Book title: Designing Sustainable Products, Services, and Manufacturing Systems

Editors: Amaresh Chakrabarti (IISc), Sudarsan Rachuri (NIST), Prabir Sarkar (NIST), and Srinivas Kota (IISc)

Preface

This book is based on an anthology of papers from the experts from the United States and India, along with a summary of focused discussions and suggestions in several areas of critical importance within the broad topic of sustainability in the development of products, services, and manufacturing systems. The material is based on the work presented and discussed at the Indo-US Workshop on Designing Sustainable Products, Services, and Manufacturing Systems, organized jointly by Indian Institute of Science, India and National Institute of Standards and Technology, USA during 18-20 August 2009, at Indian Institute of Science, Bangalore, India. The workshop was fully funded by the Indo-US Science and Technology Forum, New Delhi, India. The primary objective of the workshop was to bring together domain experts from India and the USA to discuss the social, economic, environmental, and technological aspects of designing sustainable systems, especially manufacturing systems. The workshop was highly interactive in nature and was held for three days. The workshop had keynote talks, technical sessions, panel discussions, and breakout sessions that addressed several important issues about the production of sustainable systems. The workshop was intended to lead to the formation of an Indo-US Joint Networking Centre for sustainable design to foster collaboration between Indian and US researchers, educators, and practitioners.

The goals of the workshop were to enhance awareness of research, education, and practice of sustainability, and to catalyze formation of networks among institutions and organizations in India and the USA in this area.

The workshop was by invitation only and in total 120 delegates from different institutions from India and the USA participated. Following is the list of topics covered:

1. Designing sustainable products, services, and manufacturing systems
2. Preparing engineers,designers and managers for the 21st century
3. Developing policies, standards and industry best practices for sustainable systems
4. Showcasing sustainable technology.

The workshop contained four keynote talks and twenty-seven research presentations from the invited experts, two panel discussions on government and industry initiatives on sustainability, and three breakout sessions. The purposes of these breakout sessions were to produce an in-depth discussion on definitions, measures and methods for supporting sustainability; to prepare engineers for the 21st century, and policies and government initiatives on sustainability; and to understand how collaboration in these could be enhanced using a joint networking centre as a common platform. This book titled “Designing Sustainable Products, Services, and Manufacturing Systems” provides not only a collection of papers that reflect the variety of research areas within which researchers, educationists, and practitioners have been engaged in exploring the frontiers of, and promoting the cause of sustainability, but also a summary of the discussions. We hope that this book will act as a useful reference and as a catalyst for innovative research, teaching, and practice of design for environment and sustainability.

We thank all those who helped to make it a success.

Amaresh Chakrabarti, Sudarsan Rachuri, Prabir Sarkar, and Srinivas Kota
Editors

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Amaresh Chakrabarti, Sudarsan Rachuri, Prabir Sarkar, and Srinivas Kota

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Executive Summary

Introduction

This book is based on an anthology of papers from the experts from the United States and India, along with a summary of focused discussions and suggestions in several areas of critical importance within the broad topic of sustainability in the development of products, services, and manufacturing systems. The material is based on the work presented and discussed at the Indo-US Workshop on Designing Sustainable Products, Services, and Manufacturing Systems, organized jointly by Indian Institute of Science, India and National Institute of Standards and Technology, USA during 18-20 August 2009, at Indian Institute of Science, Bangalore, India. The workshop was fully funded by the Indo-US Science and Technology Forum, New Delhi, India. The primary objective of the workshop was to bring together domain experts from India and the USA to discuss the social, economic, environmental, and technological aspects of designing sustainable systems, especially manufacturing systems. The workshop was highly interactive in nature and was held for three days. The workshop had keynote talks, technical sessions, panel discussions, and breakout sessions that addressed several important issues about the production of sustainable systems. The workshop was intended to lead to the formation of an Indo-US Joint Networking Centre for sustainable design to foster collaboration between Indian and the USA researchers, educators, and practitioners.

The goals of the workshop were to enhance awareness of research, education, and practice of sustainability, and to catalyze formation of networks among institutions and organizations in India and the USA in this area.

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4. Showcasing sustainable technology.

Background

The 1987 report by the World Commission on Environment and Development (WCED), defined sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

Sustainable development aims for a future where products are 100% recyclable, where manufacturing itself has a zero net impact on the environment, and where complete disassembly of a product at its end of life is routine. Ensuring a sustainable future requires a systems approach. Sustainable systems are characterized by interlinked interactions at various levels spanning economic, ecological, and societal issues. Emphasis on interactions within and across these levels is critical to the fundamental understanding of sustainable design and manufacturing systems, because tackling any one of the issues in isolation can result in unintended consequences along other dimensions. The primary goal of a systems approach is to capture and formalize descriptions of these processes and interactions. Because of the complexity of these

systems, simulation and modelling will play a large part in understanding the overall impact of changes in any one part.

Substantial climate changes all over the world due to global warming in the recent past have compelled several researchers to focus their research in the area of sustainability. These efforts are often funded by governments and are backed by policies and standards. However, several issues such as carbon trading, selection of the appropriate standards, landfill costs, and sustainable manufacturing policies require international consensus supported by a good understanding of the issues in-depth research.

India and the USA have been working together in several sectors, for example, in power, Information Technology (IT), and textile sectors. This workshop has developed not only long-term strategies for both the countries to achieve sustainable societies but also open up new areas for further research on sustainability. There are several lessons on sustainability that India and the USA could learn from each other through research collaboration and exchange of knowledge. There have been many long-term bilateral agreements in the past between India and the USA that had propelled government authorities, researchers, and industrialists to work together on various bi-lateral issues. India and the USA are currently supporting emerging research areas such as sustainability for bilateral improvements. This workshop created a platform to share important issues that have long-term implications on the countries' sustainable infrastructure development and economy. This workshop initiated and catalyzed dialogues for developing long-term strategies for the two countries to achieve more sustainable societies and open up new areas for further research on sustainability.

The National Institute of Standards and Technology (NIST) and the Indian Institute of Science (IISc) organized this workshop. NIST has been extensively involved in research on sustainable approaches. Some of the notable contributions are the Building for Environmental and Economic Sustainability (BEES) model, formal product and process models, exploration of the standards landscape for product lifecycle management, and the new initiative on Sustainable Manufacturing. Manufacturing System Integration Division (MSID), NIST has a major program related to sustainable manufacturing.

The Centre for Product Design and Manufacturing at IISc has been actively involved in research on sustainability, product development, creativity, and knowledge management for the past six years. Development of strategies to enable designers to generate sustainable products at the early stages of the design process is a major research focus of this centre.

Purpose of the workshop

One of the main goals of this workshop is to write a proposal for the creation of a center of excellence on sustainable manufacturing based on the workshop outcomes and recommendations. This centre would act as a focal point for research engineers, scientists, industrialists, environmentalists, social entrepreneurs, non-governmental organizations (NGOs), and legislators to exchange views and develop viable solutions at the system level. The aim of this workshop was to focus on the following:

1. Form strategies for curriculum development incorporating knowledge on how to develop sustainable systems. This would better equip upcoming engineers with the knowledge of designing and developing sustainable products and enacting

sustainable systems.

2. Discuss and formalize suggestions to the resprctive governments regarding possible policies that could be enacted to create a more sustainable society.
3. Catalyze mobilization and transfer of sustainable urban and rural technologies between companies of both nations.
4. Discuss advanced technologies such as nano- and advanced materials, which could possibly contribute to the development of a more sustainable future.

Clearly, there are many scientific and technological advances that are needed in a global effort as significant as sustainable development. A major goal of this workshop was to increase awareness about sustainable systems among researchers, government policy makers, and industrialists.

Presentations

The workshop had twenty-seven technical presentations organized into five sections:

- Section I: Understanding Sustainability
- Section II: Sustainable Energy, Buildings, Cities
- Section III: Supporting Sustainability
- Section IV: Sustainable Product Development
- Section V: Reducing Pollutions and Waste.

The papers presented in these technical presentations are included in this book.

Panel Discussions

The workshop had two panel discussions. The first panel focussed on policies and government initiatives and the second panel on industry initiatives towards sustainability. The panelists for the policies and government initiatives include, Dr. V.S Arunachalam (Panel Chair), Center for Study of Science, Technology and Policy (CSTEP), India, Dr. Subhas Sikdar, US Environmental Protection Agency (EPA), USA, and Dr. Steven Ray, Carnegie Mellon University (CMU), USA. The panellists discussed and expressed their thoughts on the initiatives that are planned or implemented by governments and organizations to support collaborative research in sustainable design. The panellists also expressed their views on actions that can be carried out by the respective governments and organizations to support collaborative research in sustainable design.

The second industry panel was chaired by Ms. Kathi Futornick, URS Corporation, USA. The other members of this panel include Dr. Om Prakash, Boeing Research and Technology, India, and Mr. B R Satyan, Central Manufacturing Technology Institute, India. The panellists outlined the challenges faced by the industry and R&D institutions in adopting the sustainable design strategies and emphasized the initiatives that industry and R&D institutions have taken or planned to take in adopting sustainable design strategies.

Breakout Sessions

The breakout sessions consisted of three groups. Group 1 focused on designing sustainable products, services, and manufacturing systems. Group 2 discussed on preparing engineers, designers, and managers for the 21st century, and Group 3 on policies, standards, specific domains, research perspective, and industry best practices for sustainable systems.

Major Challanges

The following major challenges faced by the manufacturing industry in its pursuit of sustainability goals were identified during this workshop.

Metrics and standards development implementation:

- Businesses need to make decisions based on a diverse range of factors when it comes to sustainable manufacturing. To make sound decisions, they must consider compliance, economic models, profit, and case studies.
- There is a need for simple and high level metrics, and these need to be supported by good data models. Previous attempts have led to metrics that are difficult to estimate, and for which data is not readily available.
- Need to establish coordinated efforts to establish global standards and align it with regional standards.

Tools and software systems for analysis:

- Address the issue of developing integrated approaches to sustainability analysis for specific product categories. This requires a global collaboration for the development of appropriate information infrastructure, metrics, and metrology to include total lifecycle synthesis and sustainability into the early design stage of products.

Design for packaging:

- The other important factor in sustainable manufacturing is packaging materials for products for the supply chain. Packaging is not simply a cost concern but also a sustainability issue. Assessing packaging environmental performance is complex, and it involves many trade-offs. There is a strong need for developing design for packaging guidelines, appropriate marketing strategy, functional packaging, and package labeling.

Sustainable curriculum development:

- A good curriculum is an essential part of any design school. However, there are some issues related to sustainable curriculum development. One of the issues of the present curriculum is that most curricula are too crammed to add new materials through new course on sustainability. The question we need to answer is: How can principles of sustainability engineering become integrated into engineering education?

Engineering education and sustainability:

- How to enable students from different universities to collaborate and complete projects related to sustainability?

Need for harmonization of standards and reference architectures:

- Harmonize metrics for sustainability - develop and document industrial best practices on the use of such metrics and applicable standards for sustainable manufacturing.

Rapid adoption and deployment of sustainable standards:

- Disseminate best practices in sustainable manufacturing, especially among small- and medium-sized enterprises. Invest in education and training of young engineers in advancing sustainable manufacturing through doctoral and postdoctoral fellowships.

Validation, testing, and verification:

- There is presently no mechanism for systematically evaluating, comparing, selecting, and/or harmonizing sustainability standards of overlapping scope.

Public awareness on sustainability issues:

- There is a lack of appropriate incentives for manufacturers to make good sustainability choices.
- There is a lack of understanding and support of sustainability factors in the general public. The root cause identified was that the issues are sometimes abstract and distant, thus difficult to communicate.

Major recommendations

Following are some of the major recommendations of the workshop:

- Coordinate efforts among the standards development organizations and consortia: The benefit of this harmonization, as seen by the group, was that it would ease the regulatory pressures on Small and Medium Enterprises (SMEs) and give competitive advantage. The plan mooted was to take intra-agency effort in collaborating with standards institutions like American National Standards Institute (ANSI) and Bureau of Indian Standards (BIS) to arrange bilateral workshops and seminars for educating SMEs.

- Develop implementation guidelines and business models for software vendors/developers: The main benefit was seen as win-win for both software vendors and software developers. The plan mooted was to involve software developers/vendors right from the beginning, and funding research in academic institutions for tools development.

- Carry out cost analysis for packaging, assessing recyclability of packaging materials, and developing biodegradable packaging options: The main benefits were reuse of packaging materials, and reduction of waste and landfills.

- Develop and disseminate guidelines for packaging design, conducting packaging audits, and include packaging into design courses.

- Develop a course on sustainable engineering integrating with other courses, and provide reference materials: The plan proposed was to integrate sustainability with existing engineering subjects, establish separate departments for sustainability, and redesign existing university curriculum structure to include sustainability.

- Incorporate ethics in every curriculum: The plan proposed was to start working in rural areas and extend the efforts to work with local and regional authorities.

- Develop a practice-oriented curriculum, give choice to students to choose science or technology based courses, give more weights to projects, and encourage students to study sustainability.
- Develop a Web portal that provides detailed information about various ongoing projects for research collaborations.
- Implement a sustainability labeling system, a “green consequence meter”, and/or a green certification program, to show the effect of product and services consumption in terms of environmental, social, and economic impact: The benefit envisaged is that sustainability factors will become an element of daily decision-making.

Workshop schedule

Day 1: Tuesday 18 August 2009

Inaugural Session:
Opening Remarks: Anindya Deb, Chairman, CPDM, IISc, India
Welcome Address: Sanjay K Biswas, Dean of Engg, IISc, India
Inaugural Address, P Balaram, Director, IISc, India

Keynote Talk 1
Speaker: *S Ranganathan*, IISc, India
Topic: Materials, civilization and choices

Paper Session I: Understanding sustainability

The economics of sustainable business: theory and evidence	*David E Ervin*, Portland State University (PSU), USA
Sustainability analysis and energy footprint based design in the product lifecycle	*S S Krishnan, N Balasubramanian, Eswaran Subramanian, V Arun Kumar, G Ramakrishna, and A Murali Ramakrishnan*, Centre for Science, Technology and Policy (CSTEP), India
A measurement and standards roadmap for sustainable manufacturing	*Steven R Ray*, Carnegie Mellon University, USA
Advanced technologically driven products: safety paradigms for sustainable systems	*Mukul Das*, Indian Institute of Toxicological Research, India
The changing face of sustainability in the CAD-CAM era	*Lalit Kumar Das*, Indian Institute of Technology Delhi, India
Understanding sustainability of products	*Prabir Sarkar, Sudarsan Rachuri, and Ram D Sriram*, National Institute of Standards and Technology (NIST), USA

Keynote Talk 2
Speaker: *Subhas K Sikdar*, EPA, USA
Topic: Industrial sustainability and how to measure it

Paper Session II : Sustainable energy, buildings, cities

Towards designing sustainable cities for India	*R Shankar and Chadchan J*, Indian Institute of Technology Roorkee, India
A model for sustainable neighbourhood re- generation towards an efficient urban form	*Debapratim Pandit and Keisuke Hanaki*, Indian Institute of Technology Kharagpur, India

Framework for sustainable urban environmental services: successful application to high-rise buildings in Mumbai	*Shyam R Asolekar, Pradip P Kalbar, and Atit K Tilwankar*, Indian Institute of Technology Bombay, India
Social dimension of bio energy development in India	*Vinod K Sharma*, Indira Gandhi Institute of Development Research (IGIDR), India

Breakout Session I
Moderators : *Sudarsan Rachuri* and *Prabir Sarkar*, NIST, USA

Day 2: Wednesday 19 August 2009

Keynote Talk 3
Speaker: *V S Arunachalam*, CSTEP, India
Topic: Design and bounded rationality in changing times

Panel Discussion I: Policies and government initiatives

Paper Session III: Supporting sustainability

Integration of sustainability into early product design	*Fu Zhao, Jun-Ki Choi, John Sutherland, Carol Handwerker, and Karthik Ramani*, Purdue University, USA
Sustainable and Lifecycle Information-based Manufacturing (SLIM)	*Sudarsan Rachuri*, National Institute of Standards and Technology (NIST), USA
Idea-sustain: an aid for environmentally friendly product lifecycle design	*Srinivas Kota and Amaresh Chakrabarti*, Indian Institute of Science, India
Generic reference architecture for digital, virtual and real representations of manufacturing systems	*Minna Lanz and Reijo Tuokko*, National Institute of Standards and Technology (NIST), USA and and Tampere University of Technology, Finland
Towards a systems approach for developing sustainable products from sustainable manufacturing	*F Badurdeen, A D Jayal, and I S Jawahir*, University of Kentucky, USA
On practicing and enabling sustainability in product lifecycle management: an interplay between engineering and business issues	*Vijay Srinivasan*, Columbia University, USA

Paper Session IV: Sustainable product development

Sustainable product design - Observations on the mutual implications among sustainability principles, product	*L S Ganesh*, Indian Institute of Technology Madras, India

design objectives and users' requirements	
Preparing the next generation of design engineers: the emerging discipline of sustainable engineering	*Cliff Davidson, Chris Hendrickson, H Scott Matthews, Michael Bridges, David Allen, Cynthia Murphy, Braden Allenby, John Crittenden, and Sharon Austin,* Carnegie Mellon University, USA
A bridge too far – participatory approach to developing sustainable products and services for rural schools in Assam : case study in developing bamboo furniture for rural schools	*Ravi Mokashi Punekar,* Indian Institute of Technology Guwahati, India
Analysis of a cooking fuel briquette-making process from waste materials and re-design of screw-press and stove for improved versatility and efficiency	*Ali Ansari, Ninad Jagdish, and Atha Ur Rahman Khan,* Muffakham Jah College of Engineering & Technology, India
Open source collaborative design platform for augmenting grassroots innovations: an expectation analysis	*Anil K Gupta,* Indian Institute of Management Ahmedabad, India
Sustainable energy technologies for rural industrialization	*M R Ravi,* Indian Institute of Technology Delhi, India
User study and design modifications of a CNG based intermediate public transport vehicle	*M Arun Kumar, K Vimal, and Bishakh Bhattacharya,* Indian Institute of Technology Kanpur, India

Breakout Session II (3 Parallel Sessions)

Breakout Session IIA (Group 1 : Designing sustainable products, services, and manufacturing systems)
Venue: SSCU Auditorium
Breakout Session IIB (Group 2 : Preparing engineering designers and managers for the 21st century)
Venue: SSCU Lounge
Breakout Session IIC (Group 3 : Policies, standards, specific domains, research perspective, and industry best practices for sustainable systems)
Venue: IDeaSLab, CPDM

Day 3: Thursday 20 August 2009

Keynote Talk 4
Speaker: *C P Rangachar,* Yuken India Ltd, India
Topic: The Lean Way to Green

Paper Session V: **Reducing pollutions and waste**

Value addition to enhance recyclability of high-volume plastic packaging waste	*Susy Varughese and D Murugana*, Indian Institute of Technology Madras, India
Improving environmental performance in sustainable lean manufacturing	*Ms Kathi Futornick*, URS Corporation, USA
Reducing carbon emissions: a supply chain approach	*N Viswanadham and S Kameshwaran*, Indian School of Business, India
Hyperaccumulation of As and Cr in plant biomass - a renewable system for mitigation of pollution	*Shweta Kalve, Bijaya Ketan Sarangi, Ram Awatar Pandey and Tapan Chakrabarti*, National Environmental Engineering Research Institute (NEERI), India

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Summary of Breakout Sessions
Summary presentation by moderator of Group A
Summary presentation by moderator of Group B
Summary presentation by moderator of Group C

Open discussion on proposal development for future collaboration
Moderators: *Amaresh Chakrabarti,* IISc, India *and Sudarsan Rachuri,* NIST, USA
Valedictory Session
Valedictory address
N Balakrishnan, Associate Director, IISc, India
Introduction to 'DESINE' Network: Madhusudanan N, IISc, India
Closing remarks
Amaresh Chakrabarti, IISc, India and Sudarsan Rachuri, NIST, USA
Vote of thanks
Amaresh Chakrabarti, IISc, India

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BREAKOUT SESSIONS
SUMMARY

Breakout Sessions Planning

The plan and agenda for the breakout sessions were based on a structured brainstorming and team-oriented problem solving process that have been applied successfully in prior NIST-led workshops. This process consists of the following two steps: 1) Problem/Opportunity Identification, and 2) Analysis and Planning. The Analysis and Planning step can be further broken down into: 2.1) Root Cause Analysis, 2.2) Recommendation Generation, and 2.3) Action Planning.

A session facilitator helped to guide, mentor and facilitate the sessions but the content, ideas, analysis, and recommendations were the group's responsibility. Each session had a scribe to take notes and to prepare the material for the group report. The participants were separated into two breakout groups. On the first day (18th August 2009) of the breakout session, all workshop participants contributed to identifying and grouping the "top attributes" pertaining to the workshop objectives, to be discussed at length by the breakout groups. On the second day (19th August 2009), the three groups spent most of the time dealing with the identified "top attributes," followed by recommendations. Three breakout groups were:

1) Designing sustainable products, services, and manufacturing systems.
2) Preparing engineers, designers, and managers for the 21st century.
3) Policies, Standards, Specific Domains, Research perspective and industry best practices for sustainable systems.

The participants generated recommendations or conclusions by selecting the best ideas or combining ideas for the "top attributes" identified. The group completed one form (see Figure 1) for each recommendation. The group covered as many of the "top attributes" as possible.

Indo-US Workshop on Designing Sustainable Products, Services and Manufacturing Systems
Team Report/Recommendation Template

Breakout Team ID	1	
Identify: Problem or Issue	Metrics and standards development implementation	
Analyze: Root Cause	Lack of coordinated efforts to establish standards Global and regional standards No quantitative measures Multiple standardizing organizations	
Recommendation	Coordinated efforts among the SDOs and std organizations	
Benefit	Ease the regulatory pressures on SMEs Competitive advantage	
Plan: Action(s) to implement		Owner/Time Frame
Intra-agency effort in collaborating with std institutions like ANSI		Sudarsan Elise Owen, Subhas
Arranging workshops and seminars for educations, for SMEs		Amaresh, Arul

Figure 1: Recommendation Template

Description of some of the terms used in Figure1

- The ‘problem’ or ‘issue’ is a statement of what is wrong.
- The ‘root cause’ is a statement of why the problem exists. Every “why” becomes another problem statement. Sometimes one has to ask “why” a number of times to try to get to the root cause. The root cause restates the observed problem in a way that lends itself more readily to “corrective action planning.” This is like trying to get from the symptoms to a disease diagnosis.
- The ‘recommendation’ is a high-level plan or strategy to address the root cause of the problem. One form is completed for each recommendation. There may be more than one recommendation for the same problem, or a team may have time to consider more than one problem.
- The ‘action plan’ is a specific set of tasks with an identified set of “roles” and (if possible) time frame, to implement the recommendation.

GROUP 1: Designing sustainable products, services, and manufacturing systems

Group 1 took up the following set of key issues and subtopics for further elaboration, starting with this set and identifying the most common themes.

- Metrics and standards development implementation
- Tools and software systems for analysis
- Packaging
- Data requirements, data availability, and data structuring
- Product stewardship

The group then discussed a few of the topics in detail as described below.

Metrics and standards development implementation
There is a need for simple and high level metrics, and these need to be supported by good data models. Previous attempts have led to metrics that are difficult to estimate, and for which data is not readily available. Simple and credible metrics are essential for sustainability standards to hold a strong market position. If a standard includes simple and representative metrics, it will be used by more companies (refer to the metrics category in this breakout session summary). In addition to the simple metrics issue, sustainability standards need to have brands of conformity associated with them. The brand quality of the standards should be maintained. A branded sustainability standard can be a positive driver of the market. If the brand is well known in the market, companies will invest money to get a certification or award of the standard.

Problem or issue:

- What are the current sustainability metrics and standards? What are the key issues in the implementation of sustainability factors in the product design?

Root cause:

- Lack of coordinated efforts to establish global and align it with regional standards.
- Lack of availability of quantitative sustainability measures.
- Presence of multiple standards development organizations.

Recommendation:

- The main recommendation was to coordinate efforts among the standards development organizations and consortia. The benefit of this harmonization, as seen by the group, was that it would ease the regulatory pressures on Small and Medium Enterprises (SMEs) and give competitive advantage.
- The plan mooted was to take intra-agency effort in collaborating with standards institutions like ANSI and Bureau of Indian Standards, and arranging bilateral workshops and seminars for educating SMEs.

Tools and software systems for analysis

Sustainable manufacturing stresses the importance of understanding manufacturing as a science of producing things taking into account sustainability factors during design, manufacture, distribution (supply chain and reserve supply chain), use, and post use. Traditional engineering tools such as Computer Aided Design, Manufacturing, and Engineering (CAD/CAM/CAE), Product Data Management and Product Lifecycle Management (PDM/PLM) relied heavily on mathematical algorithms (geometry), information modeling, and interoperability standards to enable data aggregation, analysis, and decision support system. Many of these systems mainly focused on post-design, production, and distribution. To include total lifecycle synthesis and sustainability into the early design stage of products, we need to develop appropriate information infrastructure, metrics, and metrology. This effort is very similar to the "quality movement" and requires a systems approach.

Problem or issue:

- What are the available tools and software systems for life cycle analysis interoperating with engineering tools (CAx/PxM), Life Cycle Assessment tools (LCA) ?

Root cause:

- Lack of decision tools in the early design stages.
- Lack of integrated approaches to sustainability analysis for specific product categories.

Recommendation:

- The main recommendation was to issue implementation guidelines, and business models for software vendors/developers.
- The main benefit was seen as win-win for both software vendors and software developers. The plan mooted was to involve software developers/vendors right from the beginning, and funding research in academic institutions for tools development.

Packaging

The other important factor in sustainable manufacturing is packaging materials for products for the supply chain. There are various global efforts in developing sustainable packaging guidelines, such as, Sustainable Packaging Coalition (SPC)[1], an industry working group dedicated to a more robust environmental vision for packaging, the American Society for Testing and Materials (ASTM) Committee D-10 on Packaging, and the Institute of Packaging Professionals, are currently experimenting with a ranking system. Packaging is not simply a cost concern but also a sustainability issue. Assessing packaging environmental performance is complex, and it involves many trade-offs. The selection of packaging material in terms of reuse, recycle, and toxicity is a major concern for many industries. This is emphasized by Hewlett-Packard (HP)[2], "*in North America, boxes with 35% minimum post-consumer recycled content cost up to 10% to 15% more than boxes with virgin content. In addition, to match virgin fiber*

[1] http://www.sustainablepackaging.org

[2] http://www.hp.com/hpinfo/globalcitizenship/gcreport/products/packaging.html

performance, the box weight needs to increase, which may raise transportation costs. In such cases, we consider total costs, including transport and disposal, as opposed to material cost only."

Problem or issue:

- What are the design for packaging guidelines and industry best practices?

Root cause:

- Lack of design for packaging guidelines, appropriate marketing strategy, functional packaging, and package labelling.

Recommendation:

- The main recommendation was to carry out cost analysis for packaging, assess recyclability of packaging materials, and develop biodegradable packaging options. The main benefits were reuse of packaging materials and reduction of waste and landfills.
- Develop and disseminate guidelines for packaging design, conducting packaging audits, and include packaging into design courses.

GROUP 2: Preparing engineering designers and managers for the 21st century

The focus of Group 2 was on design education. Design education is the teaching of theory and application of the design of products to students and practitioners of product design. Group 2 took up the following set of key issues for further elaboration, starting with this set and identifying the most common themes.

- Sustainable curriculum development
- Engineering education and sustainability
- Case studies

The group then discussed a few of the topics in detail as described below.

Sustainable curriculum development

A good design curriculum is an essential part of any design school. Apart from learning courses related to designing, all designers must be knowledgeable on sustainable design. To design sustainable products and services, one should be exposed to the methods and tools available for sustainable design. However, there are some issues related to sustainable curriculum development. Some of these issues are discussed by this group in detail.

Problem or issue:

- One issue of present curriculum is that most curricula are too crowded to add new materials through new course on sustainability. The question we need to answer is: How can principles of sustainability engineering become integrated into engineering education?

Root cause:

- The root cause was the social attitude towards education.

Recommendation:

- The recommendation was to develop a course on sustainable engineering integrating with other courses, and provide reference materials. The plan proposed was to integrate sustainability with existing subjects, establish separate departments for sustainability, and redesign existing university structure to include sustainability.

Problem or issue:

- How would one address socio-economic values of a given region in the context of lack of multi-disciplinary and trans-disciplinary curriculum for sustainable manufacturing?

Root cause:

- Lack of multidisciplinary approach in design education for subjects related to sustainability.

Recommendation:

- The recommendation was to incorporate ethics in every curriculum. The plan proposed was to start working in rural areas and working with local authorities.

Problem or issue:

- What would be desirable to include in sustainable design curriculum?

Root cause:

- Students are not adequately aware of sustainability.
- Students not having the right attitude.

Recommendation:

- The recommendation was to put more emphasis on practice, experimentation, imagination, and creativity. The benefit was seen as self-realization, students becoming more practical and understanding natural systems better.
- The plan proposed is to develop a practice-oriented curriculum, give choice to students to choose science or technology based courses, give more weights to projects, and encourage students to study all the components of a sustainability program.

Engineering education and sustainability

Engineers and designers develop most of the products that we use in our daily life. To develop sustainable products, engineers should be trained in sustainable principles and practices. To develop responsible engineers, engineers should be made conscious about the possible damage that their products and processes does to the environment. So, a course on sustainability should be added to the engineering curriculum.

Problem or issue:

- How to enable students from different universities to collaborate and complete projects related to sustainability?

Root cause:

- Interaction among universities is limited.

Recommendation:

- The recommendations were: social networking, bringing in cultural issues, encouraging universities to collaborate, and making sustainable meeting groups. The benefit was seen as collaborations getting more task-focused. The plan proposed is to go for radical change towards social engineering, making universities collaborate before students can, initiation of summer schools where different students come together for project based work, and establishing similar interest groups and organizations.

Case studies

Practical knowledge can be gained through case studies. Through case studies, one can learn how others have implemented various strategies of sustainable processes in their companies.

Problem or issue:

- How to generate a set of engineering and business case studies for sustainable design, manufacturing, and services?

Root cause:

- Lack of adequate interaction among different companies, universities, and tool developers.

Recommendation:

- The recommendation was to develop a Web portal that provides detailed information about various ongoing projects and an infrastructure for research collaboration.

GROUP 3: Policies, standards, specific domains, research perspective, and industry best practices for sustainable systems

Group 3 took up the following set of key issues and subtopics for further elaboration, starting with this set and identifying the most common themes.

- **Standards**
  - Need for harmonization of standards and reference architecture
  - How to encourage rapid adoption and deployment of sustainable standards
- **Infrastructure**
  - Lack of adequate infrastructure for, and promulgation of sustainability standards
- **Policy**
  - Lack of public awareness of sustainability issues
  - Lack of appropriate incentives for manufacturers to make good sustainability choices
  - Lack of appropriate incentives for consumers to make good sustainability choices

The group then discussed a few of the topics in detail as described below.

Need for harmonization of standards and reference architectures

The basic need for sustainability metrics can be traced to the Lord Kelvin's dictum that if you cannot measure, your knowledge is meager and unsatisfactory. In the modern industrial context, the needs for sustainable manufacturing metrics are several and compelling[3]:

- There is a growing demand from customers and industrial buyers for easy-to-use numbers to compare and select what they deem to be "sustainable" products.
- Industry needs such metrics to conform to an increasing number of environmental regulations.
- Internally, industry needs these metrics to measure their progress, benchmark against best practices and their competition, and take corrective action. These often lead to product design changes, investment in new technologies, and educating or switching suppliers.
- Savvy companies use such metrics to gain competitive advantage and enhance their brand image as environmentally conscious manufacturers.

The need for metrics and their popularity has spawned several efforts to define such sustainability metrics. Figure 3 shows some of these metrics with some indications on the level of technical detail and the unit domain of applicability. These are but a few of many

[3] Nabil Nasr, *A framework for sustainable manufacturing*, Int. Conf. on Sustainable Manufacturing, Chennai, India, Dec. 2009.

metrics and indicators that have emerged in recent times; more are likely to follow. Such proliferation of metrics, all created with good intentions, has caused considerable confusion among industrial users. Even those who studied and used some of these metrics complain about their complexity and unreliability. The challenge now is to harmonize, simplify, and improve the applicability of these metrics. In addition, the methods of their use in the form of best practices have to be developed and communicated as recommended practices to industry.

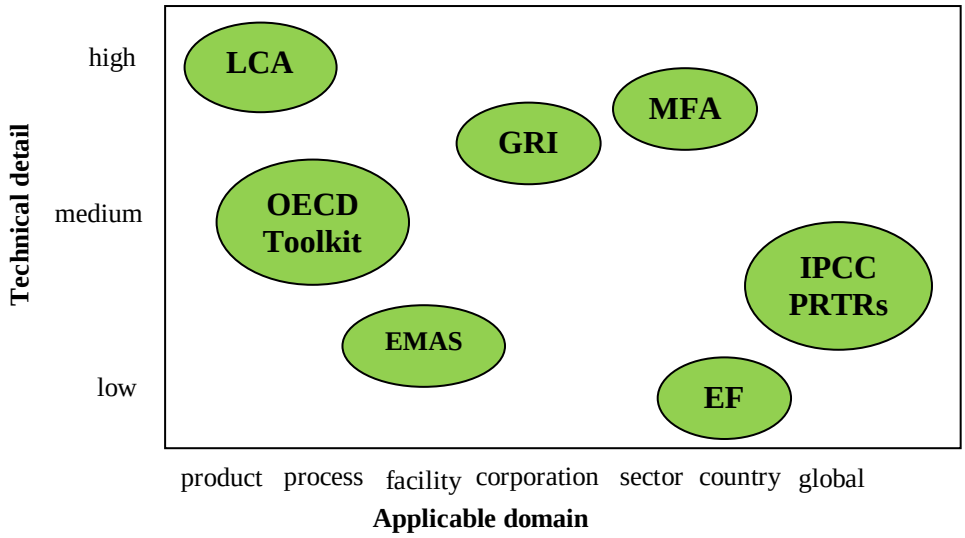

Figure 3. Some of the existing metrics and their characteristics.

LCA: Life Cycle Assessment; EMAS: EU's Environmental Management and Audit Scheme;
OECD: Organization for Economic Cooperation and Development; EF: Ecological Footprinting;
MFA: Material Flow Analysis; GRI: Global Reporting Initiative;
IPCC: Intergovernmental Panel on Climate Change; PRTRs: Pollutant Release and Transfer Registries.
[Bordt, U.S. Department of Commerce Sustainable Manufacturing Summit, 2009]

Problem or issue:

- How to harmonize metrics for sustainability? How to develop and document industrial best practices on the use of such metrics and applicable standards for sustainable manufacturing?

Root cause:

- Incompatible representations and contexts for different standards.
- Lack of a consolidated metrics and their categorization to clarify their applicability in industry.

- Inadequate evaluation of these metrics in the industrial context, in collaboration with lead industries.

Recommendation:

- The recommendation was to consider The Confederation of Indian Industry (CII)/ American National Standards Institute (ANSI)/ Bureau of Indian Standards (BIS) Memorandum of understanding (MOU)[4] as a guide for future harmonization work. The benefit will be the development of a strategic approach to the sustainable standards landscape, minimizing wasted effort, and providing a consistent, integrated solution.

How to encourage rapid adoption and deployment of sustainable standards?

In a recent survey [5] conducted by the American Society of Mechanical Engineers (ASME), practicing engineers pointed out several hurdles to sustainable manufacturing. Among them are:

- "There exists a large knowledge gap in the industry currently, which is inevitably leading toward much 'green-washing' in existing products rather than true sustainable products/processes."

- "We must change the emphasis of 'cost' to include issues like 'having less scrap can save the cost of a product.' Many processes that are sustainable can and do save money. These processes need to be documented and taught in the education systems so that engineers are thinking sustainability when they enter the workforce."

- "Some sustainable practices are relatively simple to implement, and the hurdle is merely normal human laziness institutionalized. Some sustainable practices require significant investment, so economic factors weigh more heavily. Perhaps the biggest hurdle is the lack of a clear 'roadmap' to effective sustainable practices. As there is no single technique or practice, each industry or even location must figure out on its own what sustainable practices it can effectively implement."

In the same survey, the engineers also expressed their opinion on what will encourage adoption of sustainable practices:

- "The case for the ultimate economic and health benefits of adopting sustainable practices needs to be made and widely disseminated. Studies of successes and failures in adopting sustainable practices to be conducted by credible and impartial entities and disseminated widely via the Web, trade and professional journals, and the popular media (expressed appropriately for each medium). Failures need to be understood and discussed, not hidden. Maintaining credibility is crucial. Disseminate the facts, not propaganda."

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[4] http://www.standardsportal.org/usa_en/toolbox/us_indiasccp.aspx
[5] http://memagazine.asme.org/Web/Thoughts_Sustainability.cfm

- "Case studies that link sustainable projects and financial return. I know many companies do not like to share this much detailed information. However, sharing information can be used as ammunition when trying to convince the holders of the purse strings that it is a good idea. We many times can put a dollar amount on it, but there are also intangibles that are difficult to quantify."

- "I'd like to see the standards organizations provide as guidance the mandates that currently come from government. As the customers become more environmentally conscious, they will apply these mandates to their suppliers, and the suppliers can let market forces determine their willingness to participate."

- "Perhaps nonprofit think tank type enterprises can focus on certain industries to accomplish several useful things. First, establish reference materials that are clearly organized and searchable, that detail available best practices for existing and emerging products, methods, practices that can readily be incorporated by all."

- "First, education is very important. The general view that green technology is cost-prohibitive may be true in some areas, but not in many. We as the designers and engineers need to know what technology is out there, how it can be applied, and what the costs and savings are. We also need to have education and training on what practices can be implemented in our designs to make the design more sustainable."

In these raw responses, one can hear a cry for help from practicing engineers who want to do the right thing and answer the call for sustainability from their management, but lack the tools and methodologies.

In the popular media, the battle for bragging rights has already begun, with Newsweek's publication[6] of the first annual green rankings of America's 500 largest corporations – most of them are in the manufacturing sector. The pressure on these companies is palpable as many of them voluntarily participate[7] in the carbon disclosure project[8], which gives them a roadmap for measuring their emissions and pointing out how they compare with their peers. Companies benefit from such participation because they can change their energy practices well before governments step into regulate emissions.

Problem or issue:

- Disseminate best practices in sustainable manufacturing, especially among small- and medium-sized enterprises. Invest in education and training of young engineers in advancing sustainable manufacturing through doctoral and postdoctoral fellowships.

Root cause:

- Large complex standards are difficult to understand for implementers and users, so these standards are met with resistance.

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[6] http://greenrankings.newsweek.com/
[7] Emissions disclosure as a business virtue, New York Times, Dec. 28, 2009.
[8] https://www.cdproject.net/en-US/Pages/HomePage.aspx

Recommendation:

- The recommendation was that standards should be developed as simple, modular, and extensible. A number of factors have to be taken into account as the problems are complicated, but they can be addressed through the use of multiple compatible standard modules. The benefit will be a easily understood set of standards allowing incremental adoption, thereby increasing the chances of penetration into the marketplace.

Lack of adequate infrastructure for, and promulgation of sustainability standards

There is presently no mechanism for systematically evaluating, comparing, selecting, and/or harmonizing sustainability standards of overlapping scope. Current standards typically have narrow scopes, often overlap with other standards and usually define their own terminology and evaluation mechanisms. A uniform in-depth study of prospective sustainable related standards such as their use, their maturity, and their supporting software tools, is needed. This will help in analyzing the gaps and the overlaps of the standards through a formal approach with an information model.

Problem or issue:

- There is presently no mechanism for systematically evaluating, comparing, selecting and/or harmonizing sustainability standards of overlapping scope.

Root cause:

- The root causes were identified as the lack of knowledge of what to test, and how to validate the functionality of new sustainability standards.

Recommendation:

- Explore a synthesized methodology for testbeds based on prior experiences at NIST and to propose a reference testbed architecture.
- Develop information standards to support carbon output reporting and carbon credit trading.
- Develop information standards to support recycling, reuse, or disposal of manufactured products.
- Validate and test information models for sustainable design and manufacturing.
- Develop a testbed that validates the different aspects of the sustainable manufacturing. The testbed will apply metrics for the performance of specific applications or procedures for sustainable manufacturing.

The benefit will be a testing infrastructure enabling implementers to create new systems that can work together in an integrated fashion using the new sustainability standards.

People do not have proper awareness of sustainability issues

There are many relevant research and technology development efforts reported across the globe. In particular, the European Union is very proactive and has mandated several key

activities to alleviate greenhouse gas emissions[9]. Asia's posture in this arena is exemplified in a recent interview[10] where Mr. Katsuaki Watanabe, President of Toyota is quoted as saying "... in my vision for the future, the most important themes are the environment, energy, safety…." Hiroshi Komiyama (Japanese scientist and ex-president of university of Tokyo) explains Japan's "Vision 2050" report and steps taken by Japan in achieving a sustainable society. The essential points are:[11]

- realization of a recycling system of materials
- tripling energy efficiency
- doubling renewable energy

In the USA, many organizations have individually addressed energy or environmental issues. The National Academy of Sciences has produced many studies on climate change[12]. Recently, companies in the United States Climate Action Partnership (USCAP)—businesses including General Electric (GE), Alcoa, DuPont, and Pacific Gas and Electric Company (PG&E)—announced their call for federal standards on greenhouse gas emissions[13]. In their report, they call for "*Mandatory approaches to reduce greenhouse gas emissions from the major emitting sectors including emissions from large stationary sources, transportation, and energy use in commercial and residential buildings that could be phased in over time, with attention to near-, mid- and long-term time horizons.*" The Pew Center issued a report that states "all survey respondents believe that government involvement is necessary to address climate change."[14] The Green Supplier Network[15] is a joint effort of Environmental Protection Agency (EPA), NIST, major manufacturers and their suppliers. They provide independent assessments of manufacturing sites and offer suggestions for "lean and clean" manufacturing improvements. Other EPA programs include WasteWise[16] designed to reduce municipal solid waste and industrial wastes, and Climate Leaders[17] in which companies, primarily manufacturers, pledge to meet specific greenhouse emission reduction goals. Department of Energy (DOE) has in place a wide spectrum of energy efficiency programs[18]. The lesson is that world is moving forward aggressively to achieve sustainable manufacturing. However, a simple explanation of sustainability should be made available to the public in the popular media.

Problem or issue:

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[9] For example, see http://www.eurotreaties.com/atkey.html

[10] The HBR Interview, Harvard Business Review, October 2007

[11] Fourth International Symposium on Environmentally Conscious Design and Inverse Manufacturing, 2005, Eco Design 2005, 12-14 Dec. 2005, page(s): 2- 4

[12] For example, see "Understanding and Responding to Climate Change – Highlights of National Academies Reports," 2006.

[13] A call for action- Consensus Principles and Recommendations from the USA Climate Action Partnership: A Business and NGO Partnership, www.us-cap.org

[14] Getting Ahead of the Curve: Corporate Strategies that Address Climate Change by A. Hoffman, prepared for the Pew Center on Global Climate Change, University of Michigan, October 2006

[15] www.greensuppliers.gov

[16] http://www.epa.gov/wastewise

[17] http://www.epa.gov/climateleaders/partners

[18] http://www.eere.energy.gov

- Lack of public understanding and support of sustainability factors in their choices.

Root cause:

- The root cause identified was that the issues are sometimes abstract and distant, thus difficult to communicate.

Recommendation:

- Use visual media more effectively for public education on climate change, water use, etc. The main benefit will be that marketing of this issue can dramatically increase public support for action (witness Al Gore's work on climate change).
- Implement a sustainability labeling system, and/or a "green consequence meter", and/or a green certification program, to show the effect of consumption in terms of environmental damage done. The benefit envisaged is that sustainability factors will become an element of daily decision making.

Manufacturers do not have the appropriate incentives to make good sustainability choices.

There is a growing demand for extended producer responsibility (EPR). The non-profit group California against Waste [19] defines EPR as follows, *"extended producer responsibility is the concept that a manufacturer's responsibility for a product extends beyond the time of sale. This view incorporates a "cradle-to-the-grave" conception of products, and relieves the costs of cleanup and dangerous materials from consumers and local governments. Someone has to bear the costs of the disposal of a product: by incorporating what would otherwise be the external cost of disposal into product manufactured. Manufacturers will design products that are safer and cheaper to dispose of."* The OECD defines EPR [20] as follows, *"Extended Producer Responsibility is a concept where manufacturers and importers of products should bear a significant degree of responsibility for the environmental impacts of their products throughout the product life-cycle, including upstream impacts inherent in the selection of materials for the products, impacts from manufacturers' production process itself, and downstream impacts from the use and disposal of the products. Producers accept their responsibility when designing their products to minimise life-cycle environmental impacts, and when accepting legal, physical or socio-economic responsibility for environmental impacts that cannot be eliminated by design."*

In EU, polluter must pay is a cornerstone of EU policy. The EU integrated product policy (IPP) strategy focuses on the three stages in the decision-making process, which strongly influence the life cycle environmental impacts of products; application of the polluter pays principle [21] in fixing the prices of products, informed consumer choice, and eco-design of products.

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[19] http://www.cawrecycles.org/issues/epr

[20] http://www.oecd.org/document/53/0,3343,en_2649_34395_37284725_1_1_1_1,00.html

[21] The polluter pays principle underpins environmental policy such as an ecotax, which, if enacted by government, deters and essentially reduces the emitting of greenhouse gas emissions. Some eco-taxes underpinned by the polluter pays principle include: the Gas Guzzler Tax, in US, Corporate Average Fuel Economy (CAFE)- a "polluter pays" fine. The USA Superfund law requires polluters to pay for cleanup of hazardous waste sites, when the polluters can be identified – from wikipedia

Problem or issue:

- Lack of appropriate incentives for manufacturers to make good sustainability choices.

Root cause:

- The root cause identified was that manufacturers are currently not required to take responsibility for the full life cycle costs of their products.

Recommendation:

- Recommendation was to establish a system of fees, tariffs, penalties, and subsidies that account for presently non-market ecosystem services, such as end of life costs. The benefit will be that economic incentives will better align with societal costs and benefits.

PANEL DISCUSSIONS
SUMMARY

Topic 1: Policies and Government Initiatives

Panel Members:
Chair: Dr. V.S. Arunachalam, CSTEP, India
Members: Dr. Subhas Sikdar, EPA, USA; Dr. Steven Ray, NIST, USA

Two questions were posed to the panel to which each panellist was asked to respond:

What initiatives have been planned or taken by governments and organizations to support collaborative research in Sustainable design?

- Dr. Sikdar's response
    - The EPA has declared sustainability as an organizational principle for environmental stewardship. There is a core research program on sustainability for developing tools for sustainability analyses. More focused interdisciplinary research across EPA's research laboratories is anticipated in the near future.
    - EPA has a sustainability research plan and another on biofuels research. On the latter, cross-disciplinary and cross-organizational collaboration has been encouraged. Early signs are positive.
    - We can see the EPA track record of achieving environmental excellence by means of the Pollution Prevention Act (1990) which is not legally binding but a voluntary instrument. The result of this act was reduction in toxic emissions into atmosphere. It is a remarkable achievement; last decade saw 33% less environmental pollution and 33% more Gross National Product (GNP).
- Dr. Ray's response
    - The National Institute of Standards and Technology of the Department of Commerce, USA, has set up test beds, labs, and a sustainable manufacturing program. NIST is initiating a new program in this area. New collaborations have been set up, such as the Green Suppliers Network to help smaller manufacturers in terms of education and understanding of the sustainability issues. The Department of Commerce initiated two years ago a sustainable policy and technical collaboration with NIST. NIST and its Sustainable and Lifecycle Information-based Manufacturing [22] program focuses more on technology, while the DOC focuses on policy.
    - Also related to sustainable practices, NIST started a special program called Smart Grid. The Smart Grid Interoperability Standards Project [23] has obtained funds from the Department of Energy through the American Recovery and Reinvestment Act as an investment for the future. The Department of Energy has invested a substantial amount of money for future sustainable technologies like smart grid, electric vehicle technology, new (electric storage) battery technology. For the next year or two, there will be growth on an international level.

[22] http://www.nist.gov/mel/msid/dpg/slim.cfm
[23] http://www.nist.gov/smartgrid/index.cfm

- There is also a multinational Intelligent Manufacturing Systems collaborative program in place between the EU, USA, Korea, Japan, and Australia. NIST and its partners in the other regions are actively working on a) Sustainability and Safety, b) Energy Efficiency, c) Standards, d) Education, and e) Key Technologies.

- Dr. Arunachalam's response
  - Indian Government is funding optical fibre communication for research labs, units, and educational institutions in Delhi-Mumbai-Hyderabad and from there to small towns. It is an opportunity to increase the literacy level. We need educated India.
  - We are running out of teachers and a solution to this can be distributed learning.

What else can be done by government and organizations to support collaborative research in Sustainable design?

- Dr. Sikdar's response
  - In USA, there is a great deal of interest in sustainable designs among industries. The first international conference on sustainable science and engineering, which we organized in Cincinnati the past summer, was very successful. More than 50% speakers from industry participated.
  - Driving sustainability for production, process design, and overall environment is needed.
  - Self-motivation in the private sector and plenty of money are needed.
  - If we cannot know the environmental impact, e.g., CO_2 emissions etc., this will lead to unintended consequences and more threats. EPA is insisting on fuel efficiency, food labelling, and certified sustainable products.
  - There is a World Business Council for sustainable development, of which there is a USA counterpart. Indian counterpart could be a good start. Large Indian companies seem to be interested as well. If they can require holding senior executives accountable for sustainable development that would be a good indication for the entire private sector.
  - The counter part of World Business Council in India is CII - Green Business Initiative. The pattern in India has been for the NGOs or civil societies to put pressure on industrial bodies on taking such initiatives.

- Dr. Ray's response
  - In addition to the programs mentioned earlier, it is important to recognize that societal changes are required for recycling, energy saving, and decrease in energy consumption.

- Dr. Arunachalam's response
  - Many universities are starving in India for talent. Indian academics have been restricted to IISc and Indian Institute of Technologies (IITs). Major collaboration between institutes is needed.

- There are various problems across universities in India. Back in the 1950s in the USA there was huge government influence into universities. Subsequently universities competed and developed successfully. We need knowledge networks.
- Indians went to other countries, emigrated to USA, UK, etc., and as a result India lost one generation of scientists to other countries.
- Lack of coordination between different ministries. Some ministries need to be reorganised to control this outflow.
- India is the fourth largest in CO_2 emissions voluntary; the persuasion level is very low. It would be more effective to levy process tax on carbon and carbon trading.
- Urgent need for India is of a higher education system that teaches sustainability.

Topic 2: Industry Initiatives towards Sustainability

Panel Members

Chair: Ms. Kathi Futornick, URS Corporation, USA
Members: Dr. Om Prakash, Boeing Research and Technology, India; Mr. B R Satyan, Central Manufacturing Technology Institute, India

Two questions were posed to the panel to which each panellist was asked to respond:

What challenges do Industry and Research and Development (R&D) institutions face in adopting Sustainable design strategies?

- Ms. Kathi Futornick's response
    - During the past years, there has been a considerable decline in industry-based R & D facilities. Certain industries have collaborated with educational institutions while other, such as the aerospace industry has retained the R & D facilities. Whether an industry retains its R & D depends on the industry and the pressures it faces. Recent EU Directives have forced several industries to re-tool their products to meet these new requirements thereby creating a need to resurrect their R & D facilities.
    - Anti-trust laws by government can discourage partnerships among industries. In the USA, we have some of these challenges whereby it appears collaboration among industry and government in other countries is more accepted.
    - More industry research is needed coupled with development of standards. Market based strategies will take longer to develop and potentially lack of standardization.
- Mr. B R Satyan's response
    - There is a requirement to graduate from the existing predominant focus on 'fitness to existing standards,' which cater to concerns on functionality, features, cost, etc. to other aspects of fitnesses like, 'fitness to unmentioned needs', 'fitness to use', 'fitness to societal needs,' and 'fitness to environmental needs' throughout the spectrum of user domains and expectations. This would mean there is a definite 'Need to bring various experts from different domains and collaborate' to improve design strategies. There is a need to grow/evolve indigenous expertise with specific stress on the product development ecosystem in the national context.
    - Many software tools and repositories of potential to improve design strategies exist, but the challenge is to link and network them in the national context. There is a definite requirement to move from the predominant technology acquisition mindset to wilfully strengthening the indigenously technology development since markets are coalescing even in India and the role of sustainability needs to be more strongly affirmed with action plans to evolve competence building networks.
- Dr. Om Prakash's response
    - Need to see the relationship between sustainability and global export standards.

- In airlines industry, logistic issues are of major concern, as these are carbon intensive.
- There has been interest towards developing composite matrials for airplanes but one needs to look into disposal issues of composites.
- Following both military specifications and sustainable measures is very difficult.

What initiatives have Industry and R&D institutions taken or planned to take in adopting Sustainable design strategies?

- Ms. Kathi Futornick's response
  - Companies disassembled R&D into divisions and are now seeking collaborations with universities to compensate for loss in overall company R&D capacity to meet regulatory and globalization challenges. Concern over confidential information has forced, especially high tech companies, to re-establish some level of R&D. The EU Directives for Restriction of Hazardous Substances (RoHS) and Registration, Evaluation, Authorization, and Restriction of Chemical substances (REACH) have spearheaded some of these initiatives.
  - Design for Environment and other programs such as bio-mimicry need to be given importance while developing sustainable systems. Design for Environment is a program, which has been around for quite a while. The advantage of a Design for Environment approach is it is systematic product design from not just the planning to end-use stage, but all aspects of impacts it may have on the environment and socio-economic issues.
  - Certain industries are looking at the full life-cycle as products are designed such as incorporating waste from one industry to be used in other industry. In the USA, we have Zero-Waste alliances, which promote the re-use of waste materials.
- Mr. B R Satyan's Response
  - Over the past five years, substantial effort had been taken at the national level in India in realization of sustainability networks. The National Manufacturing Competitiveness Council has been established as a policy evolving body on national strategies of manufacturing. At the highest levels of thinking in the country, efforts are on trying to improve the key areas lacking in India with questions being articulated like why are there no significant development of advanced technology products of Indian genre? In addition, how to strengthen private public partnership initiative in the country to foster socially relevant, responsible, and application oriented R&D?
  - The Central Manufacturing Technology Institute (CMTI) is helping in the development of sustained deliverables in the form of special products, which meet special safety and environmental behaviour norms. Its basic strength is in applied R&D in manufacturing, PLM, and clean technology and helping generate in a modest way, 'industry ready' Human Resource, with exposure to 'real life' problems in product development.

- CMTI, IITs and IISc have tried to bring out product/process/technology developments to meet social needs. The ever present spectrum of concerns to bridge the 'capacity shortage' gap in design, machining, CAD / CAM, etc. is now morphing into requirements of building 'capabilities' to generate technologies of relevance, develop knowledge/experience repositories, which could help in dealing with emerging imperatives in safety, sustainability, etc. Since 2003, at CMTI, there is a shift in focus to learn from application developments for aerospace equipment and testing equipments, air filter quality testing systems for automobiles, etc. and focus on developing a 'technology development platform' available for industries and academia alike at CMTI. Right now, the interest is in developing and consolidating strengths in application of knowledge/practical experience in micro engineering, nanotechnology, and their integration into macro domains. The needs for the Indian context are being revisited, and it is found that 'knowledge constrictions' experienced by us during special product/process applications are to be seen as opportunities for R & D thrust. Sustainable models are required to be developed for harvesting such opportunities in a cohesive way with academia and industry to ensure that bulk material is not thrown out as waste and recycled/reused, for example, work on minimum quantity lubrication, dry cutting, and replacement of messy processes.
- CMTI believes that there is a necessity to move away from the defined barriers like design and manufacturing towards an integrated approach to bring in an ethos of 'manufacturing systems engineering' in the minds of engineers and aspirants. The Applied Mechatronics Integration Facility, the Digital Design Centre, the Nano-Manufacturing Technology Centre, the Metal Additive Processes Facility (e.g., Rapid prototyping (RP)), and the Advanced Machine Tool Testing Facility are some of the recent initiative at CMTI, which address 'sustainability of technology development' with an integrating ethos of multidisciplinary nature per se. Working networks are established with academia including IISc, IITM, IITK, and PSG, as well as with Indian Machine Tool Manufacturers' Association (IMTMA) and CII for technology development.
- In respect of technology-shared collaborations the aspects that need to be stressed in terms of strategic sustainability of business models begs answer to the questions like …What happens at end of collaboration? If projects require 5-6 years or more of engagement of partners how to minimize the role of interference with sustained support for R & D where the progress is not necessarily linear and metrics of evaluation are not objective or fit into the patterns of existing practices ?
- There is a definite need to develop 'Human Resource (HR) base' and 'tacit knowledge base' through application oriented R&D and product developments.
- Institutions need to be nurtured through good and bad times in business cycles so that 'resources to fall back on for R&D are not found to be absent or unavailable.'

- Dr. Om Prakash's response

- Sustainability at Boeing, e.g., in 2008 focused on emission; how the industry contributed to climate change. Now the focus is on the technical aspects – on reducing environmental impact with respect to products and service operations. It has three different strategies for these:
  - Fuel efficiency of the aeroplane: 20% improvement in fuel efficiency is one of the performance metrics used.
  - Alternate fuels: Trial flights have been undertaken: in New Zealand fuels from plant sources and important parameters are used – while trying to ensure it does not compete with the land issue, retrofire, etc.
  - Carbon footprint due to waiting time for landing: The air traffic system efficiency is another metric (Boeing and Airbus have an agreement for increasing ATS efficiency) Major airlines need to work together.
- On environment, Boeing has ISO 14001 certification. One of the drivers for Boeing Research in India is to focus on environment by collaborating with other organizations via projects on bio-fuels, sustainable manufacturing, and supply chain.
- Division of materials and manufacturing initiated new programs catering to address disposal of composites etc. Normally material development cycle time is more, and to reduce this Boeing and IISc are collaborating in materials and structure technology.
- We need to adapt from nature, knowledge from Biology / Chemistry, Bio-mimicry for developing products. Agreement between Boeing and universities and institutions are helping Boeing in developing sustainable jet fuels etc.
- Dreamliner - 787 is more sustainable than 747 and others because of 20% increasing in fuel efficiency per passenger mile, this reduces carbon footprint. Modified aerofoil shapes are helping in less drag and lesser corrosion issues.

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