

The industry cluster in our study consists of the chemical companies AGA, AkzoNobel, Borealis, INEOS and Perstorp. It is situated in the Swedish town of Stenungsund and employs approximately 2500 people. The companies are all members of large international groups. Industrial settlement started 50 years ago. The area has attracted industry because of its close proximity to a harbour and the availability of energy and land (Stenungsund Chemical Companies, 2013).

The five companies produce a range of products and intermediates, including chemicals, plastics, gases and fuels. Fig. 1 provides an overview of the exchanges in the industry cluster. The figure illustrates how the Borealis steam cracker plant functions as the heart of the industry cluster and supplies the companies with raw materials. The main raw materials and products consumed and produced by the companies in 2011 are listed in Table 1. The companies interact strongly with each other in terms of material exchange. Energy integration, however, is still limited (Jönsson et al., 2012).

Although by international standards the cluster is quite small, it is the largest chemical industry cluster in Sweden in terms of production volume. The cluster accounts for around 5% of Sweden's total fossil fuel usage (mainly feedstock), and is a major emitter of fossil CO_2. The companies thus face challenges although they also have the possibility to meet these challenges since they collaborate

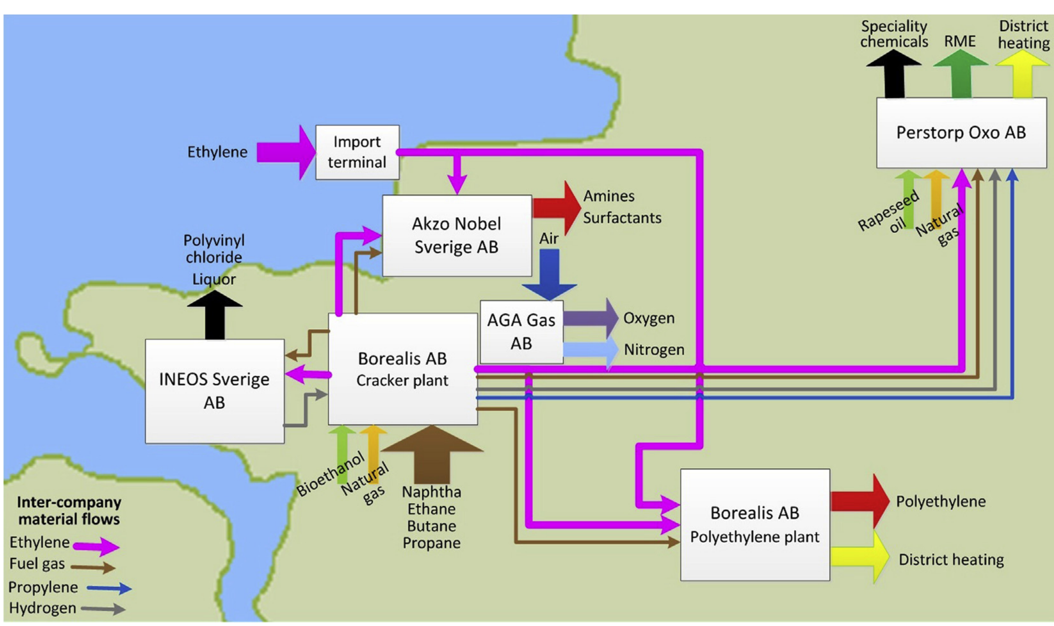

Fig. 1. Flows of materials into and products from the Stenungsund chemical cluster and exchanges within the cluster (Jönsson et al., 2012). Only major flows are shown. Arrow size indicates the flow size, while the colours differentiate the flows. Green arrows indicate bio-based flows. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)