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ORIGINAL PAPER

Integrating services and tools in an ICT platform to support eco-innovation in SMEs

Patrizia Buttol · Roberto Buonamici · Luciano Naldesi · Caterina Rinaldi · Alessandra Zamagni · Paolo Masoni

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Abstract Small and medium-sized enterprises (SMEs) represent a key vector to introduce and diffuse eco-innovation in the market, because of their relevance to both the environment and the European gross domestic product. As they are often focused on continuous and incremental innovation of their products, the optimization of product eco-innovation paths can be considered a central aspect of their business. All phases of this process (awareness building and training, analysis, product (re)design and communication/certification) need to be supported to overcome the existing barriers, which mainly consist of lack of experience inside SMEs and cost of information, data, and tools. Information and Communication Technologies can play a role to lower some of the barriers, but currently the numerous services and tools available cover only specific aspects of the whole process, and are often too complex for their direct use by SMEs. The multilingual web-based platform Ecosmes.net here presented aims to integrate user-friendly and free-of-charge services and tools to support all phases of the product eco-innovation process in SMEs. The approach behind mainly consists in developing tailored, simplified tools, and in carrying out "homogeneous product group" studies, as a basis for the production of pre-elaborated information and data to be used with the tools developed. Experience gained in 5 years of applications has confirmed that Ecosmes.net can facilitate the start-up of the product eco-innovation process, but has also shown that not all the potentialities have been fully exploited. Moreover, as the eco-innovation market is not developed enough to allow economic management of these kinds of online services, a public initiative is advocated to face this challenge and support a continuous upgrading. Modes and opportunities are proposed and discussed in the conclusion.

Keywords Eco-design · ICT · LCA · Product (re)design · Web services

Introduction

Contributing to sustainable development while enhancing Europe's innovative potential and competitiveness (EC 2005) is a central objective of the EU Sustainable Consumption and Production (SCP) and Sustainable Industrial Policy (SIP) Action Plan (EC 2008) and of other regulations aimed at promoting eco-innovation, such as the Directives 2000/53/EC, 2002/96/EC, and 2002/95/EC and Regulation no. 1907/2006.[1] More recently, the Eco-design directive on Energy-related Products (Directive 2009/125/EC), which aims to incorporate life-cycle thinking and environmental protection at the early stage of product development, stresses the importance of integrating eco-design in small and medium-sized enterprises (SMEs) and of overcoming serious barriers encountered by them, many of which are technical and managerial, others cultural, economic, and regulatory. For this reason, the European Commission has prioritized the development of specific measures supporting eco-innovation in SMEs. In particular, SMEs are the main target of the "Competitiveness and Innovation Framework Programme" (EC 2009), which

P. Buttol · R. Buonamici · L. Naldesi · C. Rinaldi · A. Zamagni · P. Masoni (✉)
ENEA, Via Martiri di Monte Sole, 4, 40129 Bologna, Italy
e-mail: paolo.masoni@enea.it

[1] An overview of the eco-innovation programs in Europe and an analysis of their impact and effectiveness can be found in Bleischwitz et al. (2009).

aims to encourage the competitiveness of European enterprises by supporting innovation activities (including eco-innovation), a better take-up and use of Information and Communication Technologies (ICT) and the development of the information society. Furthermore, specific initiatives have been promoted, like the "European Platform on Life Cycle Assessment" project (JRC-IES 2009), to supply technical instruments and reliable data for the assessment of the products environmental performance.

In such a framework, this article proposes a new approach of integrating services and tools to support the process of product eco-innovation in SMEs by using ICT, and describes the concepts that form the basis of the Ecosmes.net platform, conceived, and developed in the eLCA project (Masoni et al. 2005; Anonymous 2004).[2]

The eco-innovation process

As a definition of eco-innovation, we assume the one adopted in the MEI (Measuring Eco-Innovation) project, which proposes a life-cycle-based, incremental, and comparative approach and also includes non-technological innovations: *Eco-innovation is the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organisation (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resource use (including energy use) compared to relevant alternatives* (Kemp and Pearson 2008).

In agreement with this definition, we can group the eco-innovation processes into three main categories (Bleischwitz et al. 2009): process, product, and system eco-innovation. *Process eco-innovation* aims to improve production processes or delivery methods and can be implemented at different levels (small improvements, re-design of processes, re-design of industry value chain, etc.). It is historically the most addressed as it intervenes directly on those phases fully under the control of the enterprises. Environmental management systems (EMS) are the most commonly used environmental tools which provide a systematic way of addressing and managing the environmental impact of an organization through the allocation of resources, the assignment of responsibility and the continuous evaluation of procedures and processes. *Product eco-innovation* includes any improvement that takes into account both the environmental and technological characteristics of products/services and leads to lower the overall impact on the environment. As highlighted in the Integrated Product Policy Communication (EC 2003), Life Cycle Assessment (LCA), standardized by ISO 14040 series (ISO 2006a, b), is the basic method to analyze and compare the environmental performance of products/services in a system perspective and in a comprehensive way, and can also provide quantitative data for environmental claims (e.g., Environmental Product Declaration and Eco-label). *System eco-innovation* is the most radical type, as it refers not only to technological systems but also to developments involving the market and even behavioral changes. It requires the contribution of external conditions that are often driven by policy needs and priorities and are not under the enterprises' control. As a consequence, the enterprises are usually more prompted to the implementation of the first and second category of eco-innovation.

SMEs and the environment

The definition of SMEs varies among countries, ranging from "enterprises with fewer than 100 staff" used in New Zealand to "enterprises with fewer than 500 staff" used in the USA (Parker et al. 2009). European studies, as we do, mainly use the European Union (EU) definition of SMEs, i.e., enterprises having less than 250 staff.

In Europe, micro-, small and medium-sized enterprises account for a large share of economic and professional activity. 99% of firms in the European Union are SMEs (about 23 million) and they provide two-thirds of all private sector jobs (over 100 million); in some sectors, they account for more than three-quarters of all jobs. The vast majorities (92%) are micro-enterprises having less than ten employees (on average 2) and employing 30% of the total private labors force (Audretsch et al. 2009). Micro-enterprises dominate employment in countries such as Italy (47%) and Poland (39%) (EUROSTAT 2009). In a period when the economy is becoming more and more globalized and large firms are outsourcing production and jobs to low-cost locations, SMEs are particularly important for the creation of jobs. They are also vital in the development of knowledge spill-over (Audretsch et al. 2009).

As SMEs are the real giants of the European economy, their contribution to environmental impact is very large. It has been estimated that they are responsible for up to 70% of all global pollution (Revell et al. 2010), for example in the UK they account for around 60% of carbon dioxide emissions (Marshall 1998). However, SMEs have major problems in dealing with environmental regulations and often perceive environmental aspects (sometime unknown or hidden) as constraints and costs, in particular connected to the production phase.

The attention to product eco-innovation, also as a development opportunity for SMEs, was born at the

[2] The project was co-financed by the eContent program of the European Commission and coordinated by ENEA, with the co-operation of major European organizations.

beginning of ‘90s, first with the Integrated Product Policy (IPP) and then with the Sustainable Consumption and Production (SCP). It has progressively grown and has received a noticeable push during the last years, within a more general development of the *green economy*. Indeed, in the recent years of economic crisis the green economy stood out as the only sector that can achieve high growth rate when most of the others have negative trends. Therefore, product eco-innovation starts to be perceived, also by SMEs, as one of the principal exit strategies from the crisis.

Product eco-innovation and SMEs

Issues related to product eco-innovation in SMEs should be analyzed within a more comprehensive vision of their characteristics and innovation processes. Besides the many differences (sectoral, dimensional, managerial, etc.), SMEs have some common characteristics such as high flexibility in production, variability in supply chain, and adaptability to clients’ needs by means of continuous and incremental innovation of their products. Indeed, differently from radical innovations, often requiring technological jumps and high investments in knowledge and technologies, product eco-innovation processes are more similar to incremental innovation. Thanks to these potentialities and their influence on both the environment and gross domestic product, SMEs in Europe represent a key vector in introducing eco-innovation into the market.

Product eco-innovation, though characterized by some peculiarities, poses to SMEs the same problems as all innovation processes. As product development is a knowledge-intensive work requiring a correct balance between the two demands of knowledge exploration (acquisition of new knowledge) and exploitation (utilization of existing knowledge for innovative problem-solving) (Prieto et al. 2009), the most problematic aspects concern the *cultural* adaptation of SMEs to the eco-innovation. All in all, though eco-innovation requires specific knowledge and tools, its processes seem overall compatible with the SMEs’ habitual management techniques and market-oriented strategies, and the environment can be considered as a production factor that can be managed within the innovation strategies of the firm.

Though the development of each product requires a specific eco-innovation approach, four common recursive phases can be distinguished: awareness and training, analysis, product (re)design, and communication.

The first phase, *awareness building and training*, provides enterprises with the knowledge necessary in deciding their commitment to eco-innovation and in learning how to use available methods and tools (e.g., software tools, technical guidelines, databases, etc.).

The second phase is the *analysis of the product/processes* in terms of environmental characteristics, cost, functions, performance, and quality.

The third phase, *product (re)design* or eco-design, is recursively connected with the previous element and results in “green” innovative products.

The second and third phases are the most demanding and often require an iterative process between the assessment and the (re)design of the green product. First of all, enterprises have to guarantee that the green product quality is at least as high as the quality of the competitors’ products. Then, they need to satisfy customers’ needs for both advanced functionality and environmentally friendly characteristics. Third, they should offer more innovative solutions in the case of mature, aware “green markets”.

The last phase, *communication/certification* of the environmental quality of the product, aims to take market advantage of the eco-innovation results. This should be performed in a clear and transparent way, in compliance with ISO 14020 series (ISO 2000), to produce “accurate, verifiable, relevant and not misleading” environmental claims.

SMEs may have the knowledge and information required for one of the above-described phases, but very seldom are they able to develop all of them. The involvement of all departments of the company (marketing, purchasing, quality assurance, environment, design, and production) is crucial for the success of the process, but the internal knowledge is often inadequate. Moreover, to take into account all environmental aspects and trade-off solutions, it is necessary to analyze the whole life cycle of the product and to stimulate partnerships with suppliers/distributors/recyclers. As, in the short-term, the use of existing information may be more effective than internally creating specific technological knowledge (Devinney et al. 2003), SMEs usually approach consultants, branch organizations, and research centers to get necessary information.

Barriers and opportunities

As described above, to be accepted by SMEs, the eco-innovation process needs to be in agreement with the characteristics of their economic model, in particular with their knowledge of production and management (del Río et al. 2010; Masoni and Buonamici 2006).

Recently, the preparatory activities for the SCP and SIP Action Plan (EC 2008) have given the opportunity for deep discussion about the barriers to proactive SMEs’ participation in eco-innovation processes. In summary, the following main aspects have been observed (EC 2007):

– lack of awareness and knowledge of environmental problems, impact, and risk;

- lack of awareness of potential benefits of environmental management and life-cycle thinking;
- insufficient access to and low local availability of adequate environmental information, tools, and training;
- limited financial and human resources and expertise for dealing with compliance;
- focus on short-term planning at company level;
- limited market incentives/recognition for environmentally friendly behavior.

Here two main blocks can be distinguished: the first is represented by market barriers, which concern the real market share of the green products and the relative competitive advantages for the enterprises. The second block relates to technical, economic and cultural barriers regarding expertise, data availability, and the complexity of software tools/procedures.

In turns, the barriers of the second block can be classified in three main classes:

- *entrance barriers* which arise in the starting phase of eco-innovation and are mainly cultural. Their overcoming requires that information and knowledge are collected and made available to the different sectors of the firm. Besides the know-how about the specific environmental and technical issues of the product, information about general and local regulations, sector policies, certification opportunities, and availability of incentives, is necessary. Such an information is usually very disperse and not easily accessible, in particular to non-experts;
- *technological barriers* The key aspect is the availability of effective and user friendly tools for the crucial steps of analysis and (re)design. Many tools are today available, but, usually, they have been developed from the large sized enterprises' standpoint and therefore require high levels of knowledge and expertise;
- *cost and human resources barriers* They are mainly related to the collection of all environmental information that characterizes the whole life cycle of the product and leads to identify the "hot spots" and the possibilities of improvement. Data collection is the most costly and critic step for SMEs that decide to carry out the LCA of their products. Indeed, going back in the supply chain is time consuming and also difficult, as SMEs often do not have a constant and structured supply chain.

A detailed survey of web-provided eco-innovation service (Capponi 2004), recently updated (Rollo 2011), has shown that a notably large offer exists, but it usually only covers certain aspects of the entire process (for example, environmental management and legislation, LCA and eco-design tools,[3] information on incentives, or opportunities for funding and ecolabeling). These services are often managed by associations and private or mixed public–private organizations, which are developed from existing service centers, taking advantage of know-how and close relations already in place. They offer customized services, some free, some for a fee.

Furthermore, subjects and structures that today carry out functions of support and intermediation toward SMEs have been also analyzed, in particular: *cross-sectoral* networks such as districts services, technological centers, associations providing environmental services; *sector specific* networks with a deep knowledge of the supply chain; single *consultants* or consultant networks, who often are the only resource that SMEs activate for tackling the environmental issues.

Altogether, these analyses brought to the conclusion that ICT solutions and online services can contribute to lower the different barriers, providing a new generation of information, tools, and services.

Ecosmes.net: an innovative approach to support product eco-innovation in SMEs

The lack of integration of services and tools supporting the whole product eco-innovation process, together with the complexity of many of available tools, are critical aspects requiring innovative solutions. Building on a long tradition of national and European eco-innovation projects in partnership with SMEs and their associations, a web-based platform has been developed, Ecosmes.net. Developed in five languages (English, German, Greek, Italian, and Spanish), the platform is tailored to national/local contexts. It is free of charge and provides a comprehensive and integrated offer of information, training and tools for supporting SMEs through all of the phases of the process. More in detail, it includes: environmental information and downloadable documents concerning eco-innovation policies, regulations, and tools; simplified LCA and eco-design tools, supported by sector-specific and pre-elaborated databases; training courses targeted at SME technicians and consultants.

Ecosmes.net tackles some previously discussed barriers of SMEs toward the product eco-innovation, taking advantage of an innovative approach based on the combination of three main elements (Fig. 1):

1. integration of the all information, methods, and tools needed by SMEs to start, develop, and bring an eco-innovation process to a conclusion in all its phases;
2. tailored, simplified tools which SMEs can use easily;

[3] A full list of available LCA and eco-design tools and databases is maintained by the European Platform on LCA (JRC-IES 2009).

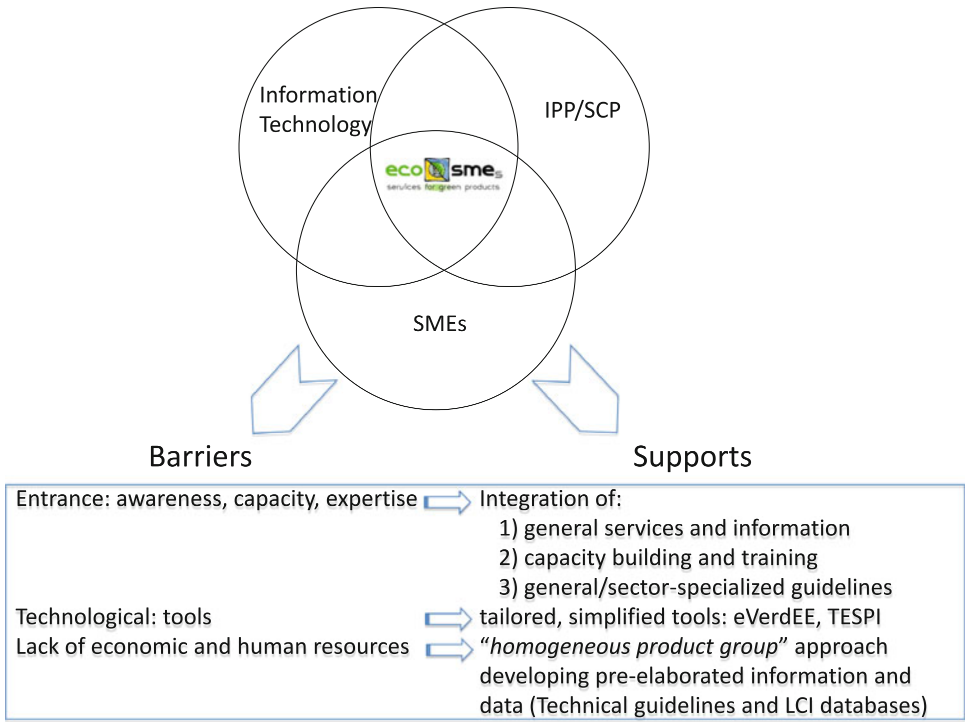

Fig. 1 Ecosmes.net, at the intersection of Information Technology, Integrated Product Policy/Sustainable Consumption and Production, and SMEs, provides specific supports to lower the existing barriers

3. information and data pre-elaborated in agreement with the *homogeneous product group* (HPG) approach, described later in this article. Used in the tools developed, they can drastically reduce costs and difficulties in the conduction of an LCA by SMEs.

Integration of information, methods, and tools

Ecosmes.net integrates three content classes (general services and information; capacity building and training; general and sector-specialized guidelines) with two simplified software tools for SMEs and their sector-specific database (Fig. 2).

Figure 3 shows how each of the four phases of product eco-innovation can be supported by specific parts of Ecosmes. The class *General services and information* is mainly aimed at providing concise, basic information about eco-innovation and SMEs. The purpose is to create a common vocabulary among non-expert users and to lower the first barriers that SMEs encounter toward the product eco-innovation. As described in the section "Product eco-innovation and SMEs", awareness is the first phase of any eco-innovation process and is crucial for its success. The informative part of Ecosmes.net is accessible by a menu that lists the principal concepts of product eco-innovation and the available tools for analyzing, managing, and improving the products environmental performance. Each menu item is described by four sub-menu items: (i) an introduction to the concept/tool, with synthetic

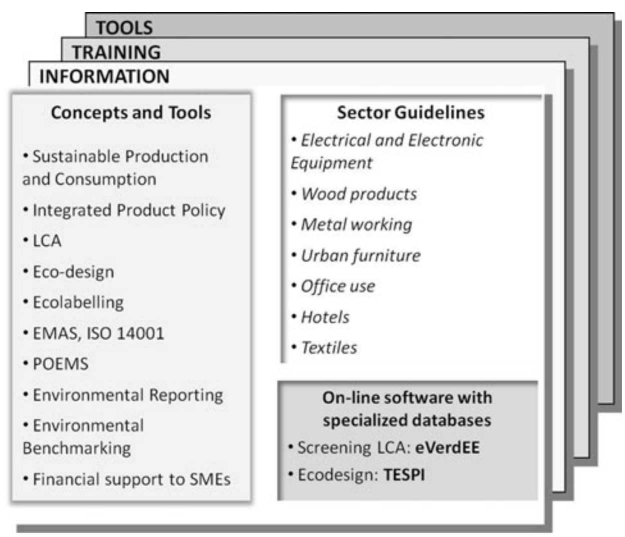

Fig. 2 Ecosmes.net content structure

information; (ii) a description of the procedure to follow in using it; (iii) the relevant existing standard and regulations; (iv) services and contacts available for getting help in applying the concept/tool.

The class *Capacity building and training* complements the support for the first step of the product eco-innovation process and provides practical advice and training courses to apply concepts and tools for IPP and SCP. Its goal is to offer the access to adequate training and expertise for dealing with environmental issues. Here users can find technical descriptions, useful checklists, and forms to

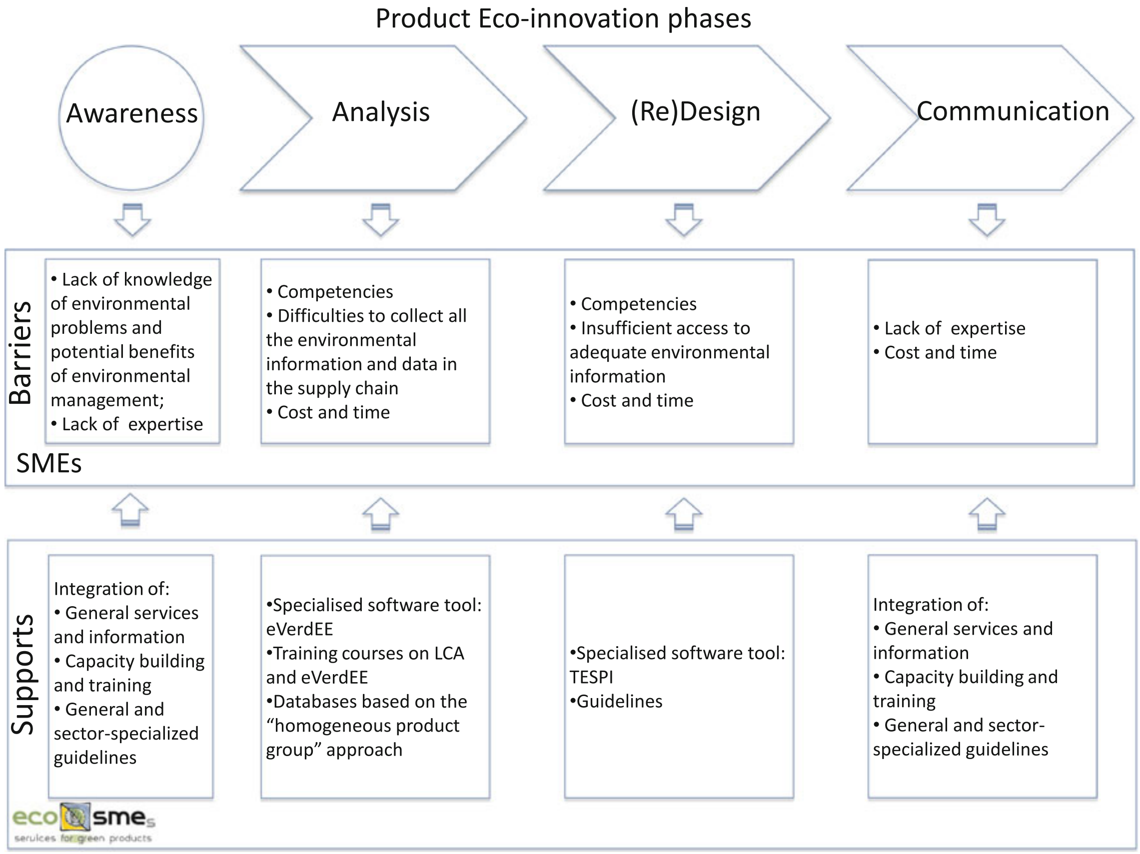

Fig. 3 Barriers that SMEs experience in each phase of the product eco-innovation process, and supports available from Ecosmes.net to overcome them

support the use of instruments, such as LCA, Eco-design, the ISO 14020 eco-labeling framework (type I certified ecolabels, type II self-declarations, type III environmental product declaration-EPD), EMS (Environmental Management System), POEMS (Product-Oriented EMS), Environmental Reporting, Financial Support to SMEs. The section *Training Courses* includes a basic course on LCA and a training package on the use of the simplified LCA tool eVerdEE (see following section). Training packages on eco-design and the use of the software tool TESPI are currently hosted on the ENEA e-learning platform.[4]

The class *General and sector-specialized guideline* offers technical guidelines specialized for sector/product chain and provides information on environmentally significant processes, best practices, case studies, economic trends, and legislation. Developed for Electrical and Electronic Equipment, Wood Products, Metalworking, Urban Furniture, Office Use, Hotels, and Textiles, they summarize the know-how of experts in different fields and can support the product (re)design when used in combination with the online LCA and eco-design tools. In synthesis, guidelines are practical way to offer relevant eco-innovation expertise and knowledge at no cost to the user, i.e., SMEs.

Simplified software tools for SMEs

The need for simplified LCA and life-cycle thinking (LCT) approaches is recognized in European Commission policies (see, for instance, the Green Paper on Integrated Product Policy (EC 2001) and several calls of the 7th Framework Programme), and in the numerous studies aimed at developing simplified LCA methods (Rebitzer et al. 2004; Hur et al. 2005). Though finding general methods is not easy, an agreement seems to have been reached on two points. First, the availability of detailed LCA studies for specific applications is important to define simplifying methods for those applications (Rebitzer et al. 2004; Rinaldi et al. 2006). Second, the exchange of relevant data along the supply chain and the availability of averaged data concerning a range of products rather than a specific product can be a

[4] The full list of the e-learning courses is available at http://192.107.92.31/fadivgen2/ (Accessed October 2010). Launched in 1996 with a narrower scope, the e-learning platform now provides a huge number of courses aimed at the promotion of sustainable development through the free diffusion of scientific and technological culture.

solution to the problem of data collection and confidentiality (Mueller et al. 2004; Rydh and Sun 2005; Geisler et al. 2004; Hischier et al. 2005).

On Ecosmes.net two software tools for supporting the two phases of *analysis of the product/processes* and *product (re)design* are available via web and free-of-charge: eVerdEE, tool for screening LCA, and TESPI, tool for supporting the environmentally conscious design. Their simplified approach, tailored to SMEs' needs, allows time- and resource -saving analysis of the products' environmental hot spots on the basis of a life-cycle approach. They are suited to users without specific expertise in the field, require only information available inside the enterprise and are supported by sector-specific data. As on-line free tools, they are accessible without buying a license or installing on a specific machine.

eVerdEE can be used anytime sufficient quantitative information is available on materials, components, and manufacturing processes. It can be used, for example, for identifying the environmental hot spots of a product, before redesigning it, and, then, for comparing the environmental performance of the redesigned product with the previous one. TESPI, in turn, assists in identifying the most preferable options for an environmentally conscious design comparing the quality and environmental performance of a product with those of a reference competitor. Because the use of TESPI requires only qualitative information on material, components, and processes, it is also suitable for the phase of conceptual design, when quantitative information is not available yet. eVerdEE and TESPI can be used either alone or together. In the latter case, after identifying with eVerdEE the hot spot of the existing product, TESPI helps to identify the best options for the re-design, and again, eVerdEE allows the quantification of the achieved improvements.

eVerdEE

The simplified tool for LCA is the result of activities started in 2000 with VerdEE (Verifica dell'Eco-Efficienza-Verification of Eco-Efficiency) (Masoni et al. 2004) and continued with the development of eVerdEE. The tool has been designed to offer easy-to-handle functions with sound scientific bases: complex methodological problems (system boundary definition, choice of elementary flows and impact categories, data quality estimation, and documentation) are simplified, according to the SMEs' needs, and pre-elaborated solutions are proposed (Naldesi et al. 2004; Porta et al. 2009). The tool is supported by a general and sector-specific database which stores environmental indicators and metadata (general information, short technical description, and data quality assessment) of materials, components, and processes. Environmental indicators are calculated by DIM (Data Input and Management), a proprietary software which also calculates and stores the Life Cycle Inventories of the detailed LCA studies carried out by LCA experts, in agreement with the HPG approach. In eVerdEE, the impact assessment results presented in a matrix are interpreted at different levels of detail and two life-cycle options can be directly compared by using a target-plot.

TESPI

TESPI (Tool for Environmentally Sound Product Innovation) is a simplified tool aimed at supporting environmentally conscious design and at increasing environmental awareness in different departments (marketing, purchasing, quality, design, and production) in the enterprise. The approach of the tool is inspired by QFDE (Quality Function Deployment for Environment), a methodology for specifying the relationship between customers' and environmental requirements (Masui et al. 2002, 2003; Sakao 2007; Vinodh and Rathod 2011). The tool can be applied to re-designing existing products, in particular modular manufactured articles, so that they can be disassembled and each component analyzed. The procedure is structured in two parts: quality analysis and environmental check. For quality analysis, users identify the customer's needs, weigh their relevance, and compare their own product with that of a reference competitor. For the environmental check, they perform a qualitative assessment of their product's environmental performance. If an LCA study of the product does exist (for example an eVerdEE study), its results are the basis for environmental check. With the application of TESPI, users identify: the most important customer needs and satisfaction, in comparison with the reference competitor; the most suitable eco-design strategies; the parts that present the most critical aspects concerning both quality (customer needs analysis) and the environment, and the 'hot spots', i.e., the quality and environmental aspects which require priority improvement efforts (Misceo et al. 2004; Buttol et al. 2005).

Information and data pre-elaborated: the *homogeneous product group* concept

The introduction of the *homogeneous product group* (HPG) concept contributes to overcome the barriers related to data collection all along the supply chain. The concept is inspired by the "product category rules" defined in ISO 14025 (ISO 2006c) and is based on the assumption that products having common main characteristics, but differing because of the technological solutions adopted, can be organized in a homogeneous group identified by the definition of a fictitious product (meta-product) and its multiple options and variants. When the different technological solutions are analyzed using an LCA approach, life cycle inventory (LCI) data can be produced and specialized databases developed.

The HPG study is organized along the following steps:

1) Identify the HPG and its main environmental, technical, and economic characteristics;
2) Set up a stakeholders' and experts' panel that provides all the necessary technical and economic know-how and contributes to the detailed description of the production process and supply chain. The panel is also responsible for defining the meta-product, and identifying best practices already available, innovation opportunities, etc.;
3) Carry out detailed LCA studies of the different technological solutions of the meta-product to quantify the environmental impact, identify hot spots in the products' life cycle, and develop sector-specific LCI databases through primary data collection along the supply chain;
4) Develop HPG technical guidelines including suggestions of methodological choices for LCA studies; information about specific eco-design procedures, best practices, and useful supporting tools for improving the products' environmental profile and, more generally, for implementing an eco-innovation process.

Though the HPG study requires a lot of resources, its results, once published and diffused, can be exploited by a large number of enterprises. In particular, the availability of technical guidelines and LCI databases, integrated with the use of simplified tools, can produce a genuine reduction in needed expertise, time, and costs of the eco-innovation path.

The exploitation and diffusion of Ecosmes.net

During the eLCA project, several stakeholders (researchers, consultants, enterprises, etc.) have directly participated in the development and testing of Ecosmes.net. During the last months of the project, some testing took place in partner countries, with interviews in Germany, the UK, and Spain. In Italy, a focus group was conducted involving 3 days of testing dedicated to the platform usability, technical guidance efficacy, and eVerdEE test. The participants were consultants in environmental management systems, total quality, and safety, experts in environmental law and policies, and SMEs managers. The results can be found in Magni and Angiuli (2004).

In 2009 about 100,000 different visitors accessed the website and just over 5.6% of the visits (more than 8,500) were longer than 30 min, which has gone up to 6.3% in 2010, suggesting a genuine use of the platform. Currently, registered users of eVerdEE and TESPI are 1750 and 865, respectively.

Structured modalities of using Ecosmes.net have been:

– directly by enterprises, after brief training. The most common approach has involved the organization of awareness-building events and training courses targeted at SMEs technicians and consultants with the support of local Public Administrations and the participation of eco-innovation experts. A number of selected SMEs have taken advantage of specific *product audits* by experts and have been trained in the use of the platform tools. The final expected goal of this training path is to make enterprises capable of interiorizing the eco-innovation process fully.
– in research and diffusion projects, with the participation of SMEs in the case studies. In this context, additional features and content have been developed for specific industrial sectors, such as wood-furniture (Rinaldi et al. 2005a) and flower cultivation (Porta et al. 2009).
– in academic and professional training courses, due to its content and user-friendly, free-of-charge tools, suitable for teaching purposes.

In the following paragraph some examples of how Ecosmes.net has been used specifically in the wood-furniture sector, are shortly described.

Examples of the use of Ecosmes.net in Italian SMEs of the wood-furniture sector

Ecosmes.net has been an opportunity for some enterprises located in the Marche furniture district, in the centre of Italy, to start an eco-innovation process with the aim of becoming largely autonomous in their progress and of cutting down considerably on both time and costs (Rinaldi et al. 2005a). The process started from increasing their awareness on environmental product innovation using the information part of Ecosmes.net. Then, internal expertise and capacity have been developed, by the help of Ecosmes training section. Finally, the eco-innovation was implemented through the selection and application of the most suitable eco-innovation tool between eVerdEE and TESPI with the help of the general and sector-specialized guidelines (i.e., through the use of their content on how to approach the LCA study, the identification of the most suitable eco-design strategies and environmental labels in this specific sector, etc.). Three sector-leading firms (two large-sized and one medium-sized) were chosen for their capability to involve the entire product chain, made up mainly by SMEs. These companies used the different tools according to their goals and the specificities of the products analyzed and created awareness about their experience along the supply chain and in the production district. A leading kitchen producer focused the analysis with eVerdEE on the various combinations of materials and components used, to define strategies to lower their impact and to start innovative industrial relations with suppliers (Luciani et al. 2007). In another company (cooker hood producers), which uses interior design as its major competitiveness factor, the use of TESPI was aimed at identifying solutions that simultaneously guarantee lower environmental impact and high technical and performance levels (Rinaldi et al. 2005b). Finally, an office furniture producer applied eVerdEE to a new product, not yet available on the market, to reduce its impact, also from the point of view of marketing communication strategies (Mantica and Zoppis 2008). The feedback from the enterprises allowed for an improvement and updating of the Ecosmes.net content and in particular of the sector specialized guidelines.

In a different context, a school furniture producer redesigned a school desk combining the use of eVerdEE and TESPI. Again, Ecosmes.net supported the firm in the awareness and training process, before the use of the two software tools. With this approach, the environmental redesign was targeted at those life cycle phases (and related materials, components, and processes) that had the most significant environmental impact, as calculated by eVerdEE and found as relevant for the overall performance of the desk with TESPI. Remarkable improvements (20–40%) were obtained for all the impact categories and also for the more traditional design aspects (functionality, ergonomics, safety, aesthetics, costs, etc.) (Sposato et al. 2010). Based on these results, the company planned further analyses aimed at obtaining a Carbon Footprint label and applying for the next Italian GPP tenders.

Conclusions and outlook

ICT and online services can help SMEs to overcome the barriers and to internalize the process of product eco-innovation. However, the lack of customized solutions, combined with a reluctance to change practices and with low willingness to pay for further services, can undermine their effectiveness.

Ecosmes.net is an example of how ICT tools can support SMEs on a path of eco-innovation by disseminating a structured approach for the implementation of all phases of the process (awareness and training; analysis; product (re)design; communication/certification) and by supplying a user-friendly system of services to lower the main existing barriers to product eco-innovation.

Five years of experience and the high number of visits, despite the still-limited number of sectors involved, show a potentially large interest in solutions offering integrated sets of information, training, tools, data, and guidelines. Almost all the enterprises involved in a structured use of Ecosmes.net have given positive feedback and shown interest in using the platform and its tools beyond the end of the specific projects. Very recently, Ecosmes.net has also been selected as an eco-innovation supporting tool in two European projects, ACT CLEAN and REMake, aimed at fostering product eco-innovation and cleaner technologies in European SMEs. However, an assessment of the direct impact of the use of Ecosmes.net by SMEs has not yet been produced.

The real limitation of Ecosmes.net depends on the resources needed for continuous improvement of all services. Presently, the eco-innovation market is not developed enough to allow economic management of these kinds of on-line services. Only a public initiative can face this challenge and support a continuous upgrading, which could go in two main directions:

- Extension of the number of sectors involved and exploitation of the results of the numerous projects and studies promoted by the public authorities. An important contribution may come from those projects funded by the 7th Framework Programme which must produce LCI data in a format compatible with the European Reference Life Cycle Database (ELCD) (JRC-IES 2009). Furthermore, results of the studies carried out for the development of European Ecolabel criteria, Energy Using and Related Products implementing measures and, in general, environmental policies may prove useful. Another meaningful contribution may come from the development of a *communication data module*[5] to be used directly by firms, which would allow the publication on the web of simplified LCA results, and which could also be useful for benchmarking.
- Exploitation of advanced knowledge management systems to reduce improvement and updating costs. Not all the potentialities of ICT have been exploited yet and much has to be done in the future to move from web-based information services, where information is mainly used and interpreted by humans, to semantic web services and tools that support users with machine-readable information. In particular, the semantic web, which establishes an infrastructure and methodology for information handling throughout the Web (Berners-Lee et al. 2001; Khilwani et al. 2009), could support the knowledge-intensive processes of detecting technology and market information and sharing product data

[5] This concept has been proposed in the Earthster project (www.earthster.org), for instance, where a data exchange standard is proposed 'to publish, share, and use life cycle results with suppliers and customers, and purchasers to have access to better information that helps them to purchase more sustainably'.

throughout products' life cycle (Yoo and Kim 2002). In this perspective, eco-innovation could be an interesting field in which to apply semantic web and ontology R&D programs.

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References

Anonymous (2004) eLCA2: databases and web site for the adoption of integrated product policy by SMEs. http://www.elca.enea.it. Accessed Oct 2010

Audretsch D, van der Horst R, Kwaak T, Thurik R (2009) First section of the annual report on EU Small and Medium-sized Enterprises. http://ec.europa.eu/enterprise/entrepreneurship/craft/sme_perf_review/doc_08/spr08_annual_report.pdf. Accessed Oct 2010

Berners-Lee T, James H, Ora L (2001) The Semantic Web—a new form of Web content that is meaningful to computers will unleash a revolution of new possibilities. Sci Am 284(5):34–43

Bleischwitz R, Schmidt-Bleek F, Giljum S, Kuhndt M et al (2009) Eco-innovation—putting the EU on the path to a resource and energy efficient economy. ISBN: 978-3-929944-77-8. Wuppertal Institute for Climate, Environment and Energy

Buttol P, Cumani C, Duranti A, Masoni P, Misceo M (2005) Environmental product innovation in SMEs: the case study of a new ecological lamp. In: Proceedings of LCM 2005, Innovation by Life Cycle Management, vol 1. ISBN 84-609-6566-X

Capponi G (2004) Realizzazione di una banca dati di siti Internet per lo sviluppo di prodotti ecocompatibili e sperimentazione presso una piccola impresa del sito Ecosmes.net [Implementation of a Database of Web sites supporting the development of environmentally friendly products and testing of Ecosmes.net in a small enterprise]. Master's Thesis, Bologna University

Del Río P, Carrillo-Hermosilla J, Könnölä T (2010) Policy strategies to promote eco-innovation. J Ind Ecol 14:541–557

Devinney TM, Soo CW, Pedersen T (2003) The importance of internal and external knowledge sourcing and firm performance: a latent class estimation. http://ssrn.com/abstract=376020. Accessed Oct 2010

Directive 2000/53/EC of European Parliament and Council on end-of life vehicles. Official Journal of the European Union L 269:34–43, 21/10/2000

Directive 2002/95/EC of European Parliament and Council on the restriction of the use of certain hazardous substances in electrical and electronic equipment. Official Journal of the European Union L 037:19–23, 13/02/2003

Directive 2002/96/EC of European Parliament and Council on Waste Electrical and Electronic Equipment (WEEE). Official Journal of the European Union L 037:24–39, 13/02/2003

Directive 2009/125/EC of the European Parliament and of the Council on establishing a framework for the setting of eco-design requirements for energy-related products. Official Journal of the European Union L 285:10–35, 31/10/2009

EC (2003) Communication from the Commission to the Council and the European Parliament. Integrated Product Policy-Building on Environmental Life-Cycle Thinking. COM 2003/302 final

EC (2005) Communication to the Spring European Council. Working Together for Growth and Jobs: a new start for the Lisbon Strategy. COM 2005/24

EC (2007) Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions on Small, clean and competitive. A programme to help small and medium-sized enterprises comply with environmental legislation. COM 2007/379

EC (2008) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan. COM 2008/397

EC (2009) The Competitiveness and Innovation Framework Programme (CIP). http://ec.europa.eu/cip/index_en.htm. Accessed Oct 2010

EC (Commission of the European Communities) (2001) Green Paper on Integrated Product Policy. COM 2001/68 final

EUROSTAT (2009) European business-facts and figures. Statistical Books. Office for Official Publications of the European Communities, Luxembourg

Geisler G, Hofstetter TB, Hungerbühler K (2004) Production of fine and speciality chemicals: procedure for the estimation of LCIs. Int J Life Cycle Ass 9:101–113

Hischier R, Hellweg S, Capello C, Primas A (2005) Establishing life cycle inventories of chemicals based on different data availability. Int J Life Cycle Ass 10:59–67

Hur T, Lee J, Ryu J, Kwon E (2005) Simplified LCA and matrix methods in identifying the environmental aspects of a product system. J Environ Manage 75:229–237

ISO (2000) ISO 14020:2000, Environmental labels and declarations—general principles

ISO (2006b) ISO 14044:2006, Environmental management-life cycle assessment—requirements and guideline

ISO (2006c) ISO 14025:2006, Environmental labels and declarations—type III environmental declarations—principles and procedures

ISO (International Standard Organization) (2006a) ISO 14040:2006, Environmental management-life cycle assessment—principles and framework

JRC-IES (Joint Research Centre—Institute for Environment and Sustainability) (2009) European platform on life cycle assessment. http://www.lct.jrc.ec.europa.eu/. Accessed Oct 2010

Kemp R, Pearson P (2008) Policy brief about measuring eco-innovation. Deliverable 17 of the project MEI (Measuring eco-innovation). http://www.merit.unu.edu/MEI. Accessed Oct 2010

Khilwani N, Harding JA, Choudhary AK (2009) Semantic web in manufacturing. Proc IMechE Part B 223:905–924

Luciani R, Masoni P, Rinaldi C, Zamagni A (2007) Implementation of a POEMS model in firms of the wood furniture sector. In: Proceedings of the 3rd international conference on life cycle management, Zurich

Magni D, Angiuli I (2004) Report on testing activities. TW83-002. Deliverable 8.2 of eLCA project. http://www.elca.enea.it/elca2/prova/deliverable.htm. Accessed Oct 2010

Mantica C, Zoppis G (2008) Made in Italy sostenibile: un intervento esemplare nel distretto marchigiano [Sustainable 'made in Italy': an example in the Marche District]. Ottagono, Compositori edn. :118–123

Marshall Report (1998) Economic instruments and the business use of energy: a report by Lord Marshall. Stationery office, London

Masoni P, Buonamici R (2006) Small and medium-sized enterprises and integrated product policy: attitudes and barriers. In: Scheer D, Rubik F (eds) Governance of Integrated Product Policy, Greenleaf publishing, Sheffield

Masoni P, Scimia E, Sára B, Raggi A (2004) VerdEE: a tool for adoption of life cycle assessment in small and medium sized enterprises in Italy. Prog Ind Ecol 1:203–228

Masoni P, Buttol P, Buonamici R, Naldesi L (2005) Experiences in promotion of IPP in SMEs via the webplatform www.ecosmes.net. In: Piqué FC, Pons JR (eds) Proceedings of LCM 2005—innovation by life cycle management, vol 2, Barcellona

Masui K, Aizawa S, Sakao T, Inaba A (2002) Quality Function Deployment for Environment(QFDE) to support design for environment (DFE). In: Proceedings of ASME design engineering technical conference. DETC2002/DFM-34199

Masui K, Sakao T, Kobayashi M, Inaba A (2003) Applying quality function deployment to environmentally conscious design. Int J Qual Reliab Manag 20:90–106

Misceo M, Buonamici R, Buttol P, Naldesi L, Grimaldi F, Rinaldi C (2004) TESPI: a simplified software tool to support the environmentally conscious design in SMES. In: Proceedings of SPIE-Environmentally Conscious Manufacturing IV, vol 5583, SPIE, Bellingham

Mueller K, Lampérth MU, Kimura F (2004) Parameterised inventories for life cycle assessment–systematically relating design parameters to the life cycle inventory. Int J Life Cycle Ass 9:227–235

Naldesi L, Buttol P, Masoni P, Misceo M, Sára B (2004) eVerdEE: a web-based screening life-cycle assessment tool for European small and medium-sized enterprises. In: Proceedings of SPIE-environmentally conscious manufacturing IV, vol 5583, Philadelphia

Parker CM, Redomond J, Simson M (2009) A review of interventions to encourage SMEs to make environmental improvements. Environ Plann C 27:279–301

Porta PL, Buttol P, Naldesi L, Masoni P, Zamagni A (2009) A simplified LCA tool for environmental product declarations in the agricultural sector. In: Nemecek T, Gaillard G (eds) Proceedings of the 6th International Conference on LCA in the Agri-Food Sector—towards a sustainable management of the Food chain, Zurich

Prieto IM, Revilla E, Rodriguez-Prado B (2009) Managing the knowledge paradox in product development. J Knowl Manag 13:157–170

Rebitzer G, Ekvall T, Frischknecht R, Hunkeler D, Norris G, Rydberg T, Schmidt WP, Suh S, Weidema BP, Pennington DW (2004) Life cycle assessment part I: framework, goal and scope definition, inventory analysis and applications. Environ Int 30:701–720

Regulation (EC) No. 1907/2006 of European Parliament and Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). Official Journal of the European Union L 136:3–280, 29/05/2007

Revell A, Stokes D, Chen H (2010) Small businesses and the environment: turning over a new leaf? Bus Strat Environ 19:273–288

Rinaldi C, Masoni P, Luciani R (2005a) The European LAIPP Project: dissemination of integrated product policy tools in the furniture industry. In: Lekkas TD (ed) Proceedings of the 9th international conference on environmental science and technology, Rodos

Rinaldi C, Masoni P, Recchioni M, Mandorli F (2005b) Application of IPP tools in the furniture district of Marche Region (Italy): an eco-design experience within an aspiration hood company. In: Proceedings of the 11th International Sustainable Development Research Conference, Helsinki

Rinaldi C, Masoni P, Zamagni A (2006) A methodological approach to simplified LCA. In: Book of abstracts of the SETAC Europe 16th annual meeting, Den Haag

Rollo M (2011) Strumenti di supporto per il management dell'eco-innovazione[Tools supporting the eco-innovation management]. Master's Thesis, Bologna University

Rydh CJ, Sun M (2005) Life cycle inventory data for materials grouped according to environmental and material properties. J Clean Prod 13:1258–1268

Sakao T (2007) A QFD-centred design methodology for environmentally conscious product Design. Int J Prod Res 45:4143–4162

Sposato P, Rinaldi C, Masoni P (2010) Use of a screening LCA tool in the environmental redesign of a school desk. In: Proceedings of SETAC Europe 16th LCA case studies symposium, Bologna

Vinodh S, Rathod G (2011) Application of ECQFD for enabling environmentally conscious design and sustainable development in an electric vehicle. Clean Tech Environ Policy 13:381–396

Yoo SB, Kim Y (2002) Web-based knowledge management for sharing product data in virtual enterprises. Int J Prod Econ 75:173–183