Sustainable Manufacturing – An Overview for Manufacturing Engineers

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What is sustainable manufacturing?

Sustainable manufacturing is part of a larger concept, sustainable development, which emerged in the early 1980's in response to increased awareness and concern over the environmental impact of economic growth and global expansion of business and trade.

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

- *the concept of **needs**, in particular the essential needs of the world's poor, to which overriding priority should be given; and*
- *the idea of **limitations** imposed by the state of technology and social organization on the environment's ability to meet present and future needs."* [1]

At the 1992 UNCED conference held in Rio de Janeiro, sustainable production was introduced and adopted as one of the guiding principles for business and governments in transitioning towards and achieving sustainable development. As sustainability is becoming an expected business practice by companies, large and small, sustainable manufacturing is being defined, developed and implemented by manufacturing companies and their networks of suppliers and customers. There are several definitions of sustainable manufacturing to consider:

US Department of Commerce:

"For the purposes of Commerce's Sustainable Manufacturing Initiative, sustainable manufacturing is defined as the creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers and are economically sound."[2]

Lowell Center for Sustainable Production:

"Sustainable Production is the creation of goods and services using processes and systems that are:

- Non-polluting
- Conserving of energy and natural resources
- Economically viable
- Safe and healthful for workers, communities, and consumers
- Socially and creatively rewarding for all working people."[3]

Institute of Manufacturing, University of Cambridge:

"Sustainable manufacturing is ...developing technologies to transform materials without emission of greenhouse gases, use of non-renewable or toxic materials or generation of waste."[4]

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The author's proposed definition:
A business practice of the industrial sector, which expands all the company's processes and decisions into the social and natural environments it operates in and affects, with the explicit objective of reducing or eliminating any negative impact, while pursuing the desired level of technological and economic performance.

How is it different from other concepts, such as green, eco-manufacturing?
Sustainable manufacturing is more comprehensive and systemic than green, eco-manufacturing, eco-machining, clean production by dealing with all three components of sustainability: environment, economy and society. While it includes all the environmental concerns, such as pollution, material toxicity, GHG emissions, it is not limited to those concerns, nor is it a component of an environmental management system.

Sustainable manufacturing uses both technological and non-technological solutions, from selection of materials and production processes to organizational mission, structure and performance reporting. It shifts the focus from "end-of-pipeline" solutions, disposal of waste, clean-up, recovery, a liability approach, to the very beginning, at product or process design stage, an opportunity approach.

It resolves some of the limitations and controversies of an exclusively green/environmental view by aiming for a balance in satisfying all three components of sustainability, by aiming for a "triple bottom line"[5] and a "triple top line"[6]. Unlike some green/environmental models and concepts, sustainable manufacturing builds upon and improves an advanced and technologically sophisticated industrial base, it does not attempt to create a path to an impossible return to a simple, natural life. However, it does recognize the weakness of economic growth which disregards the limits of natural resources and the demands of the society for sharing the benefits of successful enterprise.

Another important distinction is the inclusion of time, as a component of sustainable manufacturing, from extending the viability and longevity of the business to assessing and owning the entire life-cycle of a product or service.

Why is it important?
There are several significant drivers for adopting sustainable manufacturing into the company's strategic initiatives:

1. The current global economics crisis has exposed the fragility and, in some cases, non-viability of existing business models targeting the highest economic growth without assessing and mitigating the negative impacts outside the company's boundaries
2. The reality of climate change, its anthropomorphic causes and the need to reverse its trend, before the consequences on the human habitat are too serious
3. The pressures from all categories of stakeholders: customers, investors, employees, suppliers, competitors, communities, local and national governments, international regulatory bodies, non-governmental organizations

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4. Scarcity of critical resources for operations: energy, raw materials, water and the price volatility caused, in part, by increased competition for and increased extraction costs of depleting virgin materials and non-renewable resources (See charts below)

According to Economist Intelligence Unit "Doing Good – Business and the sustainability challenge" 2008 Report[7]: **"There is a link between corporate sustainability and strong share price performance**. In our survey, companies with the highest share price growth over the past three years paid more attention to sustainability issues, while those with the worst performance tended to do less. Causality is difficult to establish, but the link appears clear: the companies that rated their efforts most highly over this time period saw annual profit increases of 16% and share price growth of 45%, whereas those that ranked themselves worst reported growth of 7% and 12% respectively. In general, these high-performing companies put a much greater emphasis on social and environmental considerations at board level, while the poorly performing firms are far more likely to have nobody in charge of sustainability issues."

The same report quotes the results of a 2007 global survey of more than 1200 senior executives, in which the greatest influences over corporate sustainability strategy in the next five years are as follows (% respondents by region, adapted with highlights of first two rankings):

World	Western Europe	North America	Asia-Pacific	Stakeholders
46	56	44	46	All customers
36	49	37	32	Developed-world customers
46	41	41	51	Government policymakers
40	37	45	41	Competitors
15	14	11	18	Developing-world customers

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As the survey suggests, there are regional differences in the importance attributed to stakeholders, however it is clear that customers should be considered the main drivers for changing towards becoming a sustainable manufacturer.

In what regards the critically important objectives of their sustainability strategy, the rankings are as follows (adapted):

Objective	**% Respondents**
Increasing revenues	43
Enhancing brand reputation	42
Compliance with regulatory and legal obligations	41
Generating value for shareholders/investors	38
Reducing costs	29
Managing risks associated with sustainability issues	28
Attracting/retaining customers concerned about environmental and social issues	25
Differentiating products	23

It is worth noting that top line is ranked as much more important than bottom line, an encouraging position, which confirms our assumption that sustainable manufacturing will be most successful if pursued as a top-line strategy, a "triple top line" strategy, through innovation and imagination, rather than an undifferentiating, continuous cost-cutting strategy.

What is its value to engineering, in general, and manufacturing engineers, in particular?

Learning and practicing the new concepts, processes, methods and tools of sustainable manufacturing cannot be but an exceptional opportunity for engineers to apply their passion for complex problems and systems, their competence in finding technical solutions to difficult and ambiguous problems. It should incentivize them to re-assert their role in the decision-making of their companies.

Sustainable manufacturing will constitute the foundation of the new clean, carbon-neutral global economy and most probably become the equivalent of Total Quality Management or Lean Manufacturing in the next three to five decades. Unlike TQM and Lean, which impacted mainly production organization and planning, sustainable manufacturing relies significantly on technological solutions to achieve its objectives, which makes the contribution of all engineering specialties and functions more important and valuable than in any of the preceding major transformations in manufacturing.

Some of the changes induced by the new practice for engineers are:

1. Reallocate time in the product lifecycle management to the R&D stage to allow for the use of Life Cycle Assessment (LCA) and Life Cycle Costing (LCC). Time-to-market might be increased, but the time and costs required to reduce or correct adverse effects of the product production, distribution and use will decrease or be eliminated.

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2. Increase cooperation between design and manufacturing engineers, including the use of virtual manufacturing techniques before launch to full production. The current practice of Design for Manufacturability becomes Design for *Sustainable* Manufacturing.
3. Develop optimization models aimed at different targets than minimizing cost: minimize greenhouse gases (GHG) emissions, energy use, water use, material use, restricted materials use.
4. Innovate, create new materials, components, machines, controls, production processes with new attributes than low-cost and desired functionality:
    a. minimum energy, material content
    b. maximum re-usable, biodegradable, recyclable, recycled content
    c. maximum quality, longevity, reparability
5. Replace low-cost sourcing with low-energy or low-carbon footprint sourcing or make the latter a priority over the former.
6. Include in product specification and product labeling energy-use, water-use, material-use, GHG emissions, waste-generation over complete useful life-time.
7. Characterize production processes (welding, milling, casting, grinding, stamping) on sustainability criteria.

What business aspects does it address?

Sustainability reflects the economic, environmental and social performance of an organization. For each of the three dimensions of sustainability, there are certain aspects which need to be managed and measured for internal and external performance reporting purposes. An aspect is an element of an organization product, service or activity which impacts, positively or negatively, each of the sustainability dimensions. For each aspect, performance indicators are necessary to create a baseline for assessing present state of the business and to trend progress in the future, as also to allow accurate and consistent comparisons between companies.

One the most recognized and widely used sustainability reporting framework is being designed and offered for voluntary use by the Global Reporting Initiative (GRI). Its vision is "that disclosure on economic, environmental, and social performance become as commonplace and comparable as financial reporting, and as important to organizational success….

It is applicable to organizations of any size or type, and from any sector or geographic region, and has been used by thousands of organizations worldwide as the basis for their sustainability reporting.

It facilitates transparency and accountability by organizations and provides stakeholders a universally-applicable, comparable framework from which to understand disclosed information." [8]

Among the US industrial companies reporting in 2009 are Alcoa, Applied Materials, Chevron, Dell, Dow Chemical, Duke Energy, Ford Motor Company, General Electric, Herman Miller, Hess Corporation, Hewlett-Packard, IBM, Intel Corporation, Johnson Controls, Owens Corning, Seventh Generation, Weyerhauser (a random selection of companies for illustration purposes, see GRI website for complete list).

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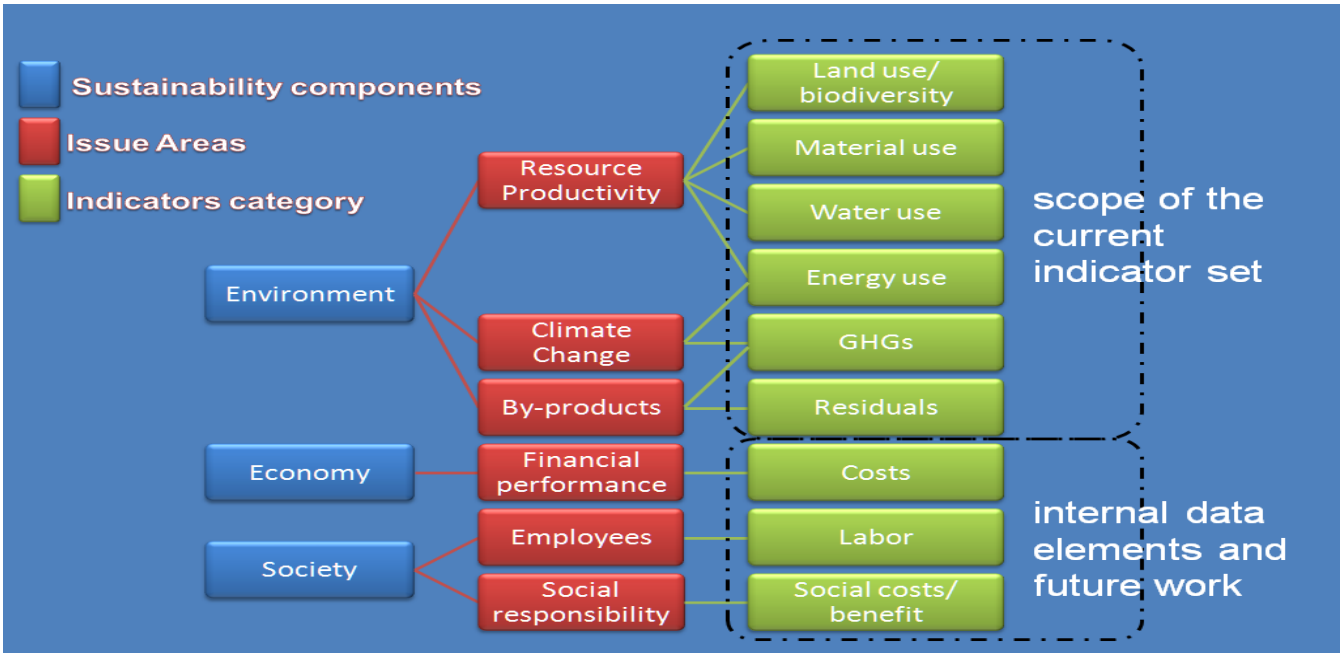
While we definitely recommend the adoption of GRI reporting framework for overall corporate performance, with the expectation that some , if not all of the sustainability requirements will be incorporated in the future corporate reporting of publicly traded companies, we recommend the use of OECD's framework for sustainable manufacturing. Although it is work in progress, it focuses exclusively on manufacturing and it is designed to be understood and used by experts and non-experts. In fact, it is to our advantage that the OECD's framework is under development, as it invites the engineers, managers and other personnel from small and medium sized companies to make their contribution in order to insure its successful adoption and effectiveness.



Source: Michael Bordt, The OECD sustainable manufacturing toolkit, Sustainability and US Competitiveness Summit, October 8, 2009, Directorate of Science, Technology and Industry, OECD, Paris www.oecd.org/sti/innovation/sustainablemanufacturing

Manufacturing companies will be required to understand evaluate, quantify and mitigate their externalities, the unrealized costs and benefits of business. They will have to develop "what-if" scenarios for the potential voluntary or mandatory internalization of their externalities. Manufacturing companies can increase their revenues, customer base, brand reputation, longevity by charging a premium for their positive externality on the life of the community they operate in. By maintaining and investing in its local presence and developing its network of suppliers locally, or even better developing "eco-industrial parks", in which the residuals and by-products of one company are the inputs of another in a potential zero-waste network, the company will be able to share the benefits of stability, development, education, skills, fair pay of its workforce. The opposite is equally probable, the negative externalities of pollution, community degradation, resource scarcity could be forced into a company's cost structure. By adopting and operating on the principles of sustainable manufacturing, a company can position itself to take advantage of significant business opportunities and avoid or mitigate significant threats.

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What are the standards and metrics for measuring it?

Academia and governmental organizations have been working since the 1980's on the research and development of the concept of sustainable manufacturing, of products, machinery, equipment and technologies which can be specified as clean and sustainable. However, companies are at the very beginning of the adoption curve of this new concept and practice. One of the causes is the lack of national and international standards, comparable with existing technical and management systems standards used in engineering and manufacturing companies. Since sustainable manufacturing includes both technical and process related, quantifiable and qualitative concepts, measures and indicators, technological and non-technological changes, standards and metrics are necessary for a consistent, systematic, harmonized, comparable understanding, implementation and measurement of this new practice.

For reference, the list below, by no means complete, includes some of the organizations working on defining the framework, standards and metrics for sustainable manufacturing and catalogs of clean technologies and products:

OECD – The Sustainable Manufacturing and Eco-Innovation Project under the Directorate for Science, technology and Industry has published the report on the first phase of the project and has released for testing the first draft of a sustainable manufacturing toolkit for use by both experts and non-experts in measuring a company's sustainability performance at facility level. It is specifically designed to be highly practical and easy-to-use by small and medium sized manufacturers.

http://www.oecd.org/document/37/0,3343,en_2649_34173_40695077_1_1_1_1,00.html

DOC – The US Department of Commerce through its Sustainable Manufacturing Initiative aims to maintain and increase the US manufacturers' competitiveness by developing and diffusing the knowledge and performance metrics of sustainable manufacturing. It is also engaged in private-public partnerships facilitating the sharing of experiences of companies adopting the new practice. It has recently released a Sustainable Business Clearinghouse available for public use.

http://www.trade.gov/competitiveness/sustainablemanufacturing/index.asp

NIST – Sustainable Manufacturing is one of the topic areas of the Manufacturing Engineering Laboratory at NIST. Their programs focus primarily on technical and technological issues related to sustainable manufacturing ranging from simulation modeling of manufacturing systems to standards and test beds for sustainable manufacturing.

http://www.nist.gov/mel/sm.cfm

NACFAM – One of the policy initiatives of the think tank is Sustainable Manufacturing. The stated goals include developing objective policy recommendations, workforce training and education, helping US manufacturers reduce or eliminate their negative environmental impacts and change their business models towards an industrial ecology.

http://www.nacfam.org/PolicyInitiatives/SustainableManufacturing/tabid/64/Default.aspx

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LMAS at University of California Berkeley – Under the management of Professor David Dornfeld, a leading expert in green/sustainable manufacturing, the laboratory conducts research on sustainable manufacturing processes and systems with the goal of reducing waste, such as time, energy and materials.

http://lmas.berkeley.edu/

LCSP at University of Massachusetts Lowell – LCSP is an internationally renowned center for the development and piloting the concepts of sustainable production and consumption. Their projects range from chemicals policy and science initiative to sustainable products design and development.

http://www.sustainableproduction.org/index.php

EBM at MIT – The Environmentally Benign Manufacturing research group is part of the Laboratory for Manufacturing and Productivity at MIT. Professor Timothy Gutowski, who has worked extensively on the subject of sustainable manufacturing, is leading the group. Their research focuses, among others, on the energy efficiency of manufacturing processes, modeling the environmental performance of manufacturing processes and the use of benign and efficient materials.

http://web.mit.edu/ebm/www/index.html

To insure the successful development of standards and metrics for sustainable manufacturing, their practicality and positive effect on manufacturers' performance, economic, social and environmental, manufacturing engineers should become involved with some of the above mentioned organizations or others by contributing to their design, testing, implementation and feedback.

Notes:

1. A/42/427. Our Common Future: Report of the World Commission on Environment and Development
2. http://www.trade.gov/competitiveness/sustainablemanufacturing/how_doc_defines_SM.asp
3. http://www.sustainableproduction.org/abou.what.php
4. Julian Allwood, Sustainable Manufacturing Seminar Series, 16th February 2005, http://www.ifm.eng.cam.ac.uk/sustainability/seminar/documents/050216lo.pdf
5. Andrew Savitz, "The Triple Bottom Line", Josey-Bass/Wiley, 2006
6. William McDonough & Michael Braungart, "Design for the Triple Top Line", 2002, http://www.mcdonough.com/writings/design_for_triple.htm
7. http://www.eiu.com/site_info.asp?info_name=corporate_sustainability&page=noads
8. http://www.globalreporting.org/Home

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