International Association for Management of Technology

Management of Green Technology

Industry Perspective

Environmentally sound technologies are regularly discussed nowadays in the popular media and professional conventions, particularly those aspects related to land use, agricultural policies, pesticides, genetically modified organisms, waste reduction and recycling, renewable energy, hybrid vehicles, etc. Not surprisingly, in several IAMOT conferences, presenters have dwelt on eco-development and sustainable growth. With the world-wide increased awareness of the threats of climate change and the depletion of fossil fuels, these subjects are expected to remain the focus of attention in the foreseeable future.

This brochure contains a compilation of key points related to green processes and technologies made at previous IAMOT conferences. It is being offered by the IAMOT Industry Committee to assist industrial practitioners, particularly in small and medium enterprises, in redesigning their processes to minimize environmental harm. The rubrics selected deal with energy efficient buildings for production facilities as well as administrative offices and the reduction of the carbon footprint through the rationalization of supply chains, product development and energy generation. The last contribution explains how the automotive industry could be rejuvenated by embracing renewable materials and green operations.

One possible follow-up would be to establish a taskforce team of interested parties to outline the role of technology management in promoting, accelerating and facilitating the implementation of these key points.

It should be noted that there was no attempt at forcing an artificial regional balance in making the selections. In effect, the brochure reflects global European leadership in environmental legislation and practices as attested by other publications (see for example, IEEE Spectrum, March 2009, p. 68).

Ben Amaba from IBM initiated the project in 2007 and invited many eminent IAMOT members from Academia and Industry. IAMOT is appreciative to the contributing authors as well as those who responded and participated in insuring the realization of the brochure in its final form.

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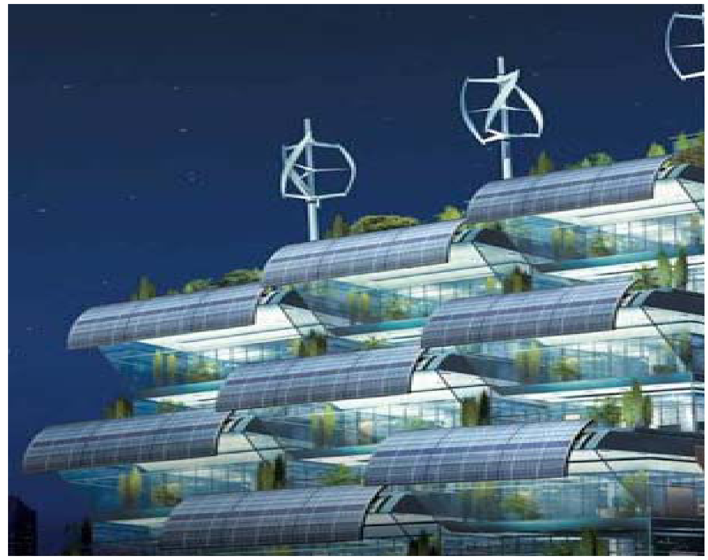
Pictures provided in the articles are not part of it. It is only meant to illustrate the topic.



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Improving the sustainability of existing buildings and new builds represents a necessary step to face the depletion of fossil fuels and climate change. Considering its high consumption of raw materials and its reliance on energy (as an example, 43% of the consumption of final energy in France), the building sector has a major role to play in the evolution towards a more sustainable future.
To achieve worthwhile results, some important facts need to be taken into consideration:

- Due to the very low renewal rate of the building stock, the majority of the opportunities for improvement lies in the **renovation of the existing buildings**,
- Reducing the energy consumption in buildings is a priority to tackle climate change. The time to react is limited, as on average buildings undergo an extensive renovation only once every 30 years. As a consequence, ambitious actions need to be undertaken as soon as possible. Renovations or new builds should **aim at the most stringent consumption ratios**. The ultimate goal for new builds should move as quickly as possible towards passive buildings and, even better, towards energy positive buildings. Renovations can achieve high standards by incorporating the most efficient materials and building procedures: sufficient insulation, very low air permeability of the building envelop, mechanical ventilation with heat recovery from the exhaust air, heat pump on the extracted air, renewable energies... Complex buildings should be modelled using dynamic simulation software to have a better understanding of their behaviour under real climatic conditions. The evolution in the construction sector is a unique chance for innovation: new eco-materials, high-tech insulation products like phase change materials... Several professional associations promote low consumption buildings and deliver technical advice: BREAM (http://www.breeam.org/index.jsp), European Promotion of Passive Houses (http://www.europeanpassivehouses.org), PassivHaus Institut (http://www.passiv.de/), Minergie (http://www.minergie.ch/),
- A major asset when limiting the energy consumption in buildings is to know the actual consumption level and pattern. **Live consumption monitoring** has started to develop widely, and should be encouraged in businesses as well as in households. Technology makes this step possible, and opens up a new area for more accurate monitoring systems (stand alone or linked to monitoring back offices). These developments can benefit from a strategic approach to design and innovation. The electrical and monitoring equipment industries can provide useful solutions via professional organisations (for example the Gimélec in France http://www.gimelec.fr)
- The **environmental quality of buildings** includes manufacturing existing materials in a more sustainable way (for example producing paints with minimum solvent side effects), and developing new eco-materials. **Eco-materials** offer many advantages compared to conventional building materials. They come from natural sources, many of whose are renewable, and sometimes offer the possibility of local supply chains. Furthermore, eco-materials have the advantage to respect the health of the tradesmen as well as preserving a good indoor air quality. Currently, the penetration of the market remains low for eco-materials. However, this sector is in full expansion and some materials are believed to account for a significant part of the market by 2030. Technology plays a main role for the development of new materials: for instance, new building components similar to hemp concrete, …Several organisations provide information on existing eco-materials: Greenspec (http://www.greenspec.co.uk/), Vibe (http://www.vibe.be/), Ecospecifier (http://www.ecospecifier.org/), Nature Plus (http://www.natureplus.org/) and cd2e (http://www.cd2e.com/sections/fr/accueil),
- Environmental considerations also encourage thinking, at the time of building, about the **flexibility of use, ease of dismantlement and recycling potentials**. These issues need to be fully integrated at the design stage of buildings systems and materials. Technology management has a key role to play for an efficient implementation,
- **Awareness of initiatives supporting product innovations** is beneficial to the building sector. For instance, the French regulating institute for building materials (CSTB) implements fast technical procedures in order to recognise innovations and encourage their experimentation. One can mention the recent 'Pass Innovation' which allows a product to obtain the first technical evaluation in 3 months instead of 18 months in order to facilitate a wide use,
- The promotion of energy efficient buildings and eco-materials can be enhanced by adopting a systematic **global cost approach** and performing **life cycle analysis** on products. The strategy is seen as an efficient marketing tool. Indeed, these figures can provide clear arguments for comparison with conventional building solutions. Tools to assess such performances are developed: the Bream package (http://www.breeam.org), the "Team Bâtiment" software from Ecobilan (link from http://www.ecobilan.com/fr_tools.php) or the "Elodie" initiative from the French CSTB (http://ese.cstb.fr/elodie/). The last two tools use Environmental Product Declarations (EPD) accessible on line at http://www.inies.fr and complying with the norm NF P 01 010. At the international level, the norm ISO 21930 :2007 regulates the environmental declaration on building products. The European Union listed a few years ago interesting examples of national EPD schemes:
http://ec.europa.eu/enterprise/construction/internal/essreq/environ/lcarep/lcaselepd.htm
- The promotion of technical innovations has to **include practical advice for the professionals** (tradesmen, architects …) in order to ensure their appropriate use. A lack of skills can lead to misuse and reduce the potential of the products. For example, the right building practices have to be used to achieve a passive house standard. Similarly, eco-materials present technical specificities due to their inherent nature, and require appropriate knowledge to use them. The manufacturers should thus provide training to ensure proper use,
- Establishing and maintaining a **professional network** is also a real asset to increase the exposure of innovative products. This could involve contributing to local sustainable building guides, participating to pilot schemes, be listed in specialist advice centres and attending trade shows. In addition to product promotion, a network can also lead to select and train tradesmen. The products are then being used by skilled professionals, and the building can then achieve maximum performance and reliability. This contributes to a better image for the company,
- Manufacturing of eco-materials should assess and take into account the **eventual constraints** specific to the sector. For example, a recurrent issue for the products based on vegetal fibbers is the regularity and extend of the supply chain. Establishing strong nation-wide supply networks and a rigorous selection process of the suppliers are key steps. This is a requirement for consistent quality and the expansion of the business. One can recommend establishing strong partnerships based on a detailed description of the raw materials. The quality of the products could be subject to regular controls,

Sustainable buildings offer opportunities for innovation and business growth. To support this evolving sector, Fondaterra (a public-private partnership to facilitate and provide research into sustainable development) is launching a research project on sustainable building concepts and materials. This project called PSPDuB will be run in partnership with some professionals of the construction sector and research centres. It aims at:

- Defining a set of environmental and economical criteria to help with the selection of building materials,
- Developing new eco-materials,
- Promoting sustainable concepts and products in the building trade,
- Strengthening the sector of sustainable construction in partnership with some regions.

REDUCTION OF CARBON EMISSIONS ACROSS THE SUPPLY CHAIN

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Combating climate change will require fundamental changes to the way in which companies produce and deliver goods and services to the end consumer. The UK Carbon Trust has developed an integrated approach for the management of carbon emissions across the supply chain from raw materials to end consumer (*The Carbon footprints in the supply chain: the next step for business*, 2008). This integrated supply-chain analysis generates a full carbon footprint for each product and a product-based view of businesses emissions. The supply chain approach differs from the traditional ‘single company’ carbon management approach in the following aspects:

Traditional Carbon Management	Carbon Management Across the Supply Chain
Single participant involved	Multiple participants, starting with a ‘lead client’, typically a large company operating at the consumer-end of the supply chain
Analysis covering single supply chain stage for multiple products	Analysis covering complete supply chain for a single product
Companies engaged individually	Companies engaged collaboratively up and down the supply chain
Carbon savings typically come from efficiencies within each company’s operations	Carbon savings come from both internal efficiencies and from external process change and reorganisation

The Carbon footprints in the supply chain: the next step for business (UK Carbon Trust Report, 2006; p.7)

Once the carbon footprint of a product is known using this approach companies can focus on the areas where most savings could be made.

In this context, there are **three general ways** in which a company might reduce its carbon emissions. All of them include either the adoption of new ‘green’ cleaner technologies and production processes or new more efficient environmental management/organisational strategies.

Direct emissions reduction by:

- Implementing cost effective energy efficiency measures, such as heating and lighting upgrades, using cleaner technologies and production processes, delivering staff training and awareness programmes, redesigning products and lean manufacturing to reduce the use of materials, developing low-carbon energy sources such as on-site generation

- Switching from air transport to shipping, rail, waterway or ‘combined transport’ (a combination of a road and non-road method), re-designing of distribution networks to reduce total product mileage; sourcing locally produced goods

- Addressing the more strategic business risks and opportunities associated with climate change; e.g. work on regulatory compliance, value at risk, future cost of carbon, other market risks and opportunities, and shareholder and other stakeholder impacts, internal carbon trading schemes to promote innovation within parts of the business.

Indirect emissions reduction by:

- Working with organisations across the supply chain: considering all the organisations involved in the supplying of raw materials and in the processes required to get a product to market and identifying opportunities to make significant additional cuts in emissions and energy costs across the]]supply chain.

- Setting environmental standards and targets when commissioning suppliers in order to pressure them to reduce emissions.

- Eliminating perverse incentives that create emissions artificially (due for instance to misaligned commercial incentives)

- Through supply chain re-configuration: changing specific processes or the way these are completed in order to reduce emission at key stages of the supply chain.

Development offsetting strategies by:

- Developing a voluntary offsetting strategy. Carbon offsetting is where a company buys credits associated with environmental projects that reduce emissions of carbon dioxide or other greenhouse gases around the world, as a way of offsetting their own carbon emissions. For some service-sector or consumer-facing organisations, there may be PR and corporate social responsibility benefits from offsetting some of their emissions. For any offsetting strategy to be successful, it is fundamental that the offsets purchased are of high quality and from verified projects that create truly additional emission reductions.

For more examples in specific sectors see www.carbontrust.co.uk/energy, and *Innovations Review Making green the new business as usual*, Environmental Defence Fund, 2008; www.edf.org)

References

Behrens, A. (2008) *Carbon footprint - an investment opportunity for innovative application developers?* e-Xpertise in Industry Issue n 33, September 2008. Deloitte (2008) ‘Mini Stern’ for Manchester. Final report September, 2008.
EDF (2008) *Innovations Review: Making green the new business as usual*, Environmental Defense Fund report.
Kolk, A. and Pinkse, J. *Business Responses to Climate Change: Identifying Emergent Strategies*, California Management Review, Spring 2005.
Orsato, R. *Competitive Environmental Strategies: When Does it Pay to Be Green?* California Management Review, Winter 2006.
Søgaard Jørgensen, M., Forman, M. and Hansen, A (2007) *Environmental management in product chains.* The Danish Environmental Protection Agency Environmental Project No. 1237.
Stuart Hart, *Beyond Greening: Strategies for a Sustainable World*, Harvard Business Review, January-February 1997.
The Carbon Trust (2006) *Carbon footprints in the supply chain: the next step for business*, UK Carbon Trust report CTC616.
The Carbon Trust (2006) *The carbon emissions generated in all that we consume*, UK Carbon Trust report CTC603.

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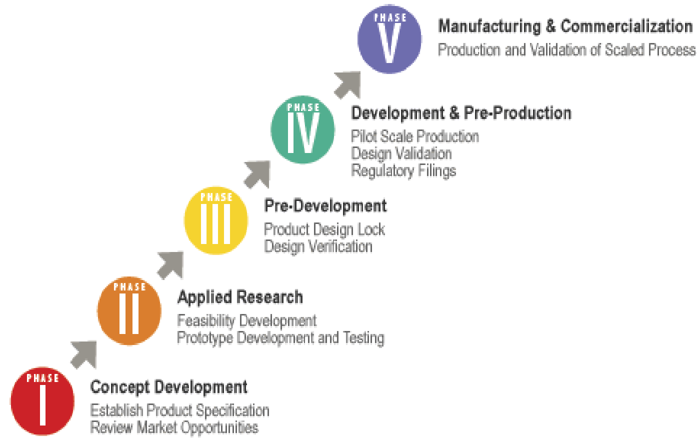
Corporate sustainability presents companies with a strategic opportunity to guide their business choices and to create long-term shareholder value by embracing opportunities and managing risks associated with economic, social and environmental development. It has two main levels of impact: the operations level (often part of a wider corporate social responsibility strategy) and the products/services level. Here we focus on the latter, and with good reason. There has long been concern over the 'limits to growth' consequences of ever increasing consumption; indeed, the need to reduce demand for carbon intensive goods and services was emphasised again by the high profile Stern Review on the Economics of Climate Change. Governments have responded with more policy-making based on evidence regarding the environmental (and social) impacts of products' production and consumption (e.g. the 'Shopping Trolley' report commissioned by the UK's Department of Environment Food and Rural Affairs) and by tightening environmental regulations on products and their use (e.g. European Directives on Energy-using Products). We have also seen labeling initiatives to encourage greener consumption and procurement (e.g. Energy labels or Energy Star labels) and, more recently, eco-labels; carbon labels are currently under development. Some retailers have implemented 'choice editing' (some overtly, like the UK's Cooperative Group, others less overtly), whereby they sell only goods and services that meet environmental (and social) criteria. Governments in Europe are doing the same with environmentally damaging products such as incandescent light bulbs. Also, the sales growth of organic and local choice products provides evidence of consumers' willingness and ability to change their behaviour.

Product development in companies follows a process from the initial idea to launching the product on the market. This process tends to be punctuated by 'stage gates'. At these gates, products are evaluated against deliverables and judgement criteria, and a decision to proceed or not to the next 'stage' is made. Measuring the environmental performance of products requires different tools than those used for testing commercial and technical criteria. There is no shortage of both sophisticated formal techniques and less elaborate informal techniques with new environmental performance tools being developed all the time. But regardless of the tool, how are environmental criteria formulated, measured and verified as part of a sustainable new product development process? Companies can operationalize corporate environmental targets using techniques like 'back casting': a method by which a desirable future state is envisioned and steps toward that state are defined. What actually gets measured and acted upon however depends on a company's capabilities (i.e. what it can and can't do), product portfolio, competitive pressures, reputation, talent management (i.e. recruitment and retention), current and emerging customer demand, and expected legislative changes. Environmental criteria formulated by companies includes carbon emissions, other emissions (to air and water), recyclability, use of virgin and renewable materials and natural resources, water and energy consumption, and waste. The criteria are evaluated at various gates along the product development process using formal and informal tools. Formal tools such as 'eco-design', 'economic input-output life cycle assessment', 'eco-efficiency' and 'foot printing' use mainly quantitative data related to the environmental impact of existing products. The aim of these tools is to focus product re-design, process re-engineering or material substitution to reduce the environmental impact of new products. Scorecards (or evaluation checklists) are often used as a less formal option. They can include quantitative or qualitative data, with options presented as binary (yes/no) or multiple choice (graded evaluation options). When it comes to a proceed/stop/go-back decision at the stage gates, sometimes the evaluation process involves a trade off between criteria. Inevitably, some criteria are weighted more heavily than others reflecting a balance between the perceived importance of criteria (garnered by learning from the market, close engagement with users, involvement of stakeholders and external experts) and the company's ability to do something about it. This weighting is built into the decision making process.



Carbon foot printing, which measures the impact products have on the environment in terms of the amount of greenhouse gases produced across their lifecycle, is the focus of much government, industry and media attention and support. Empirical analysis reveals that some of the formal tools mentioned above and used by companies in a life cycle analysis (LCA) have problems related to data, timing and communication. Due to the absence, incompleteness, aggregate nature and confidentiality of data, there are high costs associated with its generation, collection, verification and processing. This task is challenging enough across different divisions of a single company, but costs increase as more information is needed from outside the organisation. One large paints manufacturer, for instance, estimate that it costs £40000 to complete a carbon footprint of one of their products. Timing is important also because detailed data tend to be available only late in the development process, which means that LCA tools are suited better to existing products, or products with detailed plans of material and energy flows, rather than new products where estimates may only be available. This poses specific challenges for the in-use stage of a product's lifecycle. In addition, these tools can be opaque to an observer external to the testing process, especially when the weighting scheme and underlying multi-criteria decision making process is not explicit. This presents communication challenges across and beyond the product development process.

Standardisation in carbon footprint measurement, currently under development by the UK's Carbon Trust, could help alleviate some of these data, timing and communication problems. Accurate, consistent data will highlight the 'chain of custody' of carbon, supporting initiatives to reduce the carbon intensity of products along their lifecycles. Companies will be able to use the carbon foot printing framework to understand better the impact at the user stage and to develop premium products that have shared (i.e. economic and environmental) value at the user stage. The user stage is often left out of carbon footprint calculations because there are lots of uncertainty and complexity, which can be costly to model. And yet the user stage is often the most carbon intensive part of a product's life cycle, whether we're talking about a ready meal, toaster, car or building. One example is the development work of multinational consumer goods companies who, since the 1990s, have launched new laundry products (powders, tablets, liquids) that enable clothes to be washed at 30 degrees centigrade providing both lower running costs for the consumer and less environmental impacts. More recently, they have been exploring new consumer hygiene products with a built-in (optimal) dose of water, thereby eliminating the need for water to produce a lather with. Another example is contained in the article by Nunes and Bennett who discuss how reducing environmental impacts during the use stage of automobiles' life cycle is influencing the design process. Our study[8] uncovered another couple of good examples of targeting reduced carbon at the user stage and integrating it into the new product development process. On the one hand, a multinational building materials manufacturer had launched recently an asphalt product with sponge qualities (thus allowing pavements to absorb and retain high volumes of rain water for recycling).

On the other hand, a global paint product manufacturer developed coatings that reflect more light and have greater durability in buildings (reducing the demand for lighting and for re-applications), other coatings that depend on ultraviolet rather than heat to cure automobile finishes (reducing energy intensity) and others that reduce drag on the bottom of ships (reducing fuel use).

Over the last 10 years, companies in many different sectors have significantly increased their production efficiency by employing tools such as those described above. The economics of carbon and changing perceptions of risk dictate that energy and fuel use will be increasingly significant in future consumption decisions. Tools that green the new product development process of large and small companies across industry must be dynamic, cost effective to implement and use, and enable a focus on the user stage of the product lifecycle. Standardisation efforts associated with carbon labelling may help in this regard, at least with respect to environmental impacts associated with carbon emissions. They must help create products that are consistent with wider company strategies and technical capabilities and, most importantly, increase value for the company and their customers. By working closely with users, companies can gain an empathic understanding of how their product is used and can explore ways of reducing the carbon intensity of products in-use. The recent collaboration between a global paints manufacturer (ICI Paints), a large UK construction firm (Carillion) and sustainability charity (Forum for the Future) in a project funded by the UK Government's Technology Strategy Board to develop sustainable paint systems exemplifies this process. The commercial viability of low carbon products depends crucially on the effective communication of the long-term financial benefits (and reputational and other benefits) to customers. And perhaps therein lies the greatest challenge of greening the new product development process.

References

The Stern Review of the Economics of Climate Change is available at http://www.hm-treasury.gov.uk/stern_review_report.htm, last accessed February 2009. See also, Nicholas Stern's bleaker 2008 review at http://www.lse.ac.uk/collections/granthamInstitute/publications/KeyElementsOfAGlobalDeal_30Apr08.pdf, last accessed February 2009.

MBS report for DEFRA on the 'Environmental impacts of food production and consumption' (also known as the Shopping Trolley report) at http://randd.defra.gov.uk/Document.aspx?Document=EV02007_4601_FRP.pdf, last accessed February 2009. Energy labels in the EU are similar to Energy Star labels in the US. For more information see http://www.defra.gov.uk/Environment/consumerprod/energylabels/energylabel.pdf and http://www.energystar.gov/index.cfm?c=about.ab_index (last accessed February 2009) respectively.

Eco-design in Europe see http://www.eup-ecodesign.com/ (last accessed February 2009) and the US see http://www.idsa.org/whatsnew/sections/ecosection/index.html (last accessed February 2009).

The Green Design Institute at Carnegie Mellon University's research on economic input-output life cycle assessment, see http://www.eiolca.net/ (last accessed February 2009).

World Business Council for Sustainable Development's guide to eco-effciency, available at www.wbcsd.org/web/publications/eco_efficiency_creating_more_value.pdf (last accessed January 2009).

For a more general introduction to footprinting, see the Global Footprinting Network at http://www.footprintnetwork.org/ (last accessed February 2009).

Dewick, P. and Peitekanen, A., (2008), Integrating sustainability into the innovation process, Presented to the *International Association for Management of Technology conference*, CERAM Business School, Nice, France, September 17-19th, available at http://webintec.ceram.fr/euromot2008/index.php?cmd=2Paper, last accessed February 2009.

The Carbon Trust is leading work on creating a framework for product-related emissions measurement (PAS 2050) and reduction (PERF). See http://www.carbontrust.co.uk/carbon/briefing/pre-measurement.htm, last accessed February 2009.

Lundholm, K., Sherwin, C., Taylor, P. and Dhami, J., (2008), The future of paint: learning from a case study on innovation, partnership and paint, presented at the *Sustainable Innovation 08* conference, Malmo, Sweden, October (see www.cfsd.org.uk/events/tspd13/abstracts/42%20-%20Kristoffer%20Lundholm.pdf, last accessed February 2009). See also http://www.forumforthefuture.org/blog/dulux-ecosure (last accessed February 2009).

GREEN ENERGY– BENEFITS AND WAY FORWARD FOR THE INDUSTRY SECTOR

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The global challenge for the industry sector

There is evidence that liberalised trade and increased incentives for imports and exports may increase the environmental burdens of manufactured products. For example, free trade has been shown to promote and facilitate the translocation of polluting industries to developing countries with less strict environmental regulations.

A specific environmental concern, as part of the global climate change focus, is the carbon footprint of manufactured products that are imported and exported. The internationally sanctioned limitations on greenhouse gas (GHG) emissions are likely to become stricter and will be increasingly enforced across the world. A consequence of these stricter international requirements is that they will make any imports with large associated carbon footprints uncompetitive. Low-carbon products will be preferred because international buyers will be subjected to substantial carbon taxes, which is likely to exceed the existing €20 per tonne of CO_2e being paid in the European Union Emissions Trading Scheme (ETS), when importing high-carbon products into those countries. To this end, environment-related issues may actually be used as trade barriers in terms of protecting local (foreign) markets.

The challenge for the industry sector is therefore to indentify means to reduce the carbon, and environmental, footprints of its products for the global marketplace. Major opportunities exist in addressing the energy usage of the industry sector. Some of these opportunities are within industry itself, in the form of energy efficiency and cogeneration technologies (see http://www.cogeneurope.eu/ for further information). Other opportunities manifest in the responses from within the energy sector that supplies industry.

Green responses, and consequences, from within the energy sector

The energy sector has placed much emphasis on alternative energy technologies (AETs) that address long-term energy security, whilst also responding to global issues such as climate change.

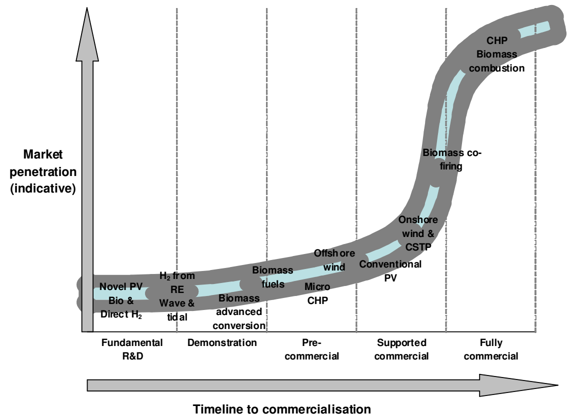
However, AETs will all require tradeoffs between potential technical advantages, and socio-economic and environmental consequences. For example, the use of bio energy will in most circumstances require a change in land use and as such present both a threat to biodiversity and food production as well as an opportunity for rural development; a disproportionate high potential impacts on some economies are likely. Also, land use change may well lead to a net increase in climate change due to first-generation bio fuel value chains.

Most AETs can still be found in the phases leading up to the pre-commercialisation phase of the innovation chain (see Figure). To enable the progression of technologies along the innovation chain multiple research and development (R&D) efforts are directed to each of the respective (energy) value chains (see Table). Also, different technology assessment and management approaches to sustainably implement AET systems are being developed to:

- Prioritise and choose from a range of AET options in terms of the robustness and resilience of systems, which requires screening of technical feasibility, economic and financial viability, and social and environmental acceptance;
- Best implement technically feasible solutions, in an integrated manner, within a country's prevailing political, socio-economic and social-ecological systems; and
- Monitor and ensure the sustainable adoption and operation of chosen AET options.

To this end the World Business Council for Sustainable Development (WBSD) provides comprehensive information through an 'energy and climate' focus area (http://www.wbcsd.org). The International Institute for Sustainable Development (IISD) also has a 'climate change and energy' theme, as well as other themes that are of value to industry, such as 'international trade' and 'sustainable markets' (http://www.iisd.org). In addition, information specific to AETs can be found through news forums (http://www.alternative-energy-news.info), and even an alternative energy focused search engine (http://www.aeoogle.com). With respect to information on carbon markets, and potential implications of such markets for the industry sector, independent news, analysis and consulting services are available (http://www.pointcarbon.com/), whilst the Carbon Markets and Investors Association (CMIA) was also formed recently (http://www.cmia.net/).

The international commercial maturity of alternative energy technologies (AETs) relative to market penetration (adapted from Foxon TJ, Gross R, Chase A, Howes J, Arnall A, Anderson D, 2005. UK innovation systems for new and renewable energy technologies: Drivers, barriers and systems failures. Energy Policy, 33 (16), 2123-2137)



Classification of directed energy R&D efforts (adopted from Roos T, Szewczuk S, North B, Hietkamp S, Jeffreys L, Engelbrecht A, Strauss K, Liphoto L, McGonigal S, Greben J, Zulu T, 2004. Techno-economic and environmental review of alternative energy resources.

Category	Type	Resource	Generation	Distribution/storage	Conversion	Cross-cutting
Fossil	oil	Reserves, availability, extraction	Combustion heat	Road tanker, pipeline, shipping	IC engines, turbines	Energy efficiency: Residential; Commercial; Industrial. Safety Regulatory frameworks Off-grid issues
	coal			Road, rail, shipping	Rankine cycle with boiler, IGCC	
	gas			Bottles, pipeline, shipping	Combined cycle, OCGT	
Nuclear		Fuel processing, enrichment	Nuclear heat: PWR, HTR, FBR		Rankine cycle, Brayton cycle	
Renewable	Solar	Insolation mapping	Photo-voltaic effect: PV	Use at source	PV cells	
			Solar heat: Thermal power generation (concentrated), water heaters	Heat stored in thermal oil and molten salts	Rankine cycle, Brayton cycle	
	Wind	Wind mapping	Mechanical motion	Use at source	Horizontal and vertical axis turbines	
	Hydro	Rainfall, terrain		Dams, rivers/waterfalls, pumped storage	Kaplan, Francis & Pelton turbines	
	Ocean	Wave, tide and current mapping		Use at source	Wave, current & tidal devices	
	Biomass	Climate, rainfall, soil	Combustion heat: Gasification, pyrolysis	Steam or electricity reticulation Use at source, reticulation or distribution	Rankine cycle	
	Geo-thermal	Geological mapping	Geothermal heat	Use at source	Rankine cycle	
	Municipal wastes	Arisings, quantity and composition, geographically	Combustion heat	Use at source, or transport over short distances	Rankine cycle	
Carriers	Electricity	Installed capacity	Mechanical motion to electric generator	Electric grid (losses), no current feasible storage	Electric motor, induction heater, appliances	
	Hydrogen	Water, hydrocarbons	Electrolysis (H_2O), stripping, production of methane	Pressurised bottles, Cryogenic, pipelines	Fuel cell, gas turbine, IC engine	

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In most of the discussions about environmental issues and policies, transportation is highlighted as one of the main sources of pollutant emissions and energy consumption. The attention given to the automotive industry is understandable in this context due to its size, expansion, presence in our daily lives, and of course its environmental impact. If we scrutinize the "greenness" of car manufacturers we will find issues of concern from the raw material use, production processes, use, and end-of-life of vehicles. The main issues for production are high consumption of energy, raw materials, water and the waste stream, which contains the four substances of concern (cadmium, lead, hexavalent chromium, mercury). In respect of carbon emissions and energy use the use of cars is the main phase of its life-cycle due to the combination of internal combustion engines with fossil fuels. The most recent pressure is aimed at the end-of-life vehicles (ELV). In addition to the pollution from vehicle use, traffic jams and car accidents continue to be part of the downside of a car culture. Landfills sites are becoming scarce and the contamination of soil and aquifers completes the picture. It is hard to predict the end.

Indeed, the World's major manufacturing enterprises are embedded in a caldron of economic and environmental complexity. In the words of Orsato and Wells (2007a): "The industry is overcapacity, struggling against low profit margins, high break-even points, and receiving increasing pressures to reduce its environmental burdens." Orsato and Wells (2007b) supplement the context of the environmental, economic and operational challenges for the automotive industry. They explain that because carmakers are locked into three technological paradigms (all-steel car bodies, internal combustion engines, and multi-purpose vehicles) these companies tend to favour incremental improvements. In addition, the existing economic and political interdependency between this industry and other sectors (e.g. the oil industry) makes radical changes towards higher levels of environmental performance more difficult due to its complexity and extension.

Orsato and Wells (2007b) explain how companies became locked into these paradigms and how they are now dependent on fossil fuels (and internal combustion engines), price competition, mass production platforms, and therefore the predominant use of steel and production of multi-purpose vehicles. They argue that car manufacturers do not see themselves as personal mobility providers or even as propulsion systems innovators - therefore, their strategies are always around the existing technological paradigms.

After providing this brief overview of the scenario in which car companies are operating we need first to acknowledge the initiatives that the largest players have taken (see GM, 2007; Toyota, 2007; Volkswagen, 2007). The world's major car manufacturers are adopting environmental practices across their operations from the construction of manufacturing plants to the end-of-life of their products. Green technologies and initiatives are being applied in the sector from automobile design (fuel, engine, materials, etc), facilities (plants, office buildings, etc), manufacturing processes (pressing, welding, painting, etc), logistics and supply chain (efficient routes, packaging, environmental guidelines and selection criteria), end-of-life vehicles and parts (air bags, batteries, etc), innovation using intelligent traffic systems, and other initiatives related to environmental protection, education programmes and philanthropy.

Thus, there are 5 main environmental practices in the industry: i) green buildings (facilities), ii) eco-design (product development), iii) green manufacturing (production), iv) green supply chain (supplier relationship and logistics), and v) reverse logistics (after sales, backwards flow of materials, etc), which is responsible for the backwards flow of products and materials during the whole life of the car.

Green building certification is being used for both production sites and non-manufacturing facilities. It involves the use of "green power" to reduce oil dependency in their plants through the use of landfill gas, wind and solar energy. CO_2 emissions were also tackled by substitution of cleaner fossil fuels for coal.

The design of the cars is considered a key activity for addressing environmental concerns through its ability to affecting the whole life of the product. Initiatives in design vary from lightweight material, fuel efficiency and diversification, elimination or reduction of Volatile Organic Compound (VOC) and the "four substances of concern", and also intelligent systems to reduce traffic congestion. Design for recycling and dismantling are the main approaches to deal with landfill shortages and new stricter ELV legislation.

Supply chain management has included environmental initiatives with three basic approaches: selection of suppliers, transfer of technology and more efficient logistics systems (e.g. packaging, reduction of empty container travelling, etc).

The main environmental impacts of manufacturing are being addressed through technology-based solutions. Paint shops have been converted to water-borne types and water-based solvents have also been introduced in the processes. Energy and water conservation, reduction of greenhouse gas emissions, waste management (including recyclable and non-recyclable waste), and recycling are the main initiatives in production.

The increasing use of batteries (in hybrid vehicles), new electronic components and safety devices may cause future concerns for reverse logistics. Currently, stricter ELV legislation (e.g. in Europe and Japan) is regarded as a learning process, which provides the company with experience to help governments and environmental agencies to design new types of legislation, mainly in developing countries.

Generally, because Toyota, GM and Volkswagen are all global players, they may take advantage of being under a stricter regulation to be the "first mover" or environmental leader and keep ahead of the regulation in other markets. This applies mainly for

construction of new production sites, plant emissions, Brownfield redevelopment, engine emissions and ELVs.

Notwithstanding all these practices and environmental initiatives, car manufactures (mainly the major ones) are under stricter environmental pressures. Their comprehensive set of green operations practices seems not enough to minimise their environmental impacts described previously. In fact, what we could infer is that car makers are in fact an expensive solution for personal sustainable mobility, and their nature and purpose are probably the main constraints to become greener despite all the legitimate efforts in greening their processes and improving the fuel efficiency of automobile engines.

Even Volkswagen Group's sustainability report warns that improved efficiency will not be sufficient to mitigate engine emissions because economic globalisation will increase the demand for freight and personal mobility, mainly in developing countries. Moreover, as the passenger car fleet increases in many cities while the traffic infrastructure does not improve, the personal benefits of having a car as mobility device reduces significantly. Are air pollution, traffic jams and accidents problems for city planners or strategic failures of car companies? Far from having the definitive answer for this question, we can guarantee one thing: technology will play a crucial role in this game.

For example, the recent notion that car emissions is the central problem has stimulated the use of green technologies such as hybrid engines, electric batteries, or flex-fuel engines. If rather than setting a technology agenda we set an emission target agenda, purists advocate that only zero-emission cars are the solution for air pollution in urban centres. However, this could still not be ideal because it depends on how the electricity or hydrogen to power the cars is generated. Even so, it is much easier to manage the emissions from a few power plants than from thousands of cars on the road. Also, internal combustion engine efficiency is around 50% in most of the cars while in power plants this could more easily be increased or the wasted energy dissipated could be used in combined heat and power systems. Hence, it is likely that moving to zero emission cars could be beneficial for the overall emissions reduction if the whole fuel life cycle is considered.

Furthermore, it is impossible to separate sustainable production from sustainable consumption and the role of green technology will be to make production and use of cars (or perhaps, another personal mobility device) sustainable at the high global consumption rates when countries like China, India, Brazil, Russia, Indonesia, Thailand and many other developing nations reach higher levels of income per capita. In this sense, with the actual technological paradigms and at the current availability of steel, iron and fossil fuels – a completely sustainable car industry is almost impossible.

Manufacturing technology for the car industry will face the challenge of moving towards renewable materials and the need to re-use, recycle and remanufacture scarce materials or expensive parts. This would also impact on the final disposal of end-of-life cars. In addition, much has been discussed about the use of product-service systems for the automotive industry, in which the manufacturer keeps the ownership of the car and sells the "service of using a car". A number of information technologies could be used to track both location and use in such system. Another relevant use for information technology is in building up intelligent traffic systems, which can result in the reduction of car accidents and traffic jams.

Apart from the main companies in the sector, there are also small factories are trying to break the technological paradigms of car industry by producing 2-seat cars, using carbon fibre, and developing electric engines. Their challenges have been related to market acceptance and safety legislation.

Whether it is a traditional and big corporation, or a small innovator entrant, a successful choice of green technology and its implementation will be the result of a consistent environmental strategy, which needs to be aligned with business and operations strategy. Therefore, it is likely that the environmental strategy of automobile manufacturers will define their survival during the next decade. For instance, Renault-Nissan has already confirmed a deal with the Israeli Government and a venture capitalist to run a zero-emission fleet there, in a business model that resembles the contracts for mobile phones. Also, the UAE government intends to create Masdar - a "sustainable city" for 50,000 people close to Abu Dhabi – in which one of the main characteristics is that it will be car-free. So the question is, what environmental strategy should automobile companies adopt if the Masdar initiative is pursued by other developing countries? In other words, what kind of green cars are they going to sell in car-free cities?

References

Orsato, R., and Wells, P. (2007a). The Automobile Industry and Sustainability. *Journal of Cleaner Production*, 15 (11-12), 989-993.

Orsato, R. J and Wells, P. (2007b), "The U-Turn: The Rise and Demise of the Automobile Industry", *Journal of Cleaner Production*, Vol. 15, Nº. 11/12, pp. 994-1006.

GM (2007), Corporate Responsibility Report 2005/2006, General Motors Corporation, Detroit, Michigan, USA

Toyota (2007), "Towards a New Future for People, Society and the Planet: Sustainability Report 2007", Toyota Motor Corporation CSR & Environmental Affairs Division, Tokyo.

Volkswagen (2007), "Sustainability Report 2007/2008: We are moving into the future responsibly", Volkswagen AG, Wolfsburg, Germany.

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