Appendices

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Appendix A

PSS Screening tools developed in SusProNet

Tukker and Tischer, 2006, cited in (Tischner, 2008).

Source: Tukker and Tischner 2006

Aspect	Score[a]
a) Economic or profit aspects	
How profitable or valuable is the solution for the providers (these can be a consortium of companies), including cost of production, cost of capital and market value of the solution for the provider(s)? Is it cheaper to produce than the competing product?	
How profitable or valuable is the solution for customers or consumers? Are there concrete, tangible savings in time, material use, etc. for the customer? Does it provide 'priceless', intangible added value such as esteem, experiences, etc., for which the customer is willing to pay highly (in comparison to a traditional product system)?	
How difficult to implement and risky is the solution for the providers? Can a promised result be measured and delivered with a high probability, or has the client a high and uncontrollable influence on the costs? When is the return on investment expected?	
How much does the solution contribute to the ability to sustain value creation in the future? Does it give the consortium that puts the PSS on the market now and in the future a crucial and dominant position in the value chain?	
TOTAL	
b) Environmental or planetary aspects	
How good is the solution in terms of material efficiency (including inputs and outputs or waste)?	
How good is the solution in terms of energy efficiency (energy input and recovery of energy without transportation)?	
How good is the solution in terms of toxicity (including input–output of hazardous substances and emissions without transport)?	
How good is the solution in terms of transport efficiency (transportation of goods and people, including transport distances, transportation means, volume and packaging)?	
TOTAL	
c) Social and people aspects	
Does the PSS contribute to quality of work in the production chain (environment, health, safety; enriching the life of workers by providing learning opportunities, etc.)?	
Does the PSS contribute to the 'enrichment' of life of users (by providing learning opportunities, enabling and promoting action rather than passiveness, etc.)?	
Does the PSS contribute to intragenerational and intergenerational justice (equal wealth and power distribution between societal groups, North–South, and not postponing problems to the next generation, etc.)?	
How much does the solution contribute to the respect of cultural values and cultural diversity (e.g. customised solutions, contributing to the social well-being of communities, regions, etc. [cultural values])?	
TOTAL	
Results: main aspect[b]	
a) Economic/profit	
b) Environmental/planet	
c) Social/people	

a 1 = 'better', 0 = 'equal', –1 = 'worse'

b Score is between +4 and –4

Appendix B

Tools and Approaches for Eco-efficiency

Life Cycle Thinking Series, Unitec – Hothouse, Auckland, New Zealand:

Workshop 2 - Life Cycle Management: from product to business, 3rd July 2008;
Corresponding New Zealand magazine article (McLaren & Allan, 2008)

Workshop 3 - Life Cycle Tools & Approaches, 7th August 2008.
Corresponding New Zealand magazine article (Allan, 2008)

Life Cycle Management

From product to business

This is the second in a series of three articles on Life Cycle Thinking and its application to Design-Led Business practice, entitled Life Cycle Management.

These articles and the aligned series of workshops series at Unitec Faculty of Design in Auckland (listed overleaf) are aimed at equipping people with the capability to promote principles of Life Cycle Thinking and initiate change within their organisation.

A practical framework

While Life Cycle Thinking enables a migration of thinking from an object to a product system, Life Cycle Management (LCM) moves you from a product view to an enterprise view. In effect it can sharpen your organisations focus on delivering more sustainable products and services.

LCM is a practical approach which focuses on the application of life cycle thinking through the use for life cycle tools and approaches. LCM has been defi ned as an integrated framework of concepts, techniques and procedures to address environmental, economic, technological and social aspects of products and organisations. Continuous environmental improvement (from a life cycle perspective) is the key tenet.

LCM provides the link between theory and practice. Its greatest advantage is the ability to identify and account of the trade-off between environmental impacts occuring at different locations, times, and life cycle stages. Moreover, this is done without losing sight of business constraints and the functionality to be delivered to the end-user.

It is important to understand that LCM as an approach is scalable so can be applied within small business and is not restricted to large enterprise. Critically LCM is being adopted by leading industries to 'operationalise' their environmental management strategies and practice.

Life Cycle Management at Formway

Formway is a design-led New Zealand company that has adopted a holistic approach to sustainability within its business. Six discrete areas have been defined in the companie's sustainability programme. These follow the main stages of the product life cycle:

1. Sustainable Product Design
2. Supply Chain Management
3. Environmental Management Systems (EMS)
4. Product Stewardship (addressing end of life issues).
5. Climate Change
6. Stakeholder Communications

The first four areas follow the main stages of the product life cycle, whilst the last two areas; Climate Change and Stakeholder Communications, receive specific attention as both are deemed essential to the continuation of the success that Formway currently enjoys with its products.

Formway uses four key instruments (approaches) to deliver integrated Life Cycle Management:

- Life Cycle Assessment (LCA) studies to inform company strategy and product development
- Environmental Management Systems according to the ISO 14001 standard
- Supplier Environmental Requirements and initiation of specific supply chain collaboration projects
- Eco-labelling: used to verify product and production environmental performance, based on life cycle thinking

The Formway LIFE chair and a number of other products and materials have been analysed from a life cycle environmental perspective (and the results peer reviewed). Analysis results for the LIFE chair, illustrated here using CO^2 impacts show three major findings:

- The majority of the LIFE chair's climate change impact is due to CO^2 emissions occuring during raw materials extraction and component processing
- Final product assembly and transport stages make a relatively small contribution to the climate change impact
- Recycling the chair gives an overall reduction in the climate change impact even when taking into account transportation and reprocessing energy

Using these LCA results as a source of innovation, the company has been able to make more informed design choices in subsequent product development projects. They have also been instrumental in stimulating the company to initiate a 'Product Stewardship' project to enable improved environmental performance at end-of-life. This product stewardship programme injects a service based component over the life of the product and offers some interesting potential for re-engagement with consumers at different touch points along the product life span.

The LCM Toolbox & Sustainability Standards

As the Formway example shows, LCM is realised within an organisation by applying an appropriate suite of tools. A crucial prerequisite to its successful application is an organisational culture which enables, fosters and maintains focus on sustainable action and dialogue with all relevant stakeholders.

A wide range of established tools approaches and international standards exist, each having different application areas and benefits.

The most well known system is the ISO 14001: Environmental Management and Audit System (EMAS). Often EMAS approaches are used to address operations or site specific issues. ISO 14001 does operate effectively within New Zealand and there are established auditors such as Telarc.

Another design led company, Design Mobel, built on an existing ISO 9000 quality system to move into ISO 14001. This defined the operational impacts and established a set of objectives and targets which would address these issues over a period of time (including all facets of the business). In this instance an internal team worked with an external ecologist who advised on the best process to work through and it resulted in internal staff presentations to all levels about the outcomes of this research.

A New Zealand developed EMS is Enviro-Mark NZ. One of the attractive things to an SME is the lower entry level and cost. It enables a company to start the process of adoption and build up to the level of ISO 14001. This approach breaks ISO14001 requirements into 5 audited sub-steps, to enable a phased EMS implementation. This method is delivered and audited by Landcare research.

Fusing Science, Business & Design

Formway and Design Mobel exemplify the fact that SME's in New Zealand can adopt an LCM approach and apply new tools and approaches to put some rubber on the road. It has directly enabled Formway to make effective decisions about the life cycle of their products simply because they have a more in depth understanding.

Life Cycle Management can be a daunting endeavour as it can move business owners and executives into areas where they have little expertise or experience. This can be overcome by taking small steps and making an enterprise level commitment to the integration of life cycle thinking. Company strategy, actions and improvements will follow this commitment.

There are huge opportunities for New Zealand designers to demonstrate leadership by creating credible and inspiring solutions for tomorrow, today. So get started.

The third concluding article in this series will provide an overview of specific life cycle tools and approaches, including approaches to sustainable ideation and life cycle tools suited to more analytical stages of the product development process.

Authors: Jake McLaren, Timothy Allan

Originally published in Prodesign - June 2008

Further Case studies

The LCA Center Denmark has a website giving examples of companies who have implemented Life Cycle Thinking. These include Electrolux, Grundfos, Novozymes, Philips, Rockwool and Vestas.

www.lca-center.dk/cms/site.asp?p=4015

Patagonia is an example of total supply chain and material understanding which leads to a product leadership position. Take a look at the footprint chronicles which explain the impacts of the product and supply chain.

www.patagonia.com/web/us/footprint/index.jsp

Ford Motor Company has developed a life cycle sustainability approach to product development. The Product Sustainability Index is one design and communication tool developed in-house.

www.ford.com/aboutford/microsites/sustainability-report-2006-07/documents/fordpsi.pdf

The United Nations Environment Program / SETAC, Life Cycle Initiative is a global program which specifically aims to bring science based life cycle approaches into practice worldwide.

www.unep.fr/pc/sustainability/lifecycle/management

Life Cycle Tools & Approaches -

Implementing Change

This is the third in a series of three articles on Life Cycle Thinking. The first two articles introduced the concept of Life Cycle Thinking and its application within a business context. This article discusses the tools which are used to affect and support decisions that are made during the development process.

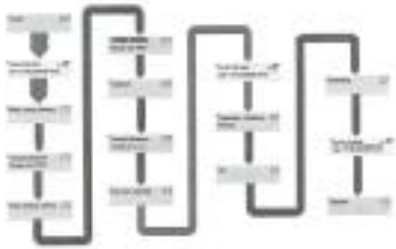
To develop more sustainable products and services it is essential that a whole life cycle approach is taken; without this, critical development areas can be missing and may not be considered.

For many, the hope is that picking up a tool will make decision making easier or simpler. The best tools and approaches advocate consideration of the whole product system (the life cycle) and have an underlying expectation that there is reasonable disclosure of information. These tools are totally reliant on the quality of information you as a designer provide, they are not a substitution for it.

Life Cycle Assessment (LCA)

Many people have heard the term 'LCA' but understand little about it and its origins; it is, in relative terms, a black box. LCA refers to 'Life Cycle Assessment', a process that germinated in the 1960's with the earliest documented example attributed to Coca Cola looking at the comparison between the impacts of a glass bottle and can.

Figure 2. GABI Cladding Flow Diagram



A critical point that is often misunderstood is that LCA is a method, not a tool. You can undertake a complete LCA without even leaving Excel. LCA is technically defined as an investigation and valuation of the environmental impacts of a product or service that are caused or necessitated by its existence. The LCA method or process can be broken down into are four major phases as illustrated in Figure 1 on page 9.

LCA is driven by the 'Goal and Scope' of the environmental assessment. In the previous article, Formway used LCA to investigate the impact of the Life Chair to provide information to enhance the design process, better understand their existing products, and reduce impacts from their production.

A critical aspect of the goal and scope is defining the 'Functional unit' (FU). This is similar to the core function described in the first article, but becomes more analytical; for example, when comparing a glass and a plastic milk bottle the functional unit would be 'the delivery of 1000 litres of milk'. This FU is sufficient to objectively capture the true impact of each life cycle (i.e. including bottle washing).

The 'Inventory Analysis' or Life Cycle Inventory (LCI) phase involves the collection and documentation of data related to the products and services being assessed. In the LCI phase the flow of the life cycle is modelled to create a system image of the life cycle. An example shown here illustrates the complete life cycle of a timber exterior cladding product. Figure 2.

The LCI phase is central to life cycle thinking because the data collected and crafted can be used for a range of purposes including eco-labelling, compliance or carbon foot printing.

There are a range of international databases which contain material, manufacturing process, and other data such as Swiss commissioned database, Ecoinvent. These databases are often specific to an industry (such as electronics) so having a good look around to find a suitable one is the best idea. Databases can be used in Life Cycle Engineering applications but contain predominantly European/International data. Currently there is a real push to collect data in New Zealand and Australia. The Australians have just initiated the AUSLCI project which aims to collect a wide range of essential data from industry throughout Australia.

The data collected can have the 'So-What' factor, i.e. you have all of this information, but so what? The next phase of LCA, the 'Life Cycle Impact Assessment' (LCIA) addresses this. In this phase the material and energy flows are characterised as impacts. For example Volatile Organic Compounds (VOC) emitted (from solvent flash off) would be attributed to 'Photo-Oxidant Creation Potential' 'POCP' or CO2attributed to 'Global Warming Potential' (GWP). They move from being materials to becoming environmental impacts.

The LCI and LCIA steps are considered sciences in their own right. The Swiss have delineated the science of 'Inventory Analysis' and 'Impact Assessment' seperately as the field continues to develop.

The fourth step is interpretation. This step involves analysing the information and determining whether the aims of the study have been met (simplified).

Tools

Finally, the software tools (LCA tools do exist). The two primary tools are SimaPro, produced by Pre Consultants in Holland, and GABI, produced by PE International in Germany. These are both full scale analytical tools and have a price tag to match (expect to pay the equivalent of Solidworks for a full version). Keep in mind that these are advanced tools that allow you to model a whole life cycle with a range of scenarios and report on them.

There are out down 'lite' tools such as EcoScan (TU Delft) and Ecost (Pre). These generally use pre-calculated impact assessment methods such as EcoIndicators99. They can be useful for screening assessments but are limited in the degree to which they can be customised.

An interesting attempt to harmonise LCA with engineering product design was undertaken by Sebastian Liebrecht's tool 'Eco-logical'. Name aside, it is the best attempt I have seen at making the LCA process easier for design engineers. Currently it only integrates with ProE but there is an API which allows for integration with other applications.

There are newer tools that have been created for simplified use such as 'Greenfly', developed in Australia with John Gertsakis and a range of other contributors. This is not an LCA tool but presents an interesting approach to designing greener products that incorporates LCA information with Eco Design strategies and guides.

Everdee and Tespi are two more tools developed through the EcoSME's programme in the EU and I have recently seen a PHD student in NZ using Everdee due to its effective electronics database (another bonus is its free!).

Tools or Approaches

It is important to have a sound grasp of Life Cycle Thinking as this will provide a platform for developing more sustainable products and services. Advanced tools such as GABI and SimaPro require a solid understanding of life cycle assessment methodology but provide a much greater degree of control over how you analyse and assess the system and how the impact assessment is undertaken.

The lighter tools all have limitations, be aware of these, and ensure that you are up front about it when you use them. Managing expectations is a critical part of using software tools in environmental assessment and none of them offer a silver bullet or replacement for good decision making.

At best they are effective tools to assist objective decision making if based on good data and assumptions.

Links:

www.pre.nl Pre Consultants: SimaPro (LCA Tool), Ecoit (Lite LCA Tool), Eco-indicators (Impact Assessment Method)

www.gabi-software.com PE International: GABI (LCA Tool), GABI SPX (LCA/Design)

www.greenflyonline.org Greenfly Sustainable Design Tool (Hybrid Guide/LCA/Analysis Tool)

www.leibrecht.org Ecological (Hybrid CAD/LCA tool with an embeddable API)

www.ecosmes.net Everdee (LCA tool) Tespi (EcoDesign Tool)

www.idemat.nl Idemat is a material database with a focus on environmental aspects.

www.setac.org Society of Toxicology and Chemistry; centre for LCA method development.

www.auslci.com The Australian Life Cycle Inventory Initiative

Appendix C

Tools and Approaches for Eco-effectiveness

Cradle-to-Cradle (C2C) Principles in detail,

(Anastas & Zimmermann, 2003).

Cradle-to-Cradle Principles in detail

(Anastas & Zimmermann, 2003)

Principle 1: Inherent rather than circumstantial

"Designers should evaluate the inherent nature of the selected material and energy inputs to ensure that they are as benign as possible as a first step toward a sustainable product, process, or system" (Anastas & Zimmermann, 2003, p. 96A). Here, it is important to consider the whole life cycle of a product, process or system, including the extraction of raw materials. Otherwise one optimal part of the process might be totally negated by another. In this step, an overall optimal choice of materials, extraction and manufacturing processes provide positive development that can be further optimized.

Principle 2: Prevention instead of treatment

Waste is described as a human concept that doesn't exist in nature, which has closed-loop systems of birth, decay and rebirth. Design of material use and how one product or process can input into another means that there will be no waste as such. It is therefore through design intent that waste can be prevented from ever coming into existence, a preferred state to the clean-up treatment of waste afterwards.

Principle 3: Design for separation

Design for disassembly needs to be considered right at the beginning of the design process, so that valuable materials can be recovered for remanufacture. This will affect design decisions of how product components and materials are fastened together, and the materials used. Ideally this will be through self-separation "using intrinsic physical/chemical properties, such as solubility and volatility rather than induced conditions, decrease waste and reduce processing times" (Anastas & Zimmermann, 2003, p. 97A).

Principle 4: Maximize mass, energy, space, and time efficiency

Space and time are to be included in making manufacturing and processing systems not just efficient, but also intense. Eco-efficient strategies should be used across the complete lifecycle and at molecular, product and process levels.

Principle 5: Output-pulled versus input-pushed

Quoting Le Châtelier's principle that when stress (temperature, pressure or concentration gradient) "is applied to a system at equilibrium, the system readjusts to relieve or offset the applied stress" (Anastas & Zimmermann, 2003, p. 98A). This means that further inputs are necessary to achieve balance, increasing energy and material expenditure. Yet balance can be achieved in reverse by minimizing/removing outputs, and the process is 'pulled' rather than 'pushed'.

Examples are given such as 'just-in-time' manufacturing to deliver only the required amounts of products and materials to satisfy demand, instead of overproduction, and that the end-user can also be the final purchaser. This can eliminate waste, waiting and processing times, stocktaking and the input of resources.

Principle 6: Conserve complexity

When products are complex, it makes sense to reuse them to uphold their high representative value of design, labour and materials. This value would otherwise be lost as they become 'down-cycled' rather than recycled. Recycling of materials only, can on the other hand, be upheld for relatively simple products, as the materials themselves comprise the greatest value.

Principle 7: Durability rather than immortality

A 'targeted lifetime' of a product is desirable within the design criteria, as immortality of a product is unnecessary and can cause future problems of waste disposal and bioaccumulation. As product aesthetics are influenced by changing consumer attitudes, behaviour, lifestyles and fashion, it makes no sense for a product to last for eternity. But it should still be fit for purpose through durability for the length of the targeted lifetime, and require minimal extra input of resources and energy throughout its complete lifecycle.

Principle 8: Meet need, minimize excess

The overdesign of a product with unnecessary design features or capabilities, and designing always for a worst-case scenario of use, results in an unnecessary expenditure of materials and energy. Therefore product use and actual consumer needs should be carefully considered, and flexibility should be integrated into a design to meet local conditions.

Principle 9: Minimize material diversity

Disassembly and recycling will be aided by reducing the number of different components and materials in a product. Different materials can comprise many combinations of chemicals (e.g. additives, plasticizers, dyes in plastics) which all require processes for their extraction at end of life. This can be affected positively through "up-front designs that minimize the material diversity yet accomplish the needed functions" (Anastas & Zimmermann, 2003, p. 99A), and achieved at different levels:

Process level: creating polymer properties to have desired functions, making certain additives superfluous in the manufacturing process
Product level: Reducing the number of plastics used, e.g. automobiles, as polymers can be constructed with useful characteristics that can aid disassembly and recycling
Molecular level: "self-assembly processes that replace multistep reactions"

Principle 10: Integrate local material and energy flows

Overall amounts of materials and energy can be reduced when use is made of local supplies and existing facilities and frameworks.

Principle 11: Design for commercial "afterlife"

Designs that are modular can facilitate an end-of-life strategy, as certain components can be reused, whilst others, such as aesthetic casings of mobile phones, can be recycled. It is important to embed these issues and to integrate an end-of-life into design decisions, so that "the value added to molecules, processes, products, and systems could be recovered and reused at their highest value level as functional components"(Anastas & Zimmermann, 2003, p. 100A).

Principle 12: Renewable rather than depleting

Applicable to all materials and sources of energy, renewable is the preferred option. All inputs and outputs have to be weighed up as to their environmental effects. The authors further define: "Renewable resources, however, can be used in cycles in which the damaging processes are not necessary or at least not required as often. Biological materials are often cited as renewables. However, if a waste product from a process can be recovered and used as an alternative feedstock or recyclable input that retains its value, this would certainly be considered renewable from a sustainability standpoint" (Anastas & Zimmermann, 2003, p. 100A).

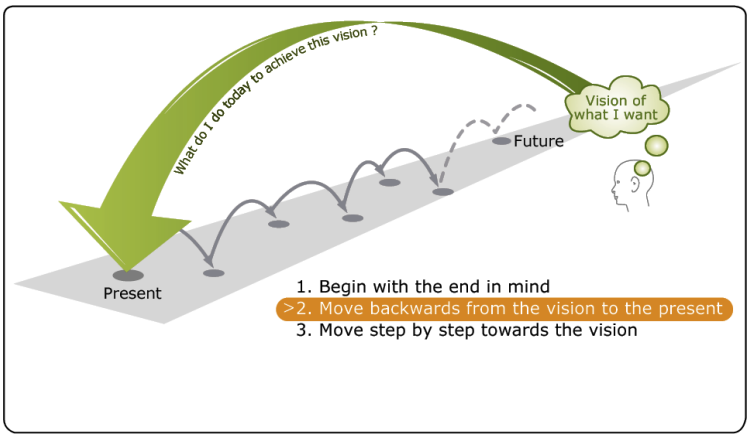
Appendix D

Backcasting

(http://www.naturalstep.org/en/backcasting) accessed 06.02.11.

Backcasting

The concept of "backcasting" is central to a strategic approach for sustainable development. It is a way of planning in which a successful outcome is imagined in the future, followed by the question: "what do we need to do today to reach that successful outcome?" This is more effective than relying too much on forecasting, which tends to have the effect of presenting a more limited range of options, hence stifling creativity, and more important, it projects the problems of today into the future.



In the context of sustainability, we can imagine an infinite number of scenarios for a sustainable society – and 'backcasting from scenarios' can be thought of as a jigsaw puzzle, in which we have a shared picture of where we want to go, and we put the pieces together to get there. However, getting large groups of people to agree on a desired future scenario is often all but impossible. Further, scenarios that are too specific may limit innovation, and distract our minds from the innovative, creative solutions necessary for sustainable development.

So strategic sustainable development relies on 'backcasting from sustainability principles' – which are based in science, and represent something we can all agree on: if these principles are violated, our global society is un-sustainable. To achieve a sustainable society, we know we have to *not violate* those principles – we don't know exactly what that society will look like, but we can define success on a principle level. In that way, backcasting from principles is more like chess – we don't know exactly what success will look like, but we know the principles of checkmate – and we go about playing the game in a strategic ways, always keeping that vision of future success in mind.

Natural systems are complex and non-linear, and while we understand more and more about how they behave on the principle level, we still cannot predict the weather. Social systems are far more complex. Still, we try to force these systems into models so we can 'understand' them and 'predict' how they will behave. To do this, we are forced to make assumptions that often make the models reductionist, simplistic, and absurd. For example, in economic systems the assumptions that all people are 'rational actors' and that there is 'perfect information'. In large part, this is due to a tradition of compartmentalized disciplines in academia, where the social scientists have pushed a quantitative, value-neutral approach to studying these systems in the misguided pursuit of establishing concrete laws similar to the laws of nature.

Even if we could predict the future, why would we want to? We have the power to create a better future. The complexity of social systems within the biosphere demands a whole-system perspective and employing backcasting from sustainability principles. In this way, we can acknowledge the value-laden reality of social systems. We can all take a transdisciplinary approach to learning to better understand the basic constraints we must operate in. And together, we can implement the dramatic change in societal design necessary to create a sustainable society.

Appendix E

Draft Survey Questionnaire for NZ Final Year ID and Engineering Students

(Haemmerle, 2011)

6th Draft Survey – Sustainable Product Design (SPD), as understood and perceived by Final Year Industrial Designers / Mechanical and Mechatronics Engineers

We are asking for your help in learning more about the level of your awareness/understanding/knowledge of Sustainable Development and Sustainable Product Design (SPD) in New Zealand. This is important as you will be contributing as future professionals in addressing these issues. The results of this survey will help us to improve the existing courses and develop new teaching programmes related to these areas. Please respond to the following items as honestly and carefully as possible (there are no right or wrong answers as we are just seeking your opinions). All answers will be kept anonymous, please read the information sheet fully before completing this survey questionnaire.

The survey has 3 parts:

1. **Awareness/Understanding/Knowledge:** to find out what you understand by the terms ***Sustainable Development*** and ***Sustainable Product Design (SPD),*** and contributing factors.

2. **Study courses:** to find out where and how you gained your understanding and knowledge.

3. **Your ratings of the importance:** to find out your knowledge and ratings

- of the wider term of Sustainable Development (concepts)
- of SPD (tools/technologies/approaches)

Please put a cross in the appropriate box.

Gender: Female [X] Male [ ]

University/Institution……..

Degree(s) enrolled in……

……..

Area: Industrial Design [ ] Mechanical Eng. [ ] Mechatronics Eng. [ ]

1. *Awareness / Understanding / Knowledge*

Sustainable Development Definition:

	Not heard of	Heard of but can't explain	Have some knowledge	Know a lot
I				
Sustainable Development Concepts				
Components of sustainable development..				
Approaches to sustainable development....				
Precautionary principle……..				
Factor 4, Factor 10, Factor 20……..				
Population growth……				
Inter- and intra-generational equity……..				
Stakeholders' participation……				
Connection between poverty, population, consumption and environment degradation				
Earth's carrying capacity……				
Social responsibility……				
Fair Trade……				
Responsible Care……				
Triple Bottom Line……..				
Triple Top Line……				
II Environmental Issues				
Climate change……				
(COP 15), Copenhagen, Denmark……..				
Global warming……				
Biodiversity……				
Ecosystems……				
Ecology……				
Acid rain……				
Air pollution……				
Water pollution……				
Depletion of natural resources……..				
Ozone depletion……..				
Deforestation……..				
Desertification……..				
Photochemical smog……				
Salinity……..				
Solid Waste……....				
Waste Management……				

Sustainable Product Design (SPD) Definition:

III Environmental Product Policy (EPP) - Legislation, Policy and Standards

	Not heard of	Heard of but can't explain	Have some knowledge	Know a lot
International:				
Montreal Protocol on CFCs.....	☐	☐	☐	☐
Intergovernmental Panel on Climate Change (IPCC)……	☐	☐	☐	☐
The Earth Summit, Rio de Janeiro……..	☐	☐	☐	☐
Agenda 21……	☐	☐	☐	☐
Rio Declaration……	☐	☐	☐	☐
Statement of Forest Principles……	☐	☐	☐	☐
UN Framework Convention on Climate Change……	☐	☐	☐	☐
Convention on Biological Diversity……..	☐	☐	☐	☐
Kyoto Protocol.....	☐	☐	☐	☐

IV Environmental Management Systems (EMS) / Standards

a) International:				
ISO 14000 / ISO 14001……	☐	☐	☐	☐
EU EMAS.....	☐	☐	☐	☐
The Florence Convention……..	☐	☐	☐	☐
Global Reporting Initiative……	☐	☐	☐	☐
Green Financial Indexes……	☐	☐	☐	☐
Forestry Stewardship Council (FSC)……..	☐	☐	☐	☐
b) New Zealand:				
Green Star NZ……	☐	☐	☐	☐
Environmental Choice NZ……	☐	☐	☐	☐
CarboNZero……	☐	☐	☐	☐
Sustainable Business Network……	☐	☐	☐	☐
DINZ Sustainable Design Awards……	☐	☐	☐	☐
DINZ Sustainable Policies……	☐	☐	☐	☐
IPENZ Sustainable Policies……	☐	☐	☐	☐

Other (please specify)

……

……

……

	Not heard of	Heard of but can't explain	Have some knowledge	Know a lot
V Tools/Technologies/Approaches				
Systems Thinking……				
Eco-efficiency……				
Industrial Ecology……				
Clean-up technology……..				
Fuel cells……..				
Tradeable permits……..				
Design for the environment (DfE)……				
Life cycle management (LCA etc.)……....				
Fast Five……				
Ecological foot-printing……				
Materials reduction……				
Waste minimisation……				
Waste management……..				
Reduce / reuse / recycle……				
Eco-effectiveness……				
Cradle-to-cradle……				
Clean technology……				
Clean materials……				
Product stewardship……				
Environmental supply chains……				
Renewable energy technologies……..				
Raw material manufacturing processes…..				
Product manufacturing processes……				
Chemical content of end products……..				
MET Matrix…….....				
Eco-Indicator 99……..				
Ecodesign Web……				
Design Abacus……				
Six Rules of Thumb……				
Eco-labelling……				
Product Service Systems (PSS)……				
Dematerialisation……				
The Natural Step……				

Other (please specify)

……

Conceptual

Foresighting……	☐	☐	☐	☐
Scenario setting……..	☐	☐	☐	☐
Scripting……	☐	☐	☐	☐
Backcasting/Intentional Design……	☐	☐	☐	☐
User Centred Design……..	☐	☐	☐	☐
Universal/Inclusive Design……	☐	☐	☐	☐
Information/Inspiration website…..……	☐	☐	☐	☐
Real People website……..	☐	☐	☐	☐
Ethnography (user profile)...……	☐	☐	☐	☐
Flowmaker / Cards……..	☐	☐	☐	☐
IDEO / Cards……	☐	☐	☐	☐
Mood/visual boards……	☐	☐	☐	☐

Other (please specifiy)

……

……

VI Design Discussions / other

Changing the Change Conference……..	☐	☐	☐	☐
Designer's Accord……..	☐	☐	☐	☐
Engineers Without Borders……	☐	☐	☐	☐
Sustainable materials libraries (Material Connexion etc.)……..	☐	☐	☐	☐

2. Study Courses

Have you had any environmental education in your university courses so far? Yes ☐ No ☐

Which courses in your curriculum gave you this sustainable development and SPD knowledge? (please give university or institution, paper name and number)

……

……

Would you have attended courses in the following, had they been offered?

Sustainable Development – basic issues from Year 1 upwards	Yes	☐	No	☐
Sustainable Product Design - knowledge " " "	Yes	☐	No	☐
Sustainable Entrepreneurship - final year project, business plan	Yes	☐	No	☐
Interdisciplinary SPD and SD Graduation track, final year project	Yes	☐	No	☐
SPD and Sustainable Development accreditation in qualification	Yes	☐	No	☐

If you have answered no to any of these questions, please give reasons below:

……

……

3. How would you rate the importance of Sustainable Development?

	Not at all important	***Not important***	***important***	***Very important***
For you personally……	☐	☐	☐	☐
For you as a professional……	☐	☐	☐	☐
State which profession……				
For society world-wide……..	☐	☐	☐	☐
For future generations……	☐	☐	☐	☐

How would you rate the importance of SPD?

	Not at all important	***Not important***	***important***	***Very important***
For you personally……	☐	☐	☐	☐
For you as a professional……	☐	☐	☐	☐
State which profession……				
For society world-wide……..	☐	☐	☐	☐
For future generations……	☐	☐	☐	☐

In your opinion, what are the 5 most important SPD or SD issues and why?

SPD / SD Issue	**Rank in order of importance** **1 = most important**	**Why**
1……	☐	……
2……	☐	……
3……	☐	……
4……	☐	……
5……	☐	……

Thank you for your time and assistance

Appendix F

Final Survey Questionnaire for NZ Final Year ID and Engineering Students

(Haemmerle, 2011)

Survey Questionnaire for Students

Industrial Design and Engineering Perspectives

in New Zealand Tertiary Education for Sustainable Product Design

Concepts understood and perceived by Final Year Students

Industrial Design / Mechanical and Mechatronics Engineering

We are asking for your help in learning more about the level of your awareness/understanding/knowledge of Sustainable Development and Sustainable Product Design (SPD) in New Zealand. This is important as you will be contributing as future professionals in addressing these issues. The results of this survey will help us to improve the existing courses and develop new teaching programmes related to these areas. Please respond to the following items as honestly and carefully as possible (there are no right or wrong answers as we are just seeking your opinions). All answers will be kept **anonymous,** please read the information sheet fully and sign the consent form before completing this survey questionnaire.

The survey has 3 parts:

1. **Awareness/Understanding/Knowledge:** to find out what you understand by the terms ***Sustainable Development*** and ***Sustainable Design (the latter contains sustainable Product Design - SPD),*** and contributing factors.

2. **Study courses or papers:** to find out where and how you gained your knowledge.

3. **Your ratings of the importance:** to find out your ratings of the wider term of Sustainable Development, and any sources that especially inspire and motivate you towards SD and SPD

Please put a cross in the appropriate box.

Gender: Female [x] Male [ ]

University/Institution.....

Degree(s) enrolled in.....

.....

Major: Industrial Design [ ] Product Design [ ]

Mechanical Eng. [ ] Mechatronics Eng. [ ]

Other.....

Sustainable Development Definition: "Sustainable development seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future" Gro Harlem Brundtland in 'Our Common Future', 1987

1. *Awareness / Understanding / Knowledge*

	Not heard of	Heard of but can't explain	Have some knowledge	Know a lot
I Sustainable Development Concepts				
Components of SD.....				
Approaches to SD.....				
Precautionary principle.....				
Factor 4, Factor 10, Factor 20.....				
Population growth.....				
Inter- and intra-generational equity.....				
Stakeholders' participation.....				
Connection between poverty, population, consumption & environment degradation...				
Earth's carrying capacity.....				
Social responsibility.....				
Fair Trade.....				
Responsible Care.....				
II Environmental Issues				
Climate change.....				
Global warming.....				
Biodiversity.....				
Acid rain.....				
Air pollution.....				
Water pollution (eutrophication etc.).....				
Depletion of natural resources.....				
Ozone depletion.....				
Deforestation.....				
Desertification.....				
Photochemical smog.....				
Salinity.....				
Waste Management (solid + liquid waste)..				
III Environmental Product Policy (EPP) - Legislation, Policy and Standards				
Montreal Protocol on CFCs (Chlorofluorocarbons).....				

	Not heard of	Heard of but can't explain	Have some knowledge	Know a lot
Intergovernmental Panel on Climate Change (IPCC).....				
UN Conference on Env. & Development				
UNCED (The Earth Summit, Rio).....				
Rio Declaration.....				
Agenda 21.....				
UN Framework Convention on Climate Change (UNFCCC or FCCC).....				
Kyoto Protocol.....				
UN Climate Change Conference (Conference of the Parties - COP 15) Copenhagen, Denmark.....				

IV Environmental Management Systems (EMS) / Standards

ISO 14000 / ISO 14001.....				
EU EMAS (EU Eco-Managemt & Audit Scheme)..				
The Florence Convention.....				
Global Reporting Initiative.....				
Green Financial Indexes.....				
Eco-labelling.....				

Other (please specify)

.....

.....

Give your own understanding of Sustainable Design (which contains Sustainable Product Design - SPD)

.....

.....

V Tools/Technologies/Approaches

Environmental Systems Thinking.....				
Eco-efficiency vs eco-effectiveness.....				
Industrial Ecology.....				
Waste minimisation/management.....				
Clean-up technology.....				
Fuel cells.....				
Tradeable permits.....				
Design for the environment (DfE).....				
Life cycle management (LCA etc.).....				

	Not heard of	Heard of but can't explain	Have some knowledge	Know a lot
MET Matrix.....				
Eco-Indicator 99.....				
Ecodesign Web.....				
Design Abacus.....				
Cradle-to-cradle.....				
Biomimicry.....				
Clean technology/materials.....				
Renewable energy technologies.....				
Product stewardship.....				
Environmental supply chains.....				
Product-Service Systems (PSS).....				
Dematerialisation, light materials.....				
Enabling design solutions.....				
Context well-being.....				
Sustainable materials libraries..... (Material Connexion etc.)				

Other (please specify).....

2. Study Courses or Papers

Have you had any environmental education in your courses/papers? Yes/No | | |

Which courses/papers in your curriculum gave you this SD and SPD knowledge?

(please give university or institution, course/paper name and number)

.....

Is there any SD or SPD topic you would like to know more about and why?

.....

3. How would you rate the importance of Sustainable Development for..?

	Not at all important	Not important	Important	Very important
You personally.....				
You as a future professional.....				
Your country.....				
The society world-wide.....				
Future generations.....				

Describe any sources that especially inspire and motivate you towards SD and SPD

(study courses/papers, academic staff and/or other influences such as personal values, family, culture, religion etc)

.....

.....

Thank you for your time and assistance! .....

Appendix G

Massey University – Human Ethics Committee – Low Risk Notification

Notification letter dated 26.04.10.

MASSEY UNIVERSITY

26 April 2010

Linda Haemmerle
150 Paremoremo Road
ALBANY 0632

Dear Linda

Re: Industrial Design and Engineering Perspectives in New Zealand Tertiary Education for Sustainability: Sustainable Product Design

Thank you for your Low Risk Notification which was received on 23 April 2010.

Your project has been recorded on the Low Risk Database which is reported in the Annual Report of the Massey University Human Ethics Committees.

The low risk notification for this project is valid for a maximum of three years.

Please notify me if situations subsequently occur which cause you to reconsider your initial ethical analysis that it is safe to proceed without approval by one of the University's Human Ethics Committees.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

A reminder to include the following statement on all public documents:

> *"This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research.*
>
> *If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Professor John O'Neill, Director (Research Ethics), telephone 06 350 5249, e-mail humanethics@massey.ac.nz".*

Please note that if a sponsoring organisation, funding authority or a journal in which you wish to publish requires evidence of committee approval (with an approval number), you will have to provide a full application to one of the University's Human Ethics Committees. You should also note that such an approval can only be provided prior to the commencement of the research.

Yours sincerely

J. O'Neill

John G O'Neill (Professor)
Chair, Human Ethics Chairs' Committee and
Director (Research Ethics)

cc Dr Aruna Shekar
School of Engineering and Advanced Technology
Albany

Assoc Prof Jayne Gooćyer
School of Engineering and Advanced Technology
PN456

Prof Don Cleland, HoS
School of Engineering and Advanced Technology
PN456

Te Kunenga ki Pūrehuroa

Research Ethics Office, Massey University, Private Bag 11222, Palmerston North 4442, New Zealand
T +64 6 350 5573 +64 6 350 5575 F +64 6 350 5622
E humanethics@massey.ac.nz animalethics@massey.ac.nz gtc@massey.ac.nz
www.massey.ac.nz

Appendix H

Extended Table of NZ and International Surveys with T-Values

(Haemmerle, 2011)

In the t-test table, using infinity and 0.01 probability, the value of 2.58 was given. Therefore all t-values greater than 2.58 were deemed significantly different, and *highlighted in colour* in the extended table found in *Appendix H.* These highlighted values were then brought together in a summary table *(Table 21)*, showing all values that were significantly different between the NZ and international studies.

If the NZ mean was greater than the international mean, it gave a positive t-value, i.e. the NZ mean (level of topical knowledge) was better than the international mean. If the NZ mean was less than the international mean, it gave a negative t-value, i.e. the NZ mean (level of topical knowledge) was worse than the international mean. Therefore the positive or negative values were only indicative of the relationship between each of the two survey data, with the actual value indicating the level of knowledge using the rating system by Azapagic et al (Azapagic, Perdan, & Shallcross, 2005) of least to most knowledge, 1 = 'Not heard of' to 4 = 'Know a lot'.

Of particular interest to educators in New Zealand is to know where New Zealand students have, statistically speaking, *significantly less* awareness and knowledge of particular topics. These were all *minus values indicated by additional shading.* They are referred to again within individual tables for significantly different data, also with additional shading (positive values are shown in blue in the tables). However, these comparative values should not detract from the *equally low values* of the majority of additional topics of this New Zealand survey, which *have not been compared to other surveys.*

Topic	NZ Mean	International Mean	NZ Variance	International Variance	t-value
Sustainable Development Concepts Components of SD	2.2	2.0	0.87	0.85	**3.38**
Approaches to SD	2.2	2	0.89	0.89	2.58
Precautionary principle	**1.4**	**1.8**	**0.46**	**0.94**	**-7.64**
Factors 4, 10, 20	1.1		0.20		
Population growth	2.8	2.8	0.56	0.76	0.20
Inter- and intra-generational equity	1.6	1.7	0.59	0.97	-0.99
Stakeholders' participation	2.1	1.6	0.75	0.88	**7.10**
Connection between poverty, population, consumption & environment degradation	2.6	2.6	0.60	0.87	0.75
Earth's carrying capacity	2.4	2.2	0.69	0.86	**3.80**
Social responsibility	2.9	2.5	0.55	0.79	**6.75**
Fair Trade	2.8		0.51		
Responsible Care	2.3	2.2	0.90	0.92	0.70
Environmental Issues Climate change	3.2	3.0	0.26	0.45	**4.70**
Global warming	3.2	3.2	0.25	0.48	0.86
Biodiversity	2.7	2.2	0.62	0.84	**8.24**
Acid rain	2.9	3.0	0.39	0.45	-1.87
Air pollution	**3.1**	**3.2**	**0.24**	**0.32**	**-3.45**
Water pollution (eutrophication	**2.9**	**3.2**	**0.33**	**0.42**	**-6.35**
Depletion of natural resources	3.1	3.0	0.30	0.58	2.48
Ozone depletion	**2.9**	**3.2**	**0.25**	**0.48**	**-6.87**
Deforestation	3.0	3.0	0.32	0.51	-0.26
Desertification	2.5	2.5	0.69	0.81	-0.22
Photochemical smog	2.0	2.1	0.71	0.83	-1.69
Salinity	2.3	2.0	0.76	0.81	**4.04**
Waste management (solid + liquid)	2.8	2.7	0.46	0.69	1.99
EPP and Legislation Montreal Protocol on CFCs	1.6	1.6	0.58	0.66	0.58
Intergovernmental Panel on Climate Change (IPCC)	1.6	1.5	0.55	0.56	2.42
UN Conference on Environment & Development UNCED (The Earth Summit, Rio)	1.7		0.48		
Rio Declaration	**1.3**	**1.6**	**0.26**	**0.63**	**-8.17**
Agenda 21	1.2		0.22		

Topic	NZ Mean	International Mean	NZ Variance	International Variance	t-value
UN Framework Convention on Climate Change (UNFCCC or FCCC)	1.6		0.56		
Kyoto Protocol	2.4	1.7	0.72	0.75	**10.20**
UN Climate Change Conference (Conference of the Parties COP 15) Copenhagen, Denmark	2.1		0.81		
Standards and EMS **ISO 14000 / ISO 14001**	**1.3**	**1.6**	**0.39**	**0.79**	**-5.75**
EU EMAS	**1.1**	**1.2**	**0.10**	**0.28**	**-4.33**
The Florence Convention	**1.1**	**1.2**	**0.10**	**0.30**	**-3.59**
Global Reporting Initiative	1.2		0.19		
Green Financial Indexes	1.2		0.17		
Eco-labelling	**1.6**	**1.8**	**0.63**	**0.75**	**-2.96**
Tool, Technologies and Approaches Environmental Systems Thinking	1.8		0.71		
Eco-efficiency v eco-effectiveness	1.8		0.66		
Industrial Ecology	**1.7**	**1.9**	**0.61**	**0.65**	**-4.01**
Waste minimization/management	2.5	2.5	0.46	0.75	0.05
Clean-up technology	2.0	2.0	0.53	0.77	0.50
Fuel cells	2.4	2.3	0.59	0.87	1.94
Tradable permits	1.7	1.7	0.67	0.89	0.49
Design for the environment (DfE)	2.1	2.1	0.75	0.76	-0.72
Life cycle management (LCA etc.)	2.3	2.1	0.78	0.79	**3.55**
MET Matrix	1.1		0.12		
Eco-Indicator 99	1.1		0.05		
Ecodesign Web	1.2		0.20		
Design Abacus	1.2		0.25		
Cradle-to-cradle	1.7		1.02		
Biomimicry	2.0		1.08		
Clean technology/materials	2.3	2.2	0.70	0.72	2.12
Renewable energy technologies	2.8	2.7	0.60	0.90	1.55
Product stewardship	**1.5**	**2.6**	**0.56**	**0.76**	**-18.79**
Environmental supply chains	1.7		0.58		
Product-Service Systems (PSS)	1.5		0.58		
Dematerialization, light materials	1.7		0.68		
Enabling design solutions	1.7		0.68		
Context well-being	1.5		0.53		
Sustainable materials libraries	1.7		0.67		

Appendix I

Synthesis of Expert Views (integrated in the *Conceptual Educational Framework*)

(Haemmerle, 2011)

Synthesis of Expert Views

Source: Linda Haemmerle, 2011

EFFECTIVE / HUMANWARE
SOCIAL CONTEXT