OPEN WINDOW ON SUSTAINABLE MATERIAL INNOVATION: EVIDENCE FROM FLEMISH PRODUCTION INDUSTRIES

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Abstract
Our paper focuses on the results of a research project called ‘Open Window on innovative material technologies for a sustainable Flemish production landscape’ (in short: ‘Open Window’). In this project, enterprises located in Flanders (Belgium) give testimony of their innovative products and processes. The aim of gathering evidence on material innovation is to inspire others, promote material innovation and help enterprises to trace and implement opportunities for material innovation, amongst others by means of a 3P scan. The paper starts off with a quote stating that sustainable development via material innovation is still at its infancy stage, with relatively few real adopters and questionable impact. Based on concrete cases in Flemish production industry, we bring in our conclusion that some persistent prejudices are gradually eroding: (1) While material innovation in the past was mainly driven by large groups and multinationals, it can be noticed today that small and medium-size enterprises are defining their own strategies for material innovation; (2) Material innovations are no longer only developed within sectors that are traditionally targeted by environmental regulations. Material innovations are generalized in many, if not all, other industrial sectors. In our paper, well-chosen testimonies on sustainable material innovation in Flanders illustrate that good financial performance is not always incompatible with good ecological and social performances, even though not all cases show win-win situations. Further, our paper contains critical reflections on the definition of so-called ‘success stories’ on material innovation. The definition of success proves all but univocal…
Keywords
Material innovation, sustainable development, Flanders, evaluation, production industry

1. Introduction
Our paper focuses on the interim results of a Flemish research project called ‘Open Window on innovative material technologies for a sustainable Flemish production landscape’ (in short: ‘Open Window’; see www.openraam.eu). The Open Window project aims at creating awareness of the possibilities for increasing product and production process sustainability through material innovation. To attain that goal the project has set itself four main practical sub-goals: (1) by means of interviews, the project team aims to assess obstacles and opportunities for implementing innovative material technologies in Flemish production industry, (2) enterprises located in Flanders are invited to give testimony of their innovative products and processes to inspire others; (3) enterprises with innovative potential, we offer the 3P opportunity scan indicating the areas in which sustainable material innovation is possible, and (4) with free advice and consultancy of more than 100 material experts, the Open Window project partners support enterprises in implementing material innovation.

While the paper of Shamuilia (2010) describes more closely the characteristics of the 3P opportunity scan, the aim of this paper is to present some of the conclusions on the first and second aims of the Open Window project. We bring a meta-analysis of testimonies of concrete cases of material innovation in Flanders, and interpret the results based on data from plural qualitative interviews with business representatives.

1.1 Open Window versus other initiatives in Europe and Flanders
In July 2008, the European Commission adopted the action plan on Sustainable Industrial Policy (SIP) and Sustainable Consumption and Production (SCP). This action plan focuses both on the industrial production process, the product itself and on consumer behaviour (see Figure 1). By undertaking simultaneous and coordinated actions in these 3 fields, an iterative cyclic process is initiated, in which sustainable production units will lead to products with a lower environmental impact over their entire lifecycle. At the same time the awareness of consumers must lead to shifts on the demand side, which will stimulate companies on the supply side to develop new sustainable products with increasingly more sustainable production methods. In practice the action plan aims at streamlining the many already existing initiatives about Integrated Product Policy, Eco-Design, Eco-labelling, cleaner production, Environmental Technology Action Plans, Green Public Procurement, Green Retailing…
Figure 1: Sustainable Consumption and Production (SCP) en Sustainable Industrial Policy (SIP) Action plan (Source: BIO IS, France)

Plan C, the Flemish transition network on sustainable material management, is supported by the Flemish government and the Public Waste Agency of Flanders (OVAM). Plan C aims at inspiring, motivating and supporting organizations towards sustainable material management at the level of societal systems. Transition pathways tackling the increasing complexity of environmental problems and resource deficiency are delineated, e.g. by closing the material loop path, by material innovation and by introducing a material efficient service economy (www.plan-c.eu).

In 2005 the Environmental & Energy Technology Innovation Platform (MIP) was founded by the Flemish government as a pool of competences in which the policy area Economics, Science and Innovation and the policy area Environment, Nature and Energy cooperated (www.mipvlaanderen.be). In 2009 the Flemish government decided to continue MIP with as main goal ‘greening’ the economy. MIP stimulates companies to invest in new products, processes and services that reduce the environmental impact by closing material and process cycles according to the ‘Cradle to Cradle’ philosophy and the development of new technologies for smart energy generation. MIP thus supports the transition to a ‘green’ economy in which consumption and economical growth are decoupled from the ecological impact on our planet.

Another initiative is the Belgian C2C platform: it allows companies and governments to assess the feasibility of C2C for their products and spatial development projects. The
platform is a medium to gather knowledge and to exchange experiences. Members of the networks can participate in workshops (www.c2cplatform.be).

Within this global framework, the Open Window project focuses on how material innovation can contribute to sustainability. As stated in the introduction, we want to inspire companies by making available testimonies of good practices of sustainable material innovation in Flanders showing that material innovation can result in benefits both for People, Planet and Profit-aspects. Further, by performing the 3P opportunity scan (developed in this project) we want to verify (future-oriented) whether companies can implement additional sustainable material innovations. Ultimately these new opportunities result in implementation trajectories (which are also guided in this project).

1.2 Materials and innovation

Materials are key for technological advances in all industrial sectors. Added value materials with higher knowledge content, new functionalities and improved performance are increasingly critical for industrial competitiveness and sustainable development. The materials themselves are the first step in increasing the value of products and their performance. Research focuses on developing new knowledge-based multifunctional surfaces and materials with tailored properties and predictable performance, for new products and processes targeting a wide range of applications. Material technology also represents an essential enabler for new environmental and energy related technologies. The energy problem for example can be translated into challenges in new material developments, e.g. new materials for windmill propellers and gears (energy generation), tribological materials (energy transmission, distribution and consumption) and battery materials (energy storage)(NMP EAG, 2009). This requires the knowledge of raw materials, the control of intrinsic properties, processing and production, taking into account potential impacts on health, safety and the environment throughout their entire life-cycle (European Commission, 2009).

Materials technology impacts a manufactured product by its choice of (a combination of) materials (metals, ceramics, glass,…) and its processing steps (shaping, joining, finishing) (Ashby et al., 2004). Technical viability is however not enough to justify the development of a new product. The investment required to commercialize a technically-viable product will be forthcoming only if the investors can capture sufficient value, which of course depends on market size and the ability to outmanoeuvre competition.
Design to minimize adverse impact of engineering products on the environment (‘green’ design) is assuming an increased importance in all branches of engineering. Eco-impact thus becomes an additional metric to be optimized, along with performance and cost. The problem is a complex one: eco-impact can be associated with the extraction and refinement of the material, with the manufacture of a product from it, with the use of that product and with its disposal (Wegst and Ashby, 2002) (see Figure 2).

![Figure 2: The material life-cycle. Ore and feedstock are mined and processed to give a material. This is manufactured into a product that is used and, at the end of its life discarded or recycled. Energy and materials are consumed at each station, generating waste heat and solid, liquid and gaseous emissions.](image)

Full sustainability is, however, more than preserving our environment by the rational (re-)use of resources and energy. Social and economical aspects are equally important, as indicated in the common 3P – people, planet & profit – sustainability model. And profit indeed, as without sustained competitiveness of EU economy, opportunities for social & environmental improvements will be lost.
2. Good Practices from Flemish industries
In the Open Window project, Flemish enterprises give testimony of their innovative products and processes. Hereafter, we describe in more detail the selection and assessment of these good practices.

2.1 Selection of cases
At this time, nine innovation cases from Flemish production industry have been analyzed and assessed with respect to their contribution to sustainable development. The selection of the testimonies was based on the potential of each material innovation case to inspire other companies. Potential enterprises for a testimony were gathered from contact databases of the Open Window project partners and of the Public Waste Agency of Flanders (OVAM). After selection, business representatives were invited each for a 2 hours interview with social scientists of the University of Antwerp. The transcription of these interviews were used to identify cases of (sustainable) material innovation, and to define obstacles and opportunities for introducing and implementing sustainable production. Based on the interview reports and additional data sources, VITO documented the selected case by qualitatively or semi-quantitatively assessing indicators for sustainability. Company reports with 3P-sustainability assessments of the selected material innovation cases were written and published at the Open Window website, aiming to inspire others (www.openraam.eu > inspiration). The nine 3P-sustainability assessments published till now, represent cases of as many individual companies from various industrial sectors: it concerns enterprises classified as chemical industry (3), building industry (2), medical sector (1), plastic processing industry (2) and furniture industry (1). Two of them are business-to-business oriented, the others are producing consumer goods. For reasons of confidentiality, the companies are not named in this paper. This, however, does not affect our conclusions negatively as our specific goal is to reflect on a meta-level scale.

2.2 Indicators for evaluation of the sustainability of the innovation cases
In order to objectify the sustainability aspects of concrete material innovations, a series of indicators was compiled, as shown in Tables 1 and 2 for processes and products respectively. The majority of these indicators is based on the 3P-opportunity scan developed in the Open Window project (Shamuilia, 2010), qualitatively assessing both the process and the product level and covering the economic (Profit), the social (People) and the ecological
(Planet) dimensions of sustainability. Furthermore, some indicators originating from IWT's DTO evaluation checklist for sustainable technological research were integrated (indicated with an *).

Process related indicators concern different elements of the in-plant or manufacturing processes. Product related indicators concern the sustainability aspects of the use and end-of-life phase of the manufactured products. Together they cover the entire material life cycle (see Figure 2), indicating all possible options to implement sustainable material innovations.

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1 The agency for innovation by science and technology (IWT) is a public agency established in 1991 to support innovation in Flanders by different means (financial support, advice, coordination and networking, policy preparation) (see www.iwt.be)
<table>
<thead>
<tr>
<th>PROCESS</th>
<th>People(1)</th>
<th>Planet(2)</th>
<th>Profit(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise nuisance (and prevention)*</td>
<td>Energy consumption of production (process energy)*</td>
<td>Integration of the processing steps</td>
<td></td>
</tr>
<tr>
<td>Odour nuisance (and prevention)*</td>
<td>Substitution of (raw) materials: this includes the use of renewable raw materials; and the use of secondary (recycled) (raw) materials* ²</td>
<td>Added value per processing step</td>
<td></td>
</tr>
<tr>
<td>Light nuisance (and prevention)*</td>
<td>Materials processing</td>
<td>Cost savings as a result of the use of less (raw) materials, energy and/or waste</td>
<td></td>
</tr>
<tr>
<td>Green procurement of the used materials and resources</td>
<td>Saving on the amount of (raw) materials used, a.o. by-products/additives and/or water consumption*</td>
<td>Investing in new sustainable technology vs. the payback time</td>
<td></td>
</tr>
<tr>
<td>Information: internal company communication (about health and safety aspects)</td>
<td>Waste prevention: reduction of (harmful and non-harmful) production waste (pre-consumer waste) and recyclability of production waste*</td>
<td>Secondary costs (e.g. health-related costs) as a result of a non sustainable process</td>
<td></td>
</tr>
<tr>
<td>Working hours</td>
<td>Improvement of the process intensification³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education/training: the</td>
<td>Harmful/toxic emissions</td>
<td></td>
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</tbody>
</table>

² This thus refers to the use of post-consumer waste, while the indicator “Reuse of raw materials (including water) during the production process” refers to the reuse of pre-consumer waste.

³ This indicator takes into account to what extent efficient production and minimization of the number of production steps has been taken into account at the designing stage and to what extent the company has expertise/know how capacity to make improvements of the process efficiency by making product adaptations.
### PROCESS

<table>
<thead>
<tr>
<th>People(1)</th>
<th>Planet(2)</th>
<th>Profit(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>opportunity for employees to enroll in a training and the ease of teaching a new process to the present workers</td>
<td>during production*</td>
<td></td>
</tr>
<tr>
<td>Safety issues</td>
<td>Consumption and production of renewable energy*</td>
<td></td>
</tr>
<tr>
<td>Toxic materials: harmful/toxic substances in materials or components*</td>
<td>Reuse of raw materials (including water) during the production process*</td>
<td></td>
</tr>
</tbody>
</table>

(1) aspects of social LCA (Hauschild 2008) and the indicators proposed by Braungart (McDonough & Braungart 2002) and the DTO-evaluation checklist

(2) indicators are taken partly from Life Cycle Analysis (LCA) evaluation, Energy/Material Flow Analysis (EFA and MFA respectively) and the DTO-evaluation checklist

(3) assessment by terms used in industrial organization

* aspects taken from or extended with definitions of the DTO (sustainable technological development) – evaluation checklist

Table 1: People, planet and Profit indicators used for the sustainability assessment of testimonies of process related materials innovation
<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>People(1)</th>
<th>Planet(2)</th>
<th>Profit(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety issues (for the user of the product)</td>
<td>Packaging of the product: saving on the amount of raw material consumption for packaging materials, and use of secondary (recycled) packaging material*</td>
<td>Optimization of the [total cost/total value] ratio of a product</td>
<td></td>
</tr>
<tr>
<td>User friendliness</td>
<td>Optimization of product distribution* 4</td>
<td>Opportunity and risk analysis for the existing customer base</td>
<td></td>
</tr>
<tr>
<td>Information: external communication (about health and safety aspects)</td>
<td>Optimization of the product use: This includes energy consumption during the use phase*</td>
<td>Opportunity and risk analysis for (attracting) prospective customers</td>
<td></td>
</tr>
<tr>
<td>Multi functionality of the product</td>
<td>Optimization of the function fulfilment of the product</td>
<td>Possibility of developing product/service combinations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Optimization of the product life span* 5</td>
<td>Green marketing</td>
<td></td>
</tr>
<tr>
<td>Optimization of product disposal:</td>
<td></td>
<td>Modular character</td>
<td></td>
</tr>
<tr>
<td>• reduction of (non-) harmful waste in the use phase (and accompanying</td>
<td></td>
<td></td>
<td></td>
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</tbody>
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4 This includes aspects such as transport weight and volume, and transport distance (4), as well as transport mode choices.

5 Economic life span (e.g. possible extension by upgrading of modules, esthetic housing can be replaced,....). Technical life span (e.g. sustainability of materials and/or components, efficient repair & maintenance, reliability of parts,...).
### Table 2: People, planet and Profit indicators used for the sustainability assessment of testimonies of product related materials innovation

<table>
<thead>
<tr>
<th>People(1)</th>
<th>Planet(2)</th>
<th>Profit(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>environmental nuisance)* and recyclability and reuse of the discarded product/technology (e.g. harmful substances are easier to recuperate, components are disassembled more easily, parts can be reused, non-recyclable materials are replaced by recyclable ones, recyclable and harmful materials can be better identified,...)*</td>
<td>Harmful/toxic emissions during use* Secondary costs (e.g. health-related costs) as a result of a non sustainable product</td>
</tr>
</tbody>
</table>

(1) indicators are partly taken for the LiDS-wheel and partly self-defined, taking into account the consumers interest  
(2) indicators are based on the Lifetime Design Strategies (LiDS) – wheel (Jones 2004) and the DTO- evaluation checklist  
(3) based on basic business economics principles (Esty & Porter 1998)  
* aspects taken from or extended with definitions of the DTO (sustainable technological development) – evaluation checklist
3. Discussion of the preliminary results

Meta-analysis of nine cases of sustainable material innovation in Flemish production industries leads us to some preliminary conclusions:

Sustainable material innovation is not limited to the production (process) phase only, but also considers the overall life cycle of the product (including use phase and end-of-life phase, see Figure 2). On the one hand we found cases where the environmental and financial gains are directly related to the production process, and thus to the benefit of the producer. On the other hand, we see cases where it is the end-user who takes advantage of the environmental and financial gains of the materials innovation. This may nevertheless also lead to a positive return for the manufacturer. E.g. as a result of customer loyalty and word of mouth marketing.

3.1 Sustainable material innovation in production processes

In cases in which materials innovation is implemented in the production process, it turns out that savings are the overall dominant driver. Enterprises can take advantage of the optimization of raw materials, energy use and waste production, next to the payback time for investment in novel sustainable technology.

Our testimonies on materials innovation in production processes illustrate that financial-economic advantages do not exclude good ecological performance. On the contrary: reduction of energy consumption, the possibility of substituting raw materials and the reduction of the amount of raw materials used compose major benefits on the environmental side of process innovation. Business representatives state during the interviews that the rising prices for resources (both energy and materials) are an important driver for companies to save on resources.

Social issues (people-aspects) seem rather underrepresented compared to the other 2 P’s (planet and profits issues). This might be explained by the fact that profit aspects are inherently connected to good operational management. Moreover, environmental and social benefits are often interconnected (as stakeholders are for example employees and local residents, benefiting from environmental improvements). This, however, does not imply that business leaders do not think high of people-aspects. On the contrary, our interviewees stress the importance of improving employees' working environments in deciding upon reorganization of production processes.
3.2 Sustainable material innovation in products

Optimizing the end-of-life of the product is by a large margin the most important environmental advantage of sustainable material innovation in products. Taking into account the end-of-life phase of products during design and consequently substituting raw materials by renewable or recyclable raw materials or by using secondary (recycled) materials in the production process, allows for less (harmful) waste at the end of life of the produced products and/or for a better recyclability and re-use of the discarded products. From the interviews we learn that companies are becoming increasingly sensitive for these kinds of arguments. Taking up responsibility for end-of-life of products is often mentioned as an important issue in today's and tomorrow's work. Unfortunately, in some cases, recycling or re-use is still too complex, mainly because of technical/technological constraints. In these cases, investing in research projects on the topic is considered relevant.

Further, we see companies making opportunity and risk analysis on sustainable material innovation in their products. Companies want to make sure their existing customer base is willing to accept material innovation in their products, and of course they hope to attract new prospective customers by innovating successfully with new/other materials in their products. Within that context, it is a logical consequence that companies attach great importance to communication on their achievements, via (green) marketing campaigns and other communication strategies.

Another driving force for sustainable material innovation in products and processes is environmental, employee (health) protection and product and process safety regulation. With respect to reduction of noise, odour and light pollution we conclude from our testimonies that little efforts are made, probably due to existing stringent regulation in these fields. On the other hand we see that companies apply specific measures in order to reduce the use of harmful and/or toxic materials in the production process, as well as harmful and/or toxic emissions from the use of the product.

3.3 Sustainable material innovation as part of change in the corporate system

We frequently identified the indicator ‘Consumption and production of renewable energy’ as an aspect implemented by companies active in sustainable material innovations. This is not counted for in the 3P-assessment table of our good practice cases as it is not exclusively related to the reported material innovation case, but to a companywide policy. We consider this conclusion worth mentioning as it indicates that these companies are aware of both the
financial and environmental cost of energy, and that they are willing to focus both on energy efficiency and clean energy.

4. Conclusions
Magee (2009) quantified the role of materials and process innovation in overall technological development. Studying the transformation, transportation and storage of information and energy, he puts that material innovations account for at least 20% up to 2/3 of overall technological progress. The Open Window project focused – in contrast to Magee - on the qualitative assessment of ‘good practices’ in sustainable materials innovation. Nevertheless, we do agree that material innovation is of major importance for the future of our economies.

For the future, it seems important that companies not let themselves be blinded by highly pitched expectations on fundamental and radical change in production and consumption processes. From what we learn from business testimonies in Flemish production industry, it seems equally important to keep investing in discrete improvements: as well in material innovation in production processes, as in the improvement of the end-of-life of products. As our evaluation of nine good practices in sustainable material innovation illustrates, incremental changes in production processes and products offer small but relevant steps towards making production industry more sustainable: in terms of economic, ecological, and social ‘gains’.

Acknowledgements
This paper is the result of a co-production between two partners of the Open Window project: the Flemish Institute for Technological Research (VITO), bringing in expertise in material technology and sustainability assessments, and the Faculty of Political and Social Sciences of the University of Antwerp, injecting social scientific expertise on institutional change, process evaluation and interpretative analysis within the context of sustainable development. Other partners within the Open Window project are: the Catholic University of Louvain, in particular the Interfaculty Materials Research Centre which links expertise on materials from various research groups, and SIRRIS: the collective centre of the Belgian technological industry. The Open window project was supported by the European Fund for Regional Development and the Flemish Government.
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