Waste Management Association of Australia - Energy from Waste Division

IEA Bioenergy Task 36: Topic 1

Extended Producer Responsibility and Product Stewardship Scheme Impacts on Municipal Solid Waste

Stage 1 Report: Discussion Paper on the Theoretical Concepts and Potential Surrounding Extended Producer Responsibility and Product Stewardship

Final Draft

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Table of Abbreviations

CCA	Copper Chromium Arsenate
C&D	Construction and Demolition
C&I	Commerical and Iindustrial
EfW	Energy from Waste
EPR	Extended Producer Responsibility
ESD	Ecologically Sustainable Development
HDPE	High Density Polyethylene
HNRV	Highest Net Resource Value
LCA	Life Cycle Analysis
MSW	Municipal Solid Waste
NPHRV	Net Present Highest Resource Value
OECD	Organisation for Economic Co-operation and Development
PR	Product Resonsibility
PS	Product Stewardship
PSP	Project Scoping Principles
PVC	Polyvinyl Chloride
SCM	Supply Chain Mapping
WMAA	Waste Management Association of Australia
VCO	Value Chain Optimisation

Glossary

C&D

Construction and Demolition (C&D) Waste – waste materials generated from construction and demolition activities both on a large scale (high rise) and small scale (residential housing). C&D along with C&I and MSW make up urban waste.

C&I

Commercial and Industrial (C&I) Waste – waste materials generated from fixed point sources related to manufacturing, wholesale, retail, professional services and administration sectors. C&I along with C&D and MSW make up urban waste.

Direct Recycling

To process a waste material into a resource for use in manufacturing a new product within the same supply chain (also know as closed loop recycling). For example recycling a PET plastic bottle into a new PET plastic bottle.

Disposal

The final placement or destruction of waste. Disposal can be achieved for example by use of “mass-dump” landfills and “mass-burn” incineration. Disposal is ideally a last resort for products and material unsuitable for reuse, direct recycling, indirect recycling or energy recovery.

Eco-services

Eco-system services refer to the range of services provided by the ecosystem (biosphere) including atmosphere and climate maintenance, water regulation and supply, biodiversity and genetic resources, soil formation and raw materials, in addition to food production.

EfW

Energy from Waste (EfW) is the recovery of the calorific value of a waste material through a range of technology processes such as combustion, anaerobic digestion, gasification and carbonisation. EfW seeks to maximise the recovered energy as the primary purpose of the operation as opposed to incineration which has the destruction of waste materials as the primary purpose.

Fully Mineralised Fraction

In this context “fully mineralised” refers to waste materials that have been processed through some form of alternative waste technology to the point where the waste no longer contains any active biodegradable materials and is fully inert.

Homogenisation

Here homogenisation refers to a group of technologies that act to process mixed urban waste streams into distinct "homogeneous" fractions, which are suitable for further processing and value adding. For example, processing mixed MSW to produce a "high-calorific" fraction comprising residual paper, cardboard, film plastic and wood.

Indirect Recycling

To process a waste material into a resource for use in manufacturing a new product into a different supply chain (also know as open loop recycling). For example, recycling a PET plastic bottle into a new "poly-fleece" jacket.

MSW

Municipal Solid Waste (MSW) – Waste materials that are primarily generated from the domestic sector and are collected in household garbage, recycling, garden organics and Council clean-up collections for bulky household waste such as appliances and furniture. MSW also includes other types of waste such as household hazardous waste and waste generated from local Council operations, for example waste from street sweeping, litter bins and parks. MSW along with C&I and C&D make up urban waste.

Urban Waste

Urban waste is a grouping term to refer to all waste generation within an urban context, as opposed to agriculture, mining or other primary resource activities. Urban waste materials are created both during pre-consumer activities as by-products from production, manufacturing and sometimes distribution, and during the post consumer phase, which includes fast moving consumer goods, end-of-life appliances and other unwanted materials discarded by the consumer or resident.

Recovery (or Resource Recovery)

Refers to the extraction of useful material or energy from urban waste using technologies (processes, practices and procedures) involving mechanical separation, biological treatment, thermal processing and combination systems. The resulting products can be grouped as reuse, direct recycling, indirect recycling and energy from waste.

Reuse

The reintroduction of a waste material or product into the economic stream without any chemical or physical change. An example is the empty glass soft drink bottle that is returned to the bottling company, sterilised, and refilled.

Waste Minimisation / Waste Avoidance

Interchangeable terms which refer to: (i) strict avoidance of waste, by avoiding use of the resource in the first place; and (ii) reduction of waste at the source – achieved by minimising the quantity or hazard of waste.

Executive Summary

The Energy from Waste (EfW) Division is a national division of the Waste Management Association of Australia and a member of Bioenergy Australia, the lead organisation for national participation in the International Energy Agency's (IEA) Bioenergy program. One component of this program is Task 36 - Energy Recovery from Municipal Solid Waste and the EfW Division is taking responsibility for delivering Topic 1 of Task 36: Product Stewardship / Producer Responsibility.

The purpose of this Topic is to provide a planning platform for resource recovery infrastructure requirements in general and energy recovery in particular. The central thesis of Topic 1 is that product design and infrastructure planning need to be integrated in order to achieve desired sustainability outcomes. This discussion paper represents the first deliverable in a three stage process. Its purpose is to review theoretical concepts surrounding Extended Producer Responsibility/ Product Stewardship and discuss the potential for product design to influence sustainable resource recovery outcomes.

The traditional approach to waste management has been firmly entrenched in a "take-make-waste" mentality relying on disposal in "mass-dump" landfill or "mass-burn" incineration to maintain a linear flow of resources throughout the economy.

The focus of waste management has changed from concerns regarding public health issues and managing impacts associated with disposal techniques. Now, using the "nature as model" approach, a new industry has emerged and is looking for opportunities to recover resources from materials that were previously wasted. The goal of the resource recovery industry is to establish a platform of cyclical material and energy flows from which sustainable outcomes can be delivered.

The current challenges for resource recovery include understanding the context of sustainability and the role of resource recovery in providing sustainability outcomes, especially with regard to resource productivity, the waste management hierarchy and waste avoidance/minimisation. Decision support tools are used to assist in meeting these challenges including: the Sustainability Guide for Energy from Waste Projects and Proposal, to identify when energy recovery is the preferred resource recovery outcome; assessment of net present highest resource value, to qualitatively differentiate between resource recovery options; and Life Cycle Assessment, which can be used to quantitatively assess resource recovery options for a given region or city.

However, despite increases in the amounts of materials recycled, composted and recovered for energy, overall waste generation has increased faster than population or economy growth rates and innovative solutions for resource recovery are still required. One approach involves an assessment of the impacts related to supply chain management in order to develop alternatives that reduce environmental impacts. Here supply chain is defined as the flow of physical resources from extraction through manufacturing, assembly service life and final disposal.

The value chain includes the physical supply chain and also the flow of information, ideas, decisions and finance that can add, retain or subtract value from a product or service, from its point of initiation to end-of-life management.

Mapping the value chain identifies the product designer as the key element in determining value balances of each stage during a product's life cycle (value added, retained or subtracted). As value here refers to a combination of environmental, techno-economic and socio-political values, the role of product design is of primary importance in determining the sustainability outcomes from the product. The recognition of this fact is part of the rationale behind Extended Producer Responsibility (EPR) and Product Stewardship (PS) principles.

Both EPR and PS focus responsibility on the original brand owner or manufacturer so that consideration is given to down stream impacts at the point of product design/initiation. For example materials selection, production process design and product packaging, distribution and marketing.

The implications for end-of-life management are influenced not only by designer decisions, but also by the availability of post consumer services and capabilities, demonstrating the need to integrate design intent with resource recovery. (However, it is recognised that the unavailability of these services is not an excuse for a producer to disregard their design responsibilities). If EPR / PS initiatives are to have a positive impact on sustainability outcomes, part of the equation must be sufficient post consumer services and capabilities to support producer original design intentions.

The post consumer services and capabilities required include a combination of collection, homogenisation and secondary processing to produce recovered resource inputs. These inputs fall into seven broad resource categories including dry recyclables, clean organics, dry high calorifics, mixed organics, metals and inert/fully mineralised materials. These may require some subsequent conversion prior to being sold into a market for reuse, direct recycling, indirect recycling or energy recovery.

The challenge that integration poses is how to establish the relationship between product designers and providers of post consumer resource recovery services. Changing market economics to better reflect the true costs of production and consumption (internalisation of externalities) will create a commercial imperative to link product design with infrastructure planning. Strategies to realise such a "perfect world" potential for EPR and PS schemes, with associated sustainable energy and material flows, can be developed by applying the principles of Value Chain Optimisation (VCO).

VCO refers to a design intent of maximising the value added to or retained with a product throughout all stages of the value chain. Such an approach integrates designers into dialogue regarding: highest resource value pathways to deliver sustainable energy and material flows; overcoming market failures; development and sharing of reverse distribution infrastructure; development of resource recovery processing technologies; and education of consumers. An example of the integration required is provided by "servicising", which concentrates on the service that a product delivers, with the producer retaining ownership of the actual product.

Here the designer must not only consider the product development, but also the required service system (including product maintenance, replacement, recycling, and/or disposal) for that product.

Value Chain Optimisation provides not only a model for engagement and integration between product designers and resource recovery service providers, but also a planning platform for resource recovery infrastructure and technology requirements in general, and energy recovery in particular.

The second stage of IEA Bioenergy Task 36 Topic 1: Product Stewardship / Producer Responsibility (led by the EfW Division of the Waste Management Association of Australia) will review actual experience and outcomes of Extended Producer Responsibility / Product Stewardship in order to identify the existing level of integration between design intent and resource recovery. A comparison will then be made between tangible results and the potential for integration of design and resource recovery infrastructure suggested through the application of VCO principles.

1. Background and Introduction

The Energy from Waste (EfW) Division, a national division of the Waste Management Association of Australia, is a member of Bioenergy Australia. Bioenergy Australia, in turn, is the lead organisation for national participation in the International Energy Agency's (IEA) Bioenergy program.

IEA Bioenergy provides opportunities for interested countries to work collaboratively on topics of mutual interest and importance, one of which is Task 36 - Energy Recovery from Municipal Solid Waste. As part of this task, the EfW Division is taking responsibility for delivering Topic 1: Product Stewardship / Producer Responsibility.

The purpose of Topic 1 is to provide a platform to plan for infrastructure requirements for resource recovery technologies in general, and energy recovery in particular. The central thesis of Topic 1 is that product design and infrastructure planning need to be integrated in order to achieve desired sustainability outcomes. In order to fully investigate this thesis, the Topic 1 Project will be undertaken in three stages:

Stage 1: review theoretical concepts surrounding Extended Producer Responsibility/ Product Stewardship and discuss the potential for product design to influence/deliver sustainable resource utilisation outcomes.

Stage 2: review actual experience and outcomes of Extended Producer Responsibility/ Product Stewardship schemes with case studies in order to identify the existing level of integration between design intent and resource recovery, and provide a comparison of tangible results against the potential for integration of design and resource recovery infrastructure outlined in Stage 1.

Stage 3: synthesise outcomes from earlier Stages 1 and 2 to scope the generic systems and infrastructure needs that should be available if energy recovery (embodied and inherent) from residual urban wastes is to be put on a sustainable footing.

This discussion paper represents the outcomes from Stage 1 of the process.

1.1 Introduction to Stage 1

The approach to urban waste management in developed countries has evolved over time. In the early days waste management relied on "mass-burn" incineration and "mass-dump" landfills. However increasing populations and economic growth placed pressure on landfill space. This in combination with heightened public awareness of environmental issues and growing demands for sustainability outcomes resulted in the metamorphosis of waste management into resource recovery.

However, despite changes in legislation, resource recovery practices and recovery rates across OECD countries, much work remains to be done in the integration of product design intent with resource recovery service delivery.

This report examines the trends evident in the transition from waste management to resource recovery and the current issues in resource recovery. Environmental impacts along the supply chain are assessed and the concept of value chain introduced to consider the role of the product designer in determining these impacts. This role is further highlighted in an examination of the purpose of Extended Producer Responsibility (EPR) and Product Stewardship schemes. This purpose sets up the challenge of integrating "design intent" with resource recovery service delivery. Finally Value Chain Optimisation is presented as an approach to realising a "perfect world" of sustainable resource use, with service based economies as a key feature.

1.2 Section outlines

The structure of this report is presented in Figure 1-1 below. Section 2 discusses the transformation of waste management to resource recovery, including the evolution of the waste management approach, trends in waste generation and the current drive for an integrated approach to sustainable resource recovery.

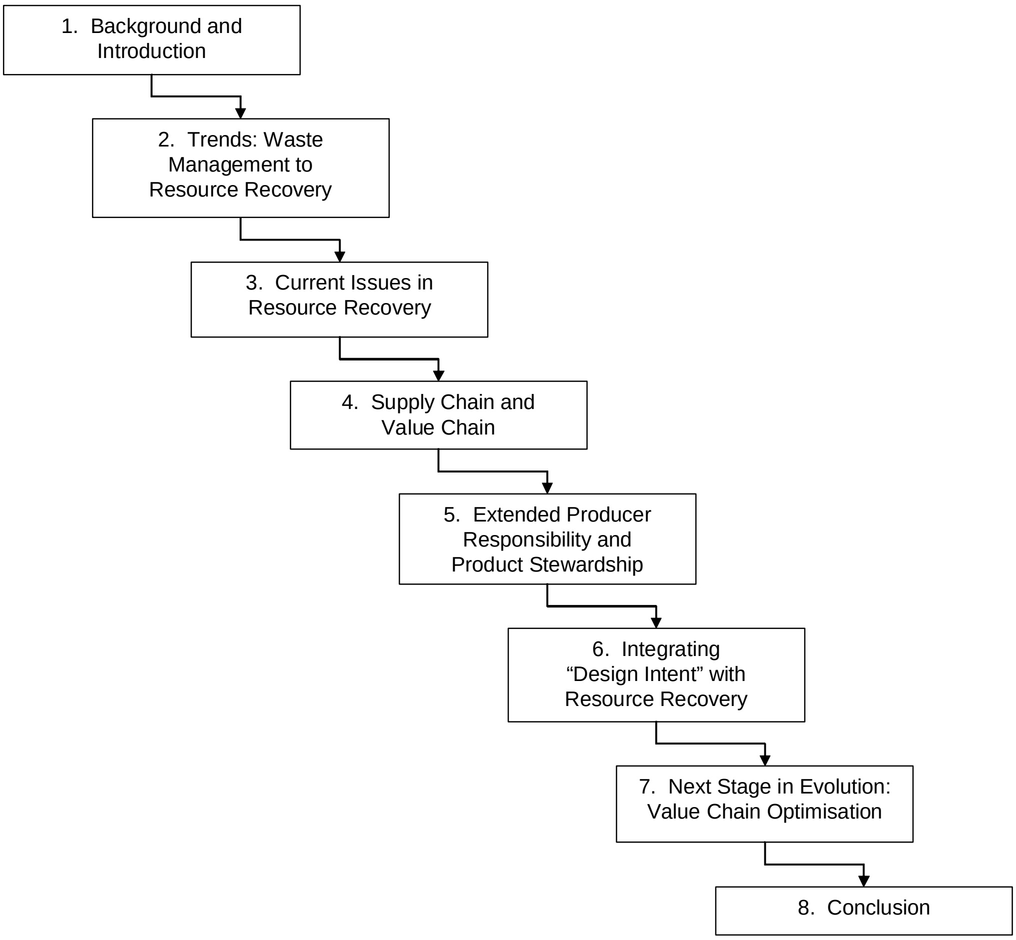


Figure 1-1 Structure of report

The drive toward sustainable resource recovery is examined more closely in Section 3, including the concepts of sustainability, waste minimisation and avoidance and resource recovery. Decision support tools are also presented, such as the Sustainability Guide for Energy from Waste Projects and Proposal, the concept of Net Present Highest Resource Value and Life Cycle Assessment (LCA).

What LCA clearly shows is that there are impacts throughout a products life cycle, also known as the supply chain. Section 4 presents elements within the supply chain and the importance of supply chain management in reducing environmental impact. The supply chain model is expanded to a “value chain” model that includes the flow of information, and especially highlights the impact of product design on resource recovery options.

Section 5 presents Extended Producer Responsibility (EPR) and Product Stewardship (PS) as approaches to assist in achieving desired sustainability outcomes for sustainable resource use, by linking upstream supply chain influence and down stream impacts with the importance of decisions made at the point of design or product initiation.

Section 6 further examines the importance of integrating design intent with resource recovery service provision, including required post consumer services and capabilities and issues in achieving a desired level of design intent integration.

In a perfect world the level of integration between product designer and resource recovery provider would be such that adding value all the way along the value chain was the universal priority. This focus on value chain optimisation is presented in Section 7. Finally the report concludes with a summary of key points in Section 8.

2. Trends: Waste Management to Resource Recovery

The traditional approach to urban waste management has been firmly entrenched in a “take-make-waste” mentality relying on disposal in “mass-dump” landfill or “mass-burn” incineration to maintain a linear flow of resources throughout the economy.

The focus of waste management has changed, however, from managing impacts associated with disposal techniques to finding opportunities to recover resources. Using the “nature as model” approach, the resource recovery industry seeks to establish a platform of cyclical material and energy flows, from which sustainable outcomes can be delivered. The evolution of this change in thinking and practice is discussed below.

2.1 Evolution of waste management approach

Urban waste management as an industry grew from concerns regarding public health issues with government authorities/councils being responsible for removing refuse from public spaces. The waste that was collected was either burnt (incinerated) or buried in landfill. Over time as landfills reached capacity and greater understanding of the pollution arising from mass-dump landfill and mass-burn incineration developed, governments and the general public reached a heightened level of concern, demanding a change in the approach to waste management. This changing approach is presented in Figure 2-1 below.

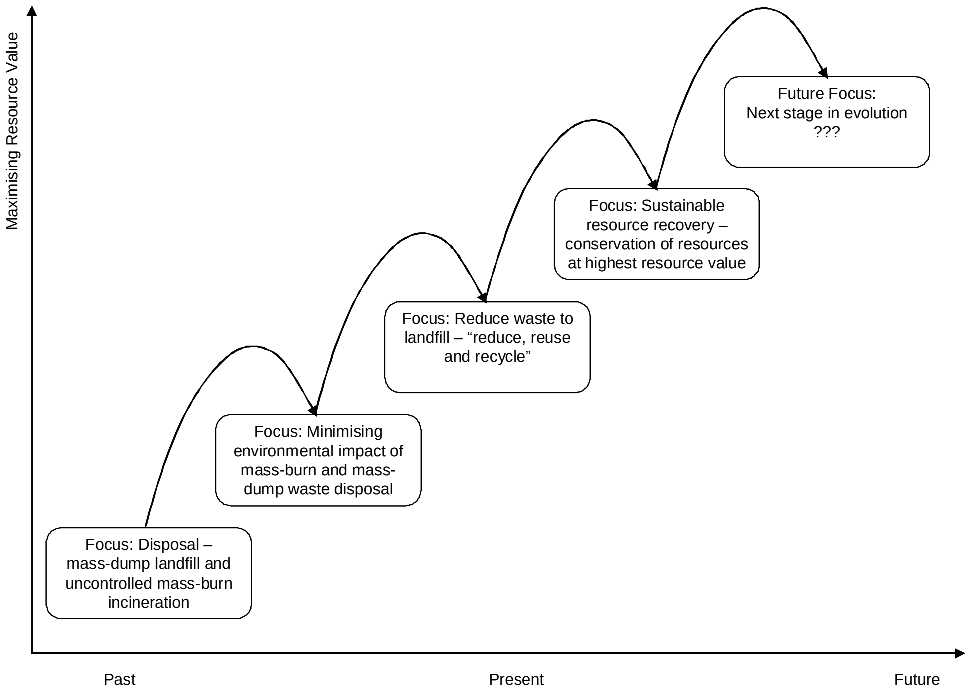


Figure 2-1 Changing approach to urban waste management

Initially the focus of waste management shifted to minimising environmental impacts of waste disposal, while ensuring landfill space was available and tipping fees low. This involved improving engineering aspects of waste disposal technologies. For example, controlling leachate and methane generation in mass-dump landfills and improving gas clean up technologies for mass-burn incineration.

With increasing pressure on landfill space associated with increased populations, urban encroachment and economic growth, the next shift in waste management involved decreasing the amount of waste to landfill. The popularised waste management hierarchy of "reduce, reuse and recycle" in its many variations was used as the public policy drive behind increased amounts of recycling, composting and energy from waste.[1] Figure 2-2 shows the impact of waste management hierarchy polices on the management of Municipal Solid Waste (MSW) in OECD[2] countries between 1995 and 2000.

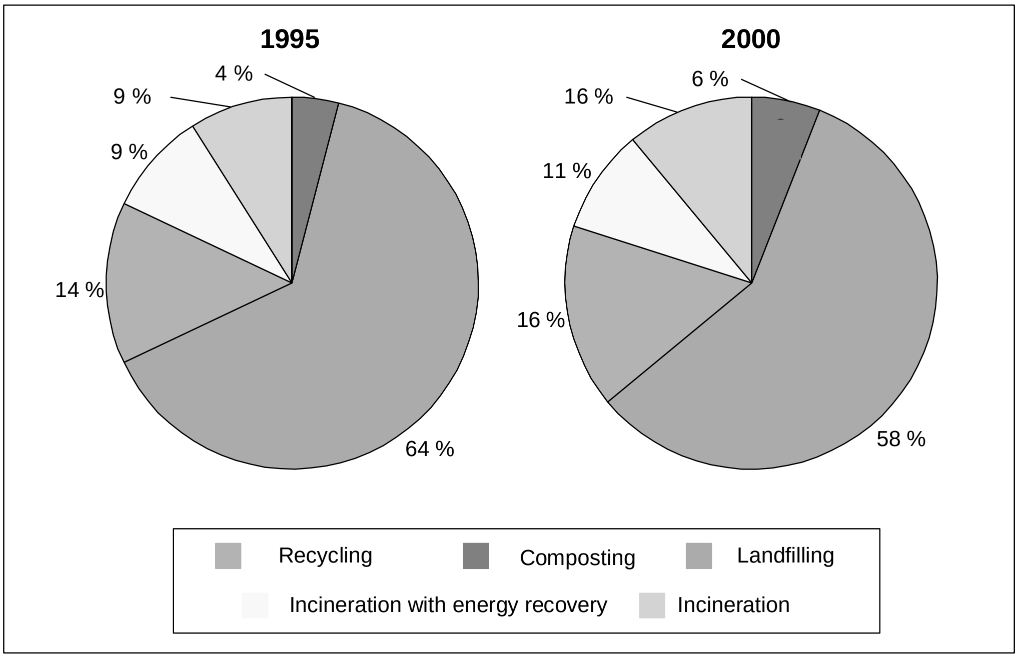


Figure 2-2 Municipal waste management in OECD member countries (adapted from de Tilly 2004)

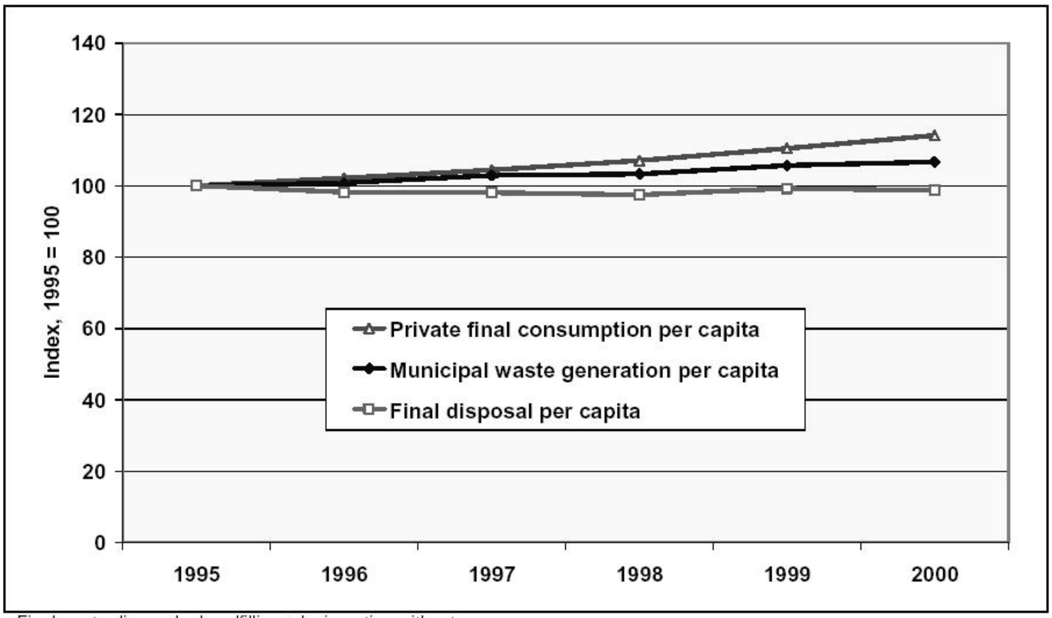
However, despite increases in the amounts of materials recycled, composted and recovered for energy, overall waste generation has increased, demonstrating a lack of waste avoidance. This trend is examined further in the following section.

[1] Note that here "energy from waste" refers to operations where the primary purpose of the facility is to optimise the recovery of the inherent energy content of waste materials. "Incineration" refers to operations where the primary purpose is to use combustion technologies to destroy waste materials.

[2] OECD – Organisation for Economic Co-operation and Development: comprises 30 member countries including Australia, Sweden, Canada, France and the United Kingdom.

2.2 Trends in waste generation

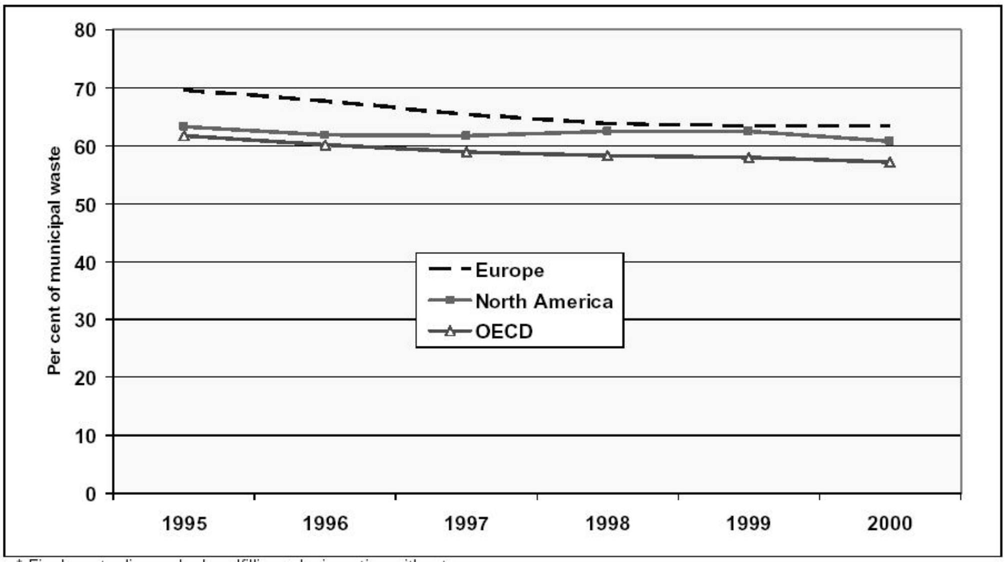
In the OECD, average quantities of MSW (measured as waste collected) are increasing as shown in Figure 2-3. Between 1990 and 2000, MSW generation increased by 14% from 530 to 605 million tonnes in OECD countries while the population of OECD countries increased by 8% over the same period (de Tilly 2004, p.23). This means that the amount of waste being generated increased on a per capita basis (by 6%), demonstrating that population growth is not the sole cause of increasing MSW generation (de Tilly 2004, p.23).



Final waste disposal = Landfilling + Incineration without energy recovery

Figure 2-3 Private final consumption, municipal waste generation and final waste disposal (de Tilly 2004)

Trends in the proportions of municipal waste going to landfill are generally decreasing (see Figure 2-4); out of European Union member countries, Ireland, Spain and UK seem to be the only exceptions. The percentage of materials recycled is also increasing in many countries, although slowly in some cases such as in the three countries mentioned above. In the United States and Australia, the same trend is also evident, with increasing amounts of urban waste generated, and decreasing proportions of waste sent to landfill, mainly due to increased recovery for recycling and composting.



* Final waste disposal = Landfilling + Incineration without energy recovery

Figure 2-4 Share of municipal waste destined for disposal in OECD regions

(Source: de Tilly 2004, p. 27)

However, an analysis based purely on percentages tells only part of the story. While overall waste management trends have been toward resource recovery measures, traditional methods of waste management (landfill and incineration) continue to be used for dealing with significant quantities of urban waste. This is largely due to their low cost and ready availability (IEA Bioenergy 2003). In general, increases in per capita volumes of MSW generated, in combination with increased populations, means that the absolute quantity of waste disposed of to landfill or incineration in OECD countries has increased.

There are exceptions to this trend on a country and material basis. For example Germany, and to a lesser extent Denmark and Sweden, have been able to narrow the gap between paper consumption and recycling to reduce absolute quantities going to landfill (EEA 2003). There has also been an overall reduction in the number of landfills, with fewer landfills of larger capacity and better engineering.

Notwithstanding these exceptions, the overall trend for OECD countries in the past decade has been increased amounts of waste disposed of through mass-dump landfill or mass-burn incineration.

2.3 Integrated approach to sustainable resource recovery

A few decades ago waste management was code for the transportation of waste to landfill or incinerator. The waste management industry is currently in the process of redefining itself within the context of sustainable resource recovery. This process of transformation involves changing the linear flow of virgin resources and energy sources with large quantities of residuals requiring disposal, depicted in Figure 2-5.

The current process of change is based on a “nature as model” approach where the focus is on cyclical “closed-loop” flows of energy and materials as shown in Figure 2-6. This approach attempts to minimise additional resource inputs into the system as well as minimising residuals with no further reuse/reprocessing value.

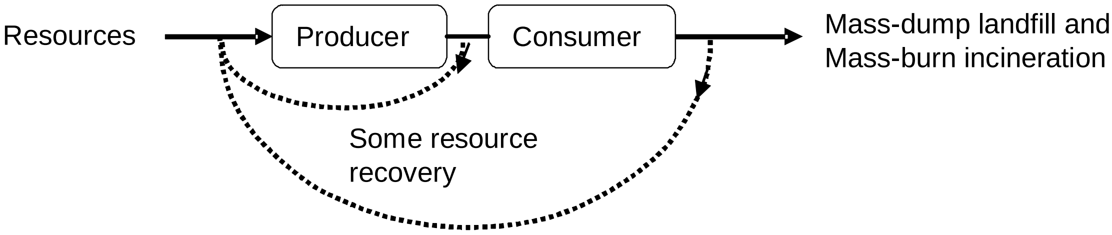


Figure 2-5 Previous approach to waste management

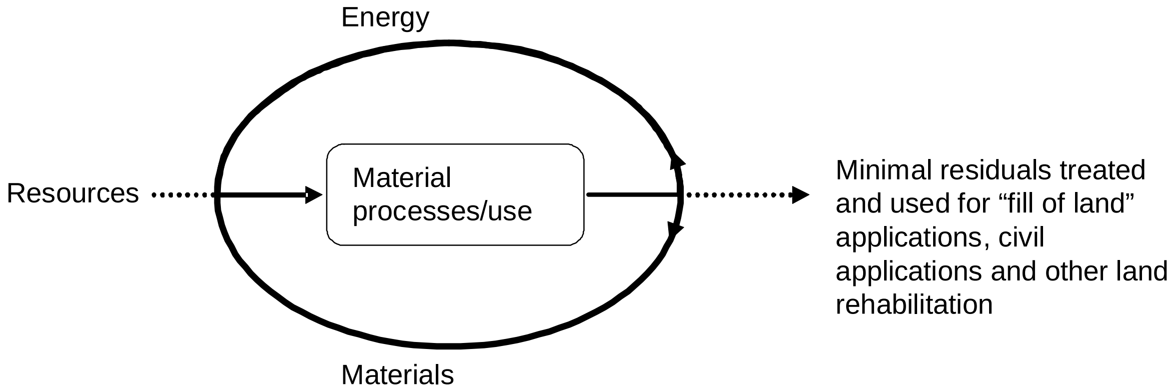


Figure 2-6 Current emphasis focusing on sustainable resource use

In order to achieve a ‘closed-loop’ approach, greater involvement from government, business and the community for product/material management is required. The focus must be shifted to the start of the life-cycle chain to also consider the requirements for post-consumer services.

The sustainable resource recovery industry must also address a wider and more sophisticated array of challenges and stakeholders than optimising “truck and dump” schedules. For instance, delivering at source waste reduction; collection, sorting, separation and marketing of recyclables and other materials; contamination prevention of input waste materials; disposal of residuals in an environmentally responsible manner; and ensuring financially viable operations.

Previous waste managers also have the opportunity to reinvent themselves as resource brokers. As a resource broker the job involves establishing systems of quality assurance and quality control so that secondary resources are made available to the market at pre-agreed specifications.

At the same time community awareness of environmental issues and environmental Non Governmental Organisation (NGO) activism has increased. While some level of the "Not-In-My-Back-Yard" (NIMBY) syndrome is unavoidable, there remains a genuine and widespread community acceptance of the need to prevent environmental pollution, reduce the depletion of natural resource and stop disruptions to natural ecosystems. This community acceptance is reflected by increased demands for government intervention. This and other prevailing issues for resource recovery are discussed further in the following section.

3. Current Issues in Resource Recovery

There are numerous issues of importance in sustainable resource recovery. Current predominant challenges are discussed briefly in this Section, including concepts of sustainability; resource productivity (including waste avoidance/minimisation and resource recovery); and decision support tools such as net present highest resource value, the Energy from Waste Sustainability Guide and Life Cycle Assessment.

3.1 Sustainability

3.1.1 Defining sustainability

The terms 'sustainability', 'sustainable development', 'ecologically sustainable development' (ESD), 'triple bottom line' (TBL) and 'corporate social responsibility' (CSR) are becoming catch phrases within industry, government and the popular press. Perhaps the most widely used related definition is that from Gro Harlem Brundtland who described sustainable development in the 1987 World Commission on Environment and Development (WCED 1987) publication, *Our Common Future* (also known as the Bruntland Report) as:

> *'Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.'*

However the connotation of sustainability has become much wider in its sphere of inclusion. As a result, a unified definition is difficult to find, with the associated interpretation of sustainability largely determined by the context. It is generally agreed that sustainability encompasses the three core areas of Environment, Society and Economics as is illustrated in Figure 3-1 below.

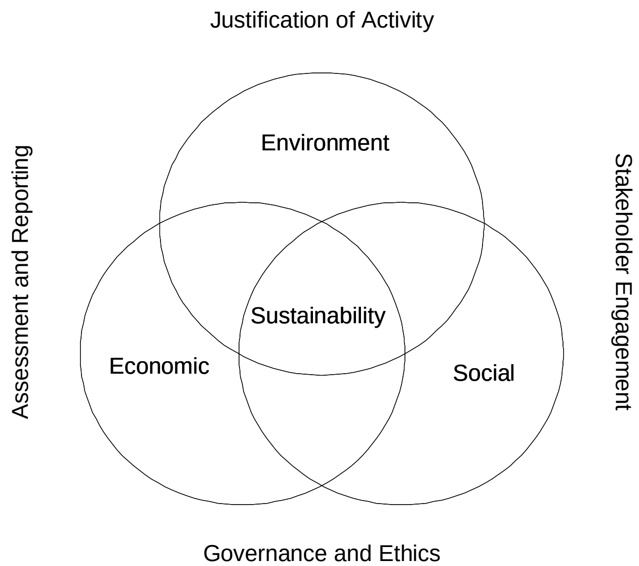


Figure 3-1 Common themes of sustainability

Peripheral elements of sustainability include justification of activity, which validates an organisation's fundamental purpose; stakeholder engagement, which ensures an inclusive approach to involving stakeholders in managing sustainability issues (as opposed to operating in isolation); governance and ethics, which provides internal leadership, assurance and accountability; and assessment and reporting, which provides external checks and balances in addition to measurement of progress, essential to a continuous improvement approach.

These components are also applied across different time scales, such as the present (inter-generational) and the future (intra-generational), and across different boundary levels, such as personal, organisational and local, regional, national and international.

The Bruntland Report also highlighted the different boundary levels and identified several social and ecological challenges that required action on a global level, for example the unsustainable pattern of industrial development:

> '*In general, industries and industrial operations should be encouraged that are more efficient in terms of resource use, that generate less pollution and waste, that are based on the use of renewable rather than non-renewable resources, an that minimise irreversible adverse impacts on human health and the environment'* (WCED 1987)

Despite the elapsed time and effort since the Bruntland Report, is clear that current rates of resource consumption and pollution remain unsustainable "because they exceed the rates at which resources can be regenerated and wastes assimilated by the Earth's natural systems" (Gertsakis & Lewis 2003).

The influence of sustainability thinking on the waste management industry is seen in the development of the waste management hierarchy, the transition into resource recovery and attempts to address resource efficiency or productivity.[3]

3.1.2 Sustainability through the waste management hierarchy

Many countries adopted the waste hierarchy as an attempt to integrate concepts of sustainability into public policy. The hierarchy (Figure 3-2) defines the preferred options for managing waste from its generation point through to final disposal. Rather than considering waste as a homogenous mass requiring burial or incineration, it was argued that waste comprises various materials that should be treated differently. That is, some should not be produced, some should be recycled or composted, some should be burnt and others should be buried (Schall 1992 in Gertsakis & Lewis 2003).

[3] Here resource efficiency and resource productivity are used interchangeably to refer to the notional measurement of materials and energy used to manufacture a given product. A product is said to be more resource efficient when less physical and energy resources are used in manufacturing and the same level of functionality is maintained. Resource efficiency of productivity is contrasted against labour productivity, which has been driving the focus of industrialised economic development, namely the increased production per unit of labour. Labour productivity is characterised by increases in resource and energy intensity.

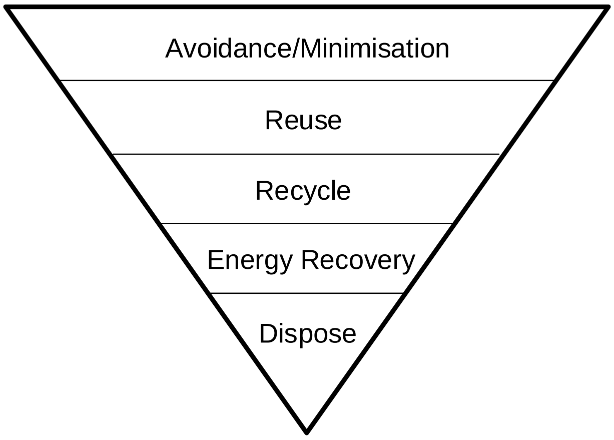


Figure 3-2 Waste management hierarchy

Figure 3-2 shows that in order to create more sustainable practices in waste management, emphasis must be placed on the avoidance or minimisation of waste in the first instance. Reuse, which is using materials or products in essentially the same form and function with a minimum of processing, is preferable to recycling. Recycling can be broken into two approaches, namely closed loop recycling (direct) and open loop recycling (indirect). Closed loop recycling is preferred in that the same material goes back for reprocessing and use in the same supply chain, for example the recycling of newspapers back into newsprint. Open loop recycling refers to a cascading effect where the material is used in a different, often lower value supply chain, for example newspaper recycled into kitty litter. In turn either form of recycling is preferred to energy recovery, which is itself ranked higher than disposal, the option of last resort.

Governments, industry, educators and environment groups have already used the waste hierarchy extensively as a guiding principle for waste policy and programs, although interpretations of the hierarchy can vary (Gertsakis & Lewis 2003).

However whether a strict approach using the hierarchy as an implementation regime produces sustainable outcomes has been questioned. For example, instances where waste avoidance is placed ahead of other environmental values such as energy conservation or air pollution prevention, and where “nature as model” does not “avoid” the generation of waste, but has systems that “digest” all outputs into resource inputs. Furthermore a strong application of waste avoidance on society at a meta-level has implications for “quality of life, innovation, personal individuality and choice”. Thus, in terms of driving sustainability outcomes, waste avoidance/minimisation should be considered as “one of many” tools to be applied, alongside reuse, recycling and energy recovery (Warnken and Stewart 2003).

3.1.3 Waste minimisation/avoidance

Waste avoidance is a tool to investigate opportunities to avoid waste and emissions at source. A starting point is questioning whether the waste should be generated in the first instance, which in turn leads to questioning whether the product should be made (justification of activity). If the waste or product is not made, then there is no waste to manage. Leaving aside this discussion and accepting waste generation and/or product manufacture as a given, there are many approaches to minimising waste.

Waste minimisation is a technique that is well established, and usually implemented within a process. As such it is closely aligned with the principles of Cleaner Production. Measures for waste minimisation in manufacturing and similar processes include:

» process modifications;

» feedstock purity improvements;

» housekeeping and management practice changes;

» increases in equipment efficiency;

» recycling within a process.

Sixteen principles for environmental management were developed by the International Chamber of Commerce to assist companies in achieving sustainable business practice. Principle eight states "Facilities and Operations: to develop, design and operate facilities and conduct activities taking into consideration the efficient use of energy and materials, the sustainable use of renewable resources, the minimisation of adverse environmental impact and waste generation, and the safe and responsible disposal of residual wastes" (Willums & Golüke 1992). Companies such as Aer Lingus, 3M, Henkel, Johnson and Johnson, and Syntex Corporation have subscribed to these principles.

Government can assist in establishing these principles as common business practice. For example, in Australia the advent of load-based licensing[4] rather than concentration based licensing has helped place the emphasis on actual waste generated, not simply concentrations of waste.

These tools and approaches to address waste minimisation and avoidance were developed as a front-of-pipe methods. Attempts to improve the sustainability of end-of-pipe solutions have concentrated on recovering resource value from materials that were previously wasted.

3.1.4 Resource recovery

Placing waste avoidance at the same level as resource recovery is a step that many countries have yet to make. However, there is growing recognition that the "most" sustainable option cannot be prescribed through the application of a hierarchy. For example, New South Wales, Australia's largest state, groups reuse, reprocessing, recycling and energy recovery on the same level as resource recovery in the Waste Avoidance and Resource Recovery Act 2001 as shown in Figure 3-3 overleaf. The preferred option needs to be determined on a case by case basis with consideration given to the efficient use of resources, reduction of environmental pollution and application of sustainability principles (ecologically sustainable development).

[4] load-based licensing – sets limits to pollutant loads emitted by holders of Environment Protection Licences and links licence fees to pollutant emissions based on total pollutant loads, rather than pollutant concentrations emitted. The fees vary according to the nature of the pollutant and impact risk.

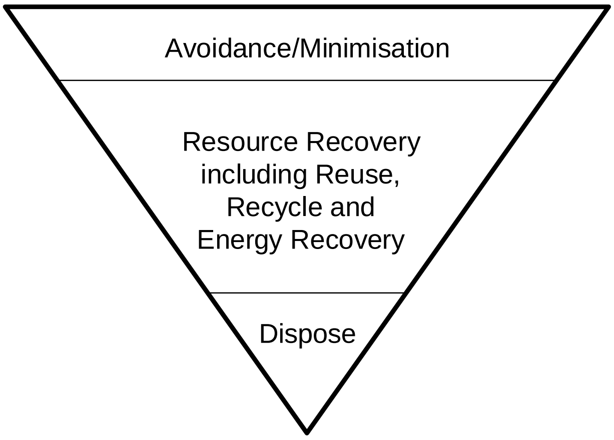


Figure 3-3 Resource recovery as a range of options

In many cases it is the lack of resource recovery technologies and associated infrastructure that presents as a serious barrier to resource recovery. Another is the availability of markets for resource recovery products. For the most part there is a supply push of waste materials requiring processing and little market pull. One of the contributors to this problem is that of externalised costs.

Alternatives to products from resource recovery operations do not internalise all costs, giving the "virgin" products a competitive advantage. Additionally the eco-service benefits of resource recovery are recognised, for example the conservation of resources, reduction of energy use and prevention of pollution. The need to address this market failure is driving many countries down the path of introducing market based instruments to drive resource recovery and avoid the use of landfill. One example is the Landfill Allowance Trading Scheme in the United Kingdom; another is the high levels of landfill tax in European Union member countries.

Additional challenges to overcome are linked to financial viability, and are influenced by the availability and reliability of incoming wastes. Since the resource recovery approach considers waste to be a process input, just like any other manufacturing/process plant, it is important that the inputs are of sufficient quality and quantity to maintain the effectiveness and efficiency of the process. At the same time arrangements that place companies or municipalities in the position of needing to make more waste to service the conditions of their contract are undesirable.

The use of resource recovery technologies is also linked strongly to public perception, an important link in the challenge of gaining community acceptance for new or emerging alternative resource recovery technologies. This is particularly true for energy recovery from MSW as public perception and hostility have been identified as "critical barriers hindering the deployment of energy recovery systems for MSW in several countries" (IEA Bioenergy 2003, p.7).

Traditional technologies that are economically proven are more likely to be adopted by waste management decision makers in government due to a perceived lower risk and less opposition from concerned communities. Therefore, a key issue in resource recovery is to prove that alternative waste technologies work and are financially viable, while at the same time educating communities about the sustainable outcomes delivered.

Sometimes there are also missing resource recovery ‘chain’ elements such as supporting infrastructure. Transportation infrastructure such as rail, roads or ports must be in place so that feedstock can be delivered and products from resource recovery technologies can be delivered to markets.

Additionally, while support for the concept of resource recovery as a mechanism to deliver sustainability outcomes has gathered widespread support, the question of which recovery technology to apply still remains. This issue of decision making is discussed in the following section.

3.2 Decision Support Tools

Decision support tools are used to provide a formalised process for determining between options on the basis of multiple and often conflicting criteria. Without diverging into the well developed body of knowledge that is decision analysis and behavioural theory, an overview of three decision support tools are presented here with resource recovery applicability (further detail is presented in Appendix A).

3.2.1 Sustainability Guide for Energy from Waste Projects and Proposals

The question of deciding when energy recovery presents as the most sustainable resource recovery option is both polarising and problematic. In order to address issues preventing EfW projects from making a bona-fide contribution to sustainable resource recovery, the Energy from Waste Division of the Waste Management Association of Australia produced a “Sustainability Guide for Energy from Waste Proposals and Projects” with funding from the Australian Greenhouse Office and other industry and government sponsors.

The main outcome of the Sustainability Guide was an assessment roadmap of six project scoping principles (PSPs) that are used as a tool to decide when the use of EfW is appropriate, based on profiling and assessing the sustainability of a proposal or project.

PSP1 is an assessment to “demonstrate that the application of urban wastes being considered for conversion for their calorific value represents the most sustainable application of the resources”. This is followed by an analysis to determine if the selected process and pathway are optimum for the available materials (PSP2). The measures to manage the environmental, social and economic impacts of the project are then assessed in PSP3 and 4.

The aim of PSP5 is “to demonstrate that the environmental, social and economic commitments defined at the initiation of the project are understood and delivered over the life of the project”. The procedure is completed with PSP6 to assess if the project structure for achieving commercial viability does not compromise the inherent sustainability achieved by observance of the other PSPs (EfW Division WMAA 2005).

The main point of the Sustainability Guide is the importance of quality assurance and control to energy recovery. It is a process geared toward product manufacture and not waste management. s such the quality assurance and quality control (QA/QC) stages become integral to differentiating between bona fide energy recovery and incineration.

While the Sustainability Guide is specifically designed with decisions regarding energy from waste in mind, the structure of the decision-making process can be used to assess alternative resource recovery technologies that seek to recover the highest resource value of a material within the context of sustainability. A similar less formalised approach with this wider applicability is the concept of Net Present Highest Resource Value assessment.

3.2.2 Net Present Highest Resource Value

There are usually a number of recovery options for a given material. Therefore, it is important that the best option is selected to maximise the highest resource value of that material. Sometimes, the solution is intuitively clear. Warnken (2004) gives the example of recycled solid hardwood floor boards: it is clear from this analysis that it is better to turn the floorboards into a dining room table than to chip up the timber for fuel or landscape mulch. However, it is not as clear as to how to balance the issues with regard to composting and energy recovery for woody waste materials.

Ideally highest resource value would be used to determine between resource recovery options of reuse, direct recycling, indirect recycling and energy recovery. The main difficulty is distinguishing which option is best when they each have advantages and disadvantages with regard to economic, environmental and social impacts.

Net present highest resource value (NPHRV) is used to qualitatively assess the range of resource recovery options available to any given material stream by asking:

» What are the recovery options for the material in question?

» How many of these are commercial at the present time?

» What kind of recovery opportunity is it?

» What is the planned and accessible end-of-life use for the recovered material?

» What is the economic case for the commercial recovery options?

» What is the environmental case for the commercial recovery options?

» What is the social case for the commercial recovery options?

» What are the prevailing local conditions?

NPHRV is a new concept for assessing resource recovery options and some considerations need addressing further in order for NPHRV to be proved a successful decision support tool for sustainable resource recovery. One limitation is in its qualitative approach, which leaves the process of evaluation open to interpretation and ambiguity, in addition to the issue of indicator selection and measurement. One decision support tool developed explicitly to overcome these types of limitations and provide quantitative environmental comparisons between options is Life Cycle Assessment (LCA).

3.2.3 Life-cycle based analysis

Life Cycle Assessment (LCA) can be defined as:

> '*a systematic inventory and comprehensive assessment of the environmental effects of two or more alternative activities involving a defined product in a defined space and time including all steps and co-products in its life cycle'* (Pederson 1993, cited in Kiely 1998)

LCA is an environmental decision support tool increasingly used to understand and compare how products or services are provided 'from cradle to grave'. The phases within LCA include (McDougall et al 2001):

1. Goal definition - options to be compared, intended use of results, the functional unit[5] and system boundaries
2. Life cycle inventory analysis - account for all materials and energy, both inputs and outputs across the whole life cycle
3. Life cycle assessment - organises or classifies the life cycle inventory inputs and outputs into specific issues or categories and models the inputs and outputs for each category into an aggregate indicator
4. Life cycle interpretation - the process of balancing the importance of different effects. Here there is no agreed scientific method and more public debate is required.

LCA is used in waste management and resource recovery applications, with considerable international effort being put into providing access to life cycle inventory data as well as effective tools for performing LCAs.

The main benefit of the life cycle approach is that it is an inclusive tool. Provided that an appropriate system boundary is chosen for the investigation, the inventory phase looks at all necessary inputs and outputs (such as emissions) in the various stages and operations of a waste management system/technology. It also includes indirect inputs and outputs and the analysis aggregates over time.

Unfortunately LCA is not able to assess the environmental effects of a resource recovery system or technology. That is, LCA does not predict actual impacts or assess safety, risks, or whether thresholds are exceeded (McDougall et al 2001). The actual environmental effects of the system or technology will depend on when, where and how the various outputs are released to the environment. Other assessment tools (such as risk assessment) and information is required to perform this function.

What LCA clearly shows is that there are impacts throughout a products life cycle, also known as the supply chain. However, one limitation is that the choice of system boundary can often exclude some of the fundamental elements that make an impact. The following section explores an "unrestricted" system boundary in examining the role of supply chain in determining sustainable outcomes.

[5] Functional unit – a measure of the performance of the functional outputs of the product system/service/technology. The functional unit is the basis on which the product/services/technologies will be compared in an LCA.

4. Supply Chain and Value Chain

"*Increasingly supply chain pressure is being exerted by business through contract specifications and procurement policies reflecting the need to reduce waste and cut costs, for example by minimising the handling of packaging waste. Equally in trying to meet other targets, producers are stimulating new techniques which use less material - and hence give rise to less waste. For example, to achieve higher fuel efficiencies in their vehicles, motor manufacturers are specifying lighter body parts and engines using less, thinner gauged or lighter metal, and alloys that can be recycled at the end of a vehicle's life*." (UK DETR, 2000)

The importance of supply chain issues rose to prominence alongside the "just-in-time" approach to manufacturing, where the coordination of suppliers from a logistics and quality perspective, was vital to final product manufacture and assembly. Today the importance of the supply chain and its potential to benefit or harm the environment is of equal concern.

Here supply chain is defined as the flow of physical resources from extraction through manufacturing, assembly service life and final disposal. Value chain is preferred as a term that describes not only the supply chain, but also the flow of information, ideas, decisions and finance that can add, retain or subtract value from a product or service, from its point of initiation to end-of-life management.

4.1 Supply chain impacts

A simplified supply chain map is presented in Figure 4-1 overleaf. The scope of supply chain issues may follow on from a general environmental review of the product design process itself, which may include life cycle assessment (LCA), or from more detailed reviews of suppliers. In general, the supply chain elements and their impacts on sustainability outcomes include:

» raw material and energy resources: the initial extraction of resources (renewable, depletable and non-depletable) for material inputs and energy, for example, mining and minerals processing, forestry harvesting and sawmilling, and livestock growing and slaughtering. Impacts at this stage can be point-source from the operation of coal fired power stations, or diffuse, such as wheat growing and harvesting

» manufacturing: the technologies and processes used to convert raw material inputs and energy into saleable products

» packaging: material selection and use for protective product packaging. It is noted that products are divided into two general classes: non-durables, for example, food and disposable items; and durables, for example electronic equipment and household furnishings. With non-durables packaging materials have a similar life expectancy to the product, while with durables packaging the product service life is far longer than that of packaging

- warehousing and distribution/retail: logistics involved in delivering products from the manufacturer to the consumer via a retail outlet
- pre-consumer collection: residues generated as part of manufacturing, packaging and warehousing/distribution elements of the supply chain are removed through Commercial and Industrial (C&I) waste collection. The focus is on the efficient removal of unwanted materials so that companies can concentrate on their core business

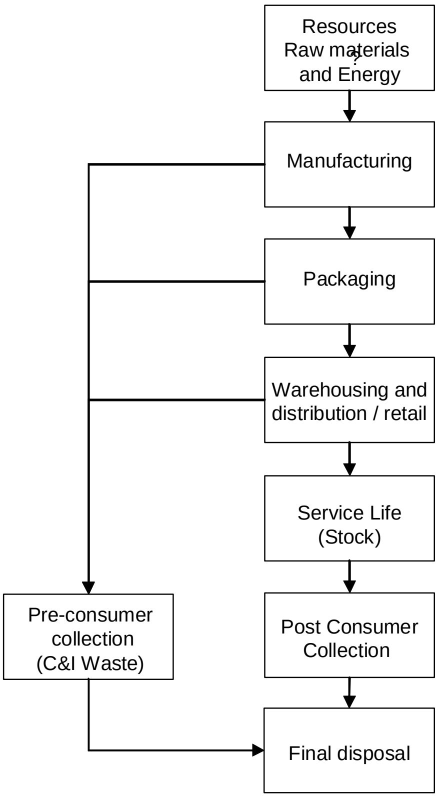


Figure 4-1 Simplified supply chain map

- service life: the length of time that a product delivers its intended service. Service life may come to an end because product has worn out, is damaged or is unwanted because of replacement. In the case of durables it is likely to be the use of the product that has the greatest impact, for example, constantly overfilling an electric water kettle results in increased water wastage and energy use. With non-durables the greatest impact is likely to result from the end-of-life management decision, for example the decision to litter a glass bottle or return for recycling. Service life also determines the "stock" of materials in the economy at any one time
- post consumer collection: at the end of a product's service life the consumer relies on the provision of collection services to remove unwanted products. Historically this has been on an "out of sight out of mind" basis
- disposal: a traditional supply chain mentality is linear in nature. Thus the only concern is for additional "consumer space" to be created through the efficient "destruction" of unwanted products either through mass-dump landfill or mass-burn incineration.

At present there is a high level of sophistication in the supply chain prior to consumer use. The process of manufacture, packaging, marketing and distribution are well coordinated with an emphasis on cost minimisation and efficiency. The systems in this part of the supply chain are also highly evolved, for example GPS tracking and online inventory databases. Unfortunately this degree of sophistication, efficiency and coordination has yet to be extended to managing supply chain environmental impacts.

4.2 Importance of supply chain management to reducing environmental impact

In order for organisations to manage environmental impacts in the face of increasing legislative and market pressure, they must not only improve the environmental performance of their own operations, but also work with companies within their supply network to improve the environmental performance of the entire network. This requires effective supply chain management (SCM), which in the environmental context includes the "*incorporation of environmental considerations into purchasing decisions and supplier management practices*" (Charter and Clark undated).

SCM is particularly important in light of increasing globalisation that has resulted in expanded global sourcing of product components and/or packaging in some major manufacturing sectors, as well as international manufacturing and distribution of products. The electronics sector, for example, is coming under increasing legislative pressure to reduce the environmental impacts of electronics products throughout their life cycle; legislative instruments aimed at reducing energy consumption, such as mandatory labelling schemes, already exist in many countries[6] (Centre for Design 2001). With increased specialisation and global outsourcing this means there will be increasing requirements for suppliers to become aware of environmental issues, especially product related impacts (Charter et al, 2003).

The scope of SCM will especially depend on a company's supply chain impacts, their significance and improvement objectives, in addition to the degree to which a company can exert influence (Charter and Clark undated). Some current examples of supply chain management in reducing the environmental impact of products are presented in the following section.

[6] Legislative drivers include the European directives for the Restriction of Certain Hazardous Substances, Waste Electrical and Electronic Equipment, and Energy-Using Products. In Japan there has been the implementation of the Home Appliances Recycling Law, the Law for the Promotion of the Effective Utilisation of Resources, and the Green Purchasing Law.

4.3 Examples of supply chain management

An organisations size, and its position within the supply chain affect the level of influence it can exert to reducing the environmental impacts of product design and manufacture. An organisation sitting in the middle of a supply chain may be able to influence "eco-thinking" in the upstream of the supply chain (materials suppliers), as well as the downstream supply chain (customers). For example:

- Nokia is currently working in close cooperation with their supplier for analog components used in hand-held wireless devices and network equipment (National Semiconductor) to develop and introduce suitable lead-free versions of its products. National Semiconductor in turn is also working with its suppliers to obtain and maintain an updated list of the material content of all products, and to phase out the use of products containing various substances such as halogenated flame retardants (Nokia, 2004). Nokia also influences downstream impacts by offering a take-back service of its mobile phones and accessories, and forwarding these items on to approved recyclers.
- Sony established the Green Partner Standards in July 2001 with the aim of encouraging suppliers to introduce Green Partner Environmental Management Systems. As Green Partners, suppliers are required to reduce or eliminate environment-related substances prescribed in Sony's management regulations. From April 2003 onwards Sony only procures parts and materials from its products from suppliers that are Green Partners. Sony has also invested significant time and money in developing recycling programs for its products in various countries (Sony undated).
- Major retailers may exert pressure on brand owners to package multi-pack products (such as 6-packs of cans or bottles) in clear shrink-wrap as opposed to other more readily recyclable packaging due to improved product appearance on shelves (marketing), and ease of opening products.[7] This is arguably an example of supply chain mismanagement where larger members of the supply chain exert pressure on the supply chain to increase environmental impacts.

In general it is those organisations that control large flows of money that have the greatest potential to influence the supply chain. Information flows are also important and have the ability to influence decision makers and the uptake of new technology. In particular the flow of information to designers at the stage of product initiation. These factors are often left out of a supply chain mapping exercise as they do not involve the flow of physical resources, yet greatly impact the flux of value along the supply chain. Here the inclusion of these intangible elements is referred to as the value chain and it is elements within the value chain that can have an even greater impact on sustainability outcomes than supply chain management.

[7] Comment provided by representative from The Coca-Cola Company, Australia, 07/06/2005. Note, shrink-wrap is not readily recyclable in Australia given current waste infrastructure.

4.4 Value chain

The importance of a value chain assessment of product delivery to the consumer is the inclusion of chain elements that are not strictly related to material flows, yet have a major influence on total value added, retained or subtracted and on the overall sustainability impacts related to product life cycle. These additional elements are shown overleaf in Figure 4-2 and include:

» justification of activity: within the context of sustainability there must be a rationale for the manufacture and distribution of products that is more evolved than a simple “we have a market” approach. While any formalised scoring system is problematic, the desired trend is for products that make positive contributions to the economy, society and environment

» product design / product initiation: arguably this point in the supply chain has the greatest impact as here decisions regarding material selection and usage, stock life, external energy sources, planned recovery, target market and pricing are made. This highlights the powerful space that producers occupy in creating and destroying “eco-value”

» advertising: this raises the age old question of whether companies act to meet market demand or whether they manipulate consumers to purchase products through advertising on the basis on status acquisition (as opposed to product benefit and features). This also raises the issue of over-consumption, which while being beyond the scope of this report, poses the challenge of who should take responsibility for increased levels of consumption and resource use

» service life - institutional and individual consumers: there are two types of consumers, individuals that have little ability to influence the delivery and form of products, in and of themselves, and bulk consumers of durable and non-durable products, such as insurance companies, government and other corporations. These institutional consumers have a great ability to influence markets and shape the delivery and form of products

» end-of-life management: the focus is on selecting end-of-life management options that create cyclical flows of materials and energy. Consumers have little choice in “doing the right thing” if materials are not recyclable, or collection infrastructure is not accessible and processing technologies are inadequate. It is also at this point where the flow of materials to landfill or incineration demonstrates a lack of attention to resource recovery issues during product design and product initiation. Specialist service providers are required to plan for the provision of resource recovery options

» resource recovery: the provision of collection infrastructure and processing technologies to convert wasted materials into resources that are suitable for assimilation back into the economy via re-use, direct recycle, indirect recycle or energy recovery pathways.

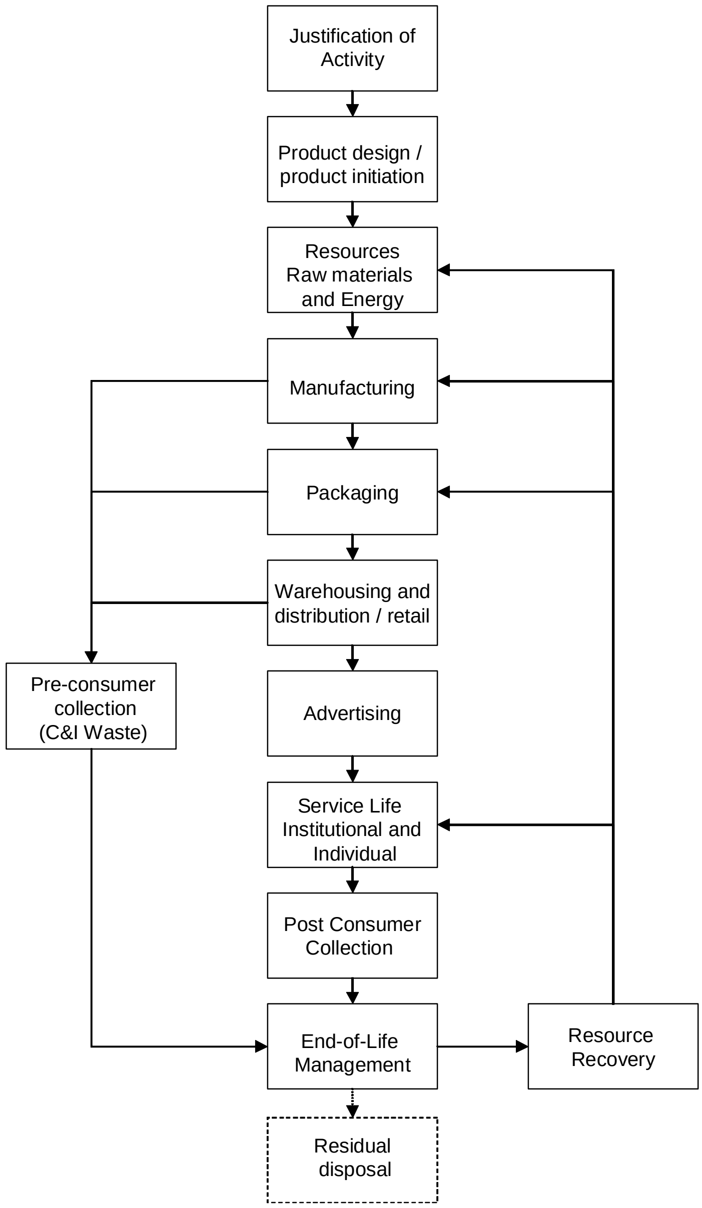


Figure 4-2 Generic supply chain map showing recycling, resource recovery and recirculation of materials and resources

An assessment of the elements within the value chain concepts demonstrates the pivotal role of product design in determining value balances (value added, retained or subtracted) of each stage of a product's life cycle. As value here refers to a combination of environmental, techno-economic and socio-political values, the role of product design is of primary importance in determining the sustainability outcomes from the product. Product design also starts to set the planning parameters for the provision of resource recovery infrastructure, and in particular, requirements for energy recovery services. The recognition of the pivotal role played by the product designer is part of the rationale behind Extended Producer Responsibility (EPR) and Product Stewardship (PS) principles, presented in the following section.

5. Extended Producer Responsibility and Product Stewardship

Extended Producer Responsibility (EPR) and Product Stewardship (PS) are approaches to assist in achieving desired sustainability outcomes for sustainable resource use. EPR and PS link upstream supply chain influence and down stream impacts with the importance of decisions made at the point of design or product initiation.

5.1 Overview of Extended Producer Responsibility and Product Stewardship

EPR is a policy approach in which a producer or manufacturer takes responsibility for the environmental impacts of their products throughout the entire product life cycle. Traditionally, the environmental responsibility of producers focused on managing the environmental impacts of the production process. EPR extends beyond this to also include any impacts of the product in its use and ultimately its end-of-life management, for example take-back, recycling, and disposal.

The term “extended producer responsibility” was introduced by Swedish academic Thomas Lindhqvist in the early 1990s. Lindhqvist identified five basic types of producer responsibility, as listed in Table 5-1. Integration between these types of producer responsibilities is shown in Figure 5-1.

Table 5-1 Types of producer responsibility (Lindhqvist 1998 in Tojo 2000)

Type	Description
Liability	Producer is responsible for proven environmental damages caused by the product in question. The extent of the liability is determined by legislation and may embrace different parts of the life-cycle of the product, including usage and final disposal
Economic responsibility	The producer will cover all or part of the costs for example the collection, recycling or final disposal of the products it is manufacturing. These costs could be paid for directly by the producer or by a special fee.
Physical responsibility	Manufacturer is involved in the actual physical management of the products or of the effects of the products. For example, this can range from developing a technology, and/or managing the total “take-back” system for collecting or disposing of products it has manufactured, for which the manufacturer may charge a fee.
Ownership	The manufacturer may retain the ownership of his products throughout their life cycle, and consequently may be linked to the environmental problems of the product. The producer would assume both physical and economic responsibility.
Informative responsibility	The producer is required to supply information on the environmental properties of the products he is manufacturing, and on its effect at various stages of its lifecycle.

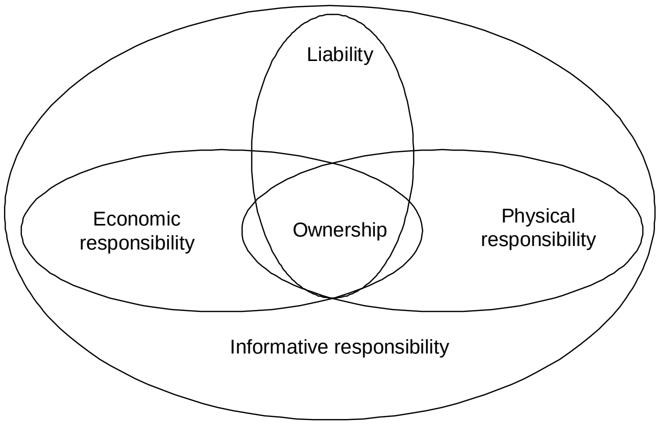


Figure 5-1 Model for extended producer responsibility (Lindhqvist 1998 in Tojo 2000)

The most widely accepted definition of EPR used presently is that outlined by the Organisation for Economic Cooperation and Development (OECD). Product Stewardship (PS) or Shared Responsibility is commonly viewed as a variant of EPR and is mainly associated with voluntary programs. There are a number of differences between the two concepts, as is shown in the contrasting definitions below.

Definitions

Extended Producer Responsibility (EPR): Transferring the cost of the environmentally significant post-consumer characteristics of products, such as waste volume, toxicity and recyclability, from local authorities to the producers. This transfer of costs is designed to provide economic incentives for producers to prevent/reduce the amount of waste generated, reduce the usage of toxic materials, increase recycling and enhance markets for secondary materials. (OECD 1996)

Product Stewardship (PS): All participants (such as designers, suppliers, manufacturers, distributors, retailer, consumers, recycler and disposers) that are involved in the product supply chain take responsibility for the full environmental and economic impacts of that product. (ILSR 2000)

The four principal goals of EPR, according to the OECD (1996), are:

» source reduction (natural resource conservation and materials conservation)

» waste prevention

» design of more environmentally compatible products

» closure of material loops to promote sustainable development.

Product Stewardship also aims to encourage manufacturers to ensure that their products have minimal environmental impacts throughout their life cycle. Both these concepts focus responsibility on the original brand owner or manufacturer so that, at the point of design/initiation, consideration is given to:

» how the enterprise is resourced

» how the product is produced

» how the product will be packaged, distributed and marketed

» how the consumer will use the product; and most important of all in this context

» the planned and anticipated post consumer fate of the product or service (including packaging and so forth).

5.2 Importance of decisions made at the point of design/initiation

One goal of EPR or PS schemes is to encourage producers to design or re-design products that will lead to reduced or less polluting waste streams. This is important as the majority of planning takes place during the product design and initiation stage. There are therefore many opportunities to fully integrate environmental consideration into the design process through adoption of "eco-design" principles.

There are many approaches to "eco-design" principles that incorporate elements including design to minimise waste, reduce emissions and energy consumption during the product use phase; and design for upgrading, repair, disassembly, reuse, and for optimal life cycle duration. For example, the manual "Ecodesign: a promising approach to sustainable consumption and production" (jointly written by the UNEP, Rathenau Institute and Delft University of Technology), the Smart ecoDesign, Eco-Design Checklist for Electronic Manufacturers, Systems Integrators, and Suppliers of Components and Sub-assemblies (The Centre for Sustainable Design), and the manual for small to medium enterprises on "Design for Environment" prepared by the National Research Council of Canada.

Such product design or re-design may be part of an overall more holistic approach to manufacturing – one that uses "*techniques and strategies which aim to increase a product's recycled content, eliminate problematic ingredients, or create a system to take-back a product or packaging for reuse, refurbishing or recycling at the end of its useful life. This includes designing products in their entirety that can be easily upgraded, rather than replaced when they become outmoded, or that can be easily dissembled for reuse or recycling*" (Stevens 2004).

5.2.1 Product and material design

Material design for sustainability can affect resource recovery options further down the product life cycle. A designer can focus on developing material substitutes for non-renewable natural resources, in addition to investigating the effect of recycling on material properties and the suitability of recyclate/virgin mixtures for high-grade applications.

A designer can also implement standardised marking of materials to facilitate resource recovery. This is used for common plastics and would be useful for products containing toxic elements so that recoverable materials can be easily identified and toxic materials safely separated for treatment. Products containing several different types of recoverable materials could also be identified so that the different material types can be separated and processed more easily.

Product design in terms of upgrade and disassembly also influences the sustainability of resource recovery options. Disassembly potential is influenced both physically in terms of the processes and labour required and financially in terms of the recoverable value from the product (Goggin & Brown 1998). Design for disassembly guidelines include the following recommendations:

» product simplification

» modular design, so as to facilitate both product upgrade and disassembly

» minimise the number of pieces requiring dismantling

» easily detachable parts, for example, the use of clips rather than adhesives for joining parts together

» designing/modifying components for reuse

» standardisation of components.

Xerox product development practices are a good example of how companies can employ design standards to minimise life cycle impacts and maximise the end-of-life potential of products and components. Xerox incorporates reuse considerations into the design process and machines are designed for easy disassembly with fewer parts. Parts are designed for durability over multiple product life cycles and are coded to simplify reuse or recycle opportunities. As a result, equipment returned to Xerox at end-of-life can be remanufactured and rebuilt to as-new performance specifications, reusing 70 to 90 percent by weight of machine components (Xerox 2004).

5.2.2 Material selection

Functionality, economics and aesthetics are the current primary determinants affecting material selection (Goggin & Browne 1998). A manufacturer/designer can assist recycling and resource recovery through a number of means. Some examples include:

» selection of raw materials that are less toxic/environmentally harmful than other viable alternatives. This helps reduce problems associated with handling of toxic materials in resource recovery operations and improves the viability of post-consumer options

» reduction in material content. by reducing the amount of materials in a product, there is less demand for material inputs and the amount of processing required at the post-consumer stage can also be reduced

» reduction in the number of material types. This can assist with material identification and separation, which will make post-consumer processing more efficient. It can also reduce levels of contamination in resource recovery input streams.

One example of material substitution is the evolution of plastic mineral water bottles on the French market, and its effect on resource recovery. The material originally used for plastic in the water bottles was polyvinyl chloride (PVC). Between 1991 and 2001, the quantity of PVC used for bottle packaging was reduced by 81.5% by using polyethylene terephthalate (PET) (Glachant 2004). This had two main impacts: overall lightening of the bottles because PET is lighter than PVC (by approximately 30%); and reduced chlorine outputs from bottles left in residual waste streams destined for energy recovery.

Another example of a PS material selection initiative is the removal of PVC labels from some PET drink containers by major retailers, resulting in improved PET recyclability and decreased contamination during the PET recycling process.[8]

It is also possible for manufacturers/designers to achieve more sustainable practice by sourcing materials from recycled products. By doing this they are driving cyclical material flows by helping to generate a market for recyclate, an important factor in the economics of resource recovery.

5.2.3 Production process design or selection

There are a range of operational options to manufacture a product or carry out a service. At the product design/product initiation stage, the designer or manufacturer must choose a process, with implications further down the product life cycle.

The choice of method/technology is of particular importance for collection services and resource recovery in terms of the C&I waste stream. The use of ‘cleaner production technologies’ usually means that either the amount of waste and/or by-products generated is reduced or the toxicity or harmfulness of these is lessened. Requirements for pre-consumer waste handling and processing will be affected by the production process.

Similarly, process choice can lead to significant impacts on post consumer resource recovery. For example, Copper Chrome Arsenic (CCA) is used to treat timber in order to protect primarily softwood timber from insect attack and fungal decay. CCA timber is commonly used for pergolas, decking, cubby houses, claddings, posts, gates, animal enclosures, and landscaping timbers. However, the post-consumer resource recovery options for CCA-treated timber products are marginal due to the hazardous nature of the chemical used for production. Energy from waste in traditional grate-fired boilers is not a viable option because of concerns with heavy metal contamination.

[8] Based on comments provided by representative from Unilever Australia, 07/06/2005. The PVC labels were difficult to separate from the PET during the recycling process due to the similar specific gravities of the two plastics.

Alternatives to CCA-treated timber exist. For example in Australia, the Sawmill Trading Company produces a product called 'waxwood' as an alternative to CCA-treated timber using a copper-based treatment. The product is called waxwood because the timber is also impregnated with wax to repel water and resist against weathering. Waxwood can also be combusted safely[9] meaning that it is more suitable to resource recovery via energy from waste than CCA-treated timber.

5.2.4 Product packaging, distribution and marketing

Product packaging can be designed and produced with the same issues in mind as those discussed in the above Sections (5.2.1 to 5.2.3to ensure a post-consumer resource recovery option for the packaging.

In the first instance, product designers and marketers can minimise packaging waste. For example Lancôme modified packaging of samples to smaller cardboard boxes that were 40% lighter than the previous packaging, and that resulted in saving 59 tonnes of plastic and 110 tonnes of cardboard each year.[10]

As well as providing protection for a product, "*the dominant concern now for packaging is shelf presence*". Graphics and package design are used to create a 'perceived value' and hence small products are often packaged in large boxes with colourful eye-catching graphics. One way to counter this problem may be to use minimal packaging but set up a few eye-catching packages for display (Welter 1990).

A product designer/marketer can also ensure that packaging ends up in a planned for resource recovery option through marketing efforts. For example, advertising that the package can be recycled and/or where it can be collected. Careful marketing strategies can also influence the efficiency and effectiveness of post-consumer collection. The contamination level in recovered resources can be influenced if, for example, product packaging gives a clear indication as to whether the packaging and/or product is unsuitable for resource recovery.

In terms of product distribution, designers can create transportation packaging with resource recovery in mind. The choice of transportation packaging may be adjusted, or more resource efficient methods can be employed, such as the use of "pooled" bulk containers like pallets. Furthermore, it is the complexity of product distribution that highlights the need for integration between design intent and resource recovery.

[9] Based on comments provided by representative from the Sawmill Trading Company, 15/08/2005.

[10] L'Oréal Safety, Health, and Environment, http://www.loreal.com/_en/_ww/dev_dur/secu/emballage.aspx, accessed 06/06/05

6. Integrating “Design Intent” with Resource Recovery

The concept of value chain assessment showed the importance of design decisions in affecting sustainability outcomes, while Extended Producer Responsibility and Product Stewardship identified mechanisms to influence design decisions for the benefit of post consumer resource recovery options. This highlights the need to integrate design intent with resource recovery services so that the requisite set of post consumer services and capabilities need to improve sustainability outcomes can be delivered.

6.1 Design and resource recovery services

The conundrum presented by attempts to integrated design intent and resource recovery services is which comes first: the design for optimal resource recovery or the post consumer infrastructure, services and capabilities. The challenge is different for existing products with legacy issues, such as cathode ray tube monitors, as compared with decisions regarding new products or the development of new packaging. Arguably for new products the starting point would be the existing levels of service provision. However, this varies across regions and nations, and it may be difficult for the original intent of product designs to fully realised where there is insufficient downstream infrastructure to support the EPR / PS design initiatives. Examples of this include:

» where lack of infrastructure exists to support downstream collection and processing of materials

> In Australia plastic bread packaging designers are light-weighting the packaging material to reduce resource consumption in the packaging production process, demonstrating a design intent for the environment.[11] However, the contamination of the plastic packaging with breadcrumb residue, with typically a high ratio of the weight of breadcrumb residue to the weight of recoverable plastic, and the lack of energy from waste recovery systems in Australia, means that existing collection and processing technology is unable to recover the materials, which are disposed of to landfill.

> Streets Ice Cream[12] recently changed the packaging design for some of their leading ice cream stick ranges from a polyethylene coated paper wrapper to a polypropylene wrapper. The paper component of the polyethylene/paper wrapper was recoverable through recycling processes, however the resultant separated polyethylene became a waste stream of the paper recovery process.
>
> The move from a polyethylene/paper wrapper to a polypropylene wrapper resulted in changing the packaging material structure from 2-layers to a single material, which using first principles, makes resource recovery easier. However as yet (in Australia), polypropylene wrappers are not commonly collected as part of the MSW or C&I post-consumer recycling system. Hence, the majority of polypropylene wrappers are landfilled.[13]

[11] Based on comments provided by representative from George Weston Foods, 10/06/2005.
[12] Streets Ice Cream is a subsidiary of Unilever.
[13] Based on comments provided by representative from Unilever Australia, 07/06/2005.

» where there are differences in the types of infrastructure and processing technologies available across the different geographic locations (regions, countries, etc) in which products are sold

Nestle Australia previously released one of its ready-to-drink products in a high-density polyethylene (HDPE) container with a PVC label. At the time, recycling technology in the eastern-states of Australia was sufficiently advanced to separate the PVC from the HDPE material, and hence recover the separated materials for further processing.

However, the same product was also sold in one of the southern-states of Australia where the recycling technology was not as advanced, making the removal of the PVC labels highly problematic.[14]

Cornstarch products used for packaging are more biodegradable compared to alternate packaging materials and can be beneficial when used in combination with an alternative waste technology that makes a range of composted products. While cost and technology are part of the issues currently challenging Australian manufacturers in implementing cornstarch packaging (as compared to some European countries),[15] a further issue is the lack of alternative waste treatment technologies able to recover value from biodegradable wastes. This makes any benefits from introducing biodegradable packaging difficult to access.

From the above examples, it can be seen that the availability of post consumer services and capabilities is essential in many cases to realising the product design intent. The reverse is also true and there must be an element of designing for the infrastructure that currently exists. For example, it is recognised that the unavailability of certain infrastructure services is not an excuse for a producer to disregard their EPR / PS responsibilities, as the following case study highlights.

As part of its commitment to PS, a major food manufacturer considered alternative packaging for one of its well-known food brands. As part of the decision making process a LCA was undertaken that considered the impacts associated with the total life cycle of each packaging option. The results indicated potential environmental benefits by adopting the new packaging even though it was not recyclable using the available recycling technology at the time.

Despite the potential environmental benefits of changing to the alternate packaging, the material was not selected as it was decided that these benefits would be offset by the lost social value the lack of recyclability could cause by sending the wrong message to the community about the importance of resource recovery of packaging materials.[16]

[14] Based on comments provided by representative from Nestle Australia, 10/06/2005.

[15] Based on comments provided by representative from Goodman Fielder Australia (Subsidiary of Burns Philp Pty Ltd), 11/06/2005.

[16] Based on comments provided by representative from Nestle Australia, 10/06/2005.

6.2 Required post consumer services and capabilities

If EPR / PS initiatives are to have a positive impact on sustainability outcomes, part of the equation must be sufficient post consumer services and capabilities to support producer original design intentions. The recovery process of transforming unwanted waste materials into resources is presented in Figure 6-1 below. At a minimum, it is suggested that there needs to be sufficient post consumer services and capabilities to establish all of these recovery pathways.

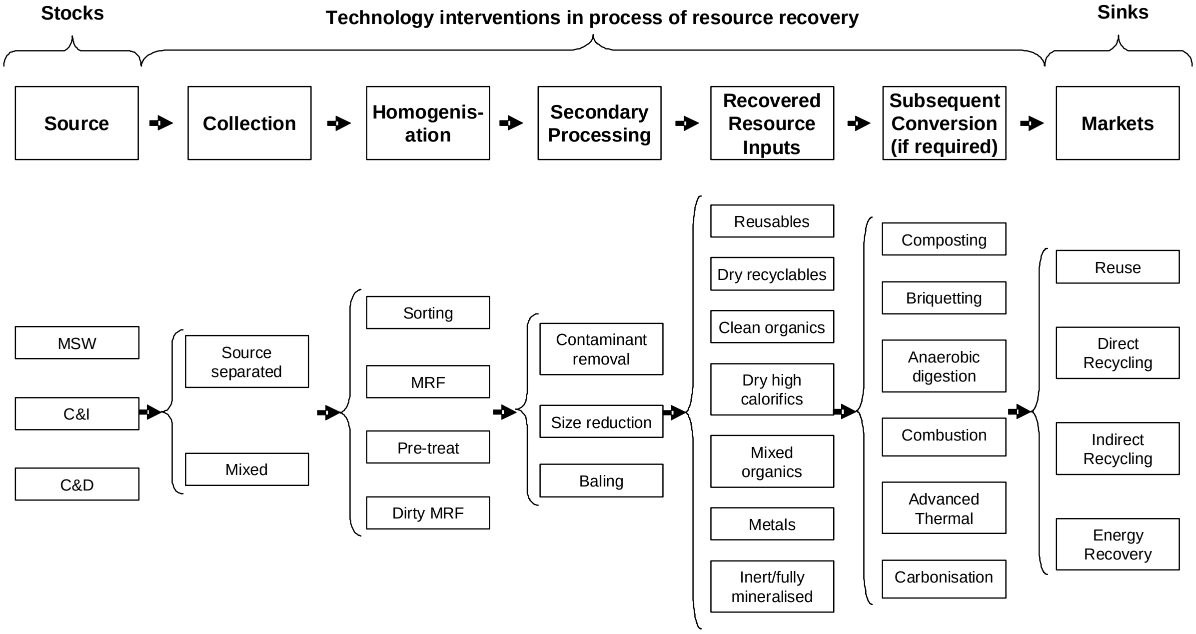


Figure 6-1 Required post consumer services and capabilities (adapted from Warnken 2004)

All products end up as "stocks" within the economy and eventually present for end-of-life management from Municipal Solid Waste (MSW), Commercial and Industrial (C&I) or Construction and Demolition (C&D) sources.

At this point there must be some for of technology intervention to prevent the disposal of the materials. The technology involved includes a combination of collection, homogenisation and secondary processing to produce recovered resource inputs. Theses inputs may require some subsequent conversion prior to being sold into a market, which acts in effect as a material sink.

The collection of materials can be mixed, for example household MSW, or source separated, for example, paper and cardboard from a printing shop. Even with source separated materials there is a requirement for further homogenisation to remove contamination and grade material inputs. This happens for kerbside recycling at a materials recovery facility (MRF). Other options include manual or automatic sorting processes; mixed waste pre-treatment, which breaks down mixed MSW into broad constituent elements; and dirty MRFing, which applies the same processes of a MRF to a mixed MSW input stream.

Secondary processing includes technologies to make product output more readily accessible as a resource input, for example, contamination removal, size reduction and baling.

Recovered resource inputs can be described in terms of seven generic fractions, including:

- reusables – products able to be directly reused for the same or similar purpose as originally intended
- dry recyclables – primarily packaging materials that are collected through household recycling services
- clean organics – source separated loads of garden organics (green waste) and in some cases kitchen organics (food waste)
- dry high calorifics – the readily combustible fraction within waste streams that can be sorted using sorting and pre-treatment technologies, for example, thin film plastics, residual paper and cardboard, wood packaging, woody garden organics and a small amount of other materials with energy content such as textiles
- mixed organics – the organic component within MSW, for example kitchen scraps and moist garden organics such as leaves and grass clippings (contrasted against clean organics where material comes from source separated collections)
- metals – all of the residual metal component in waste streams not captured as dry recyclables
- inert/fully mineralised – output from pre-treating waste streams to ensure that the material will not decompose, leach or otherwise react with the receiving environment.

In some instances subsequent conversion may be required to ready these recovered resources for market. Conversion technologies include:

- biological conversion of organic material to produce compost
- mechanical compression of material to make briquettes and pellets
- anaerobic digestion to generate methane and to produce stabilised organic humus
- combustion to produce heat, steam and in some cases electricity
- advanced thermal processes such as gasification and/or pyrolysis to produce a synthetic gas, liquid or solid fuel, char and oils depending on configuration
- carbonisation, which uses advanced thermal processes with the intent of converting surplus residual biomass from urban waste sources into a stable form of carbon suitable for land application or sequestration.

In order to match resource recovery to design intent, the range of post consumer services and capabilities (including collection, homogenisation, secondary processing and subsequent conversion) described above are required.

The challenge that integration poses is how to establish the relationship between product designers and providers of post consumer resource recovery services.

6.3 Required design intent integration

Under the approach where EPR/PS design initiatives are limited by downstream processing technology and capabilities, there is the risk of product design failing to be matched by advancements in resource recovery infrastructure development. Similarly, regardless of advancements in processing and recovery technology, if there is no linkage between manufacturing and downstream processors, there may be limited opportunities for passing economic incentives from post consumer activities to design and manufacturing activities (White et al, 1999). This limits the ability for resources to continue to go around the “loop”, perpetuating the generation of waste materials requiring disposal or destruction, rather than resource recovery.

Establishing the desired linkage, or integration, of design intent with resource recovery service provision, is thus a necessary component in achieving sustainability outcomes. The level of integration required is yet to be determined. For example, a theoretical ability to be recycled can be viewed as an attempt to avoid responsibility and points to requirements for a higher level of involvement of producers with resource recovery service provision.

Conversely, the importance of integrating post consumer processing with product design has been demonstrated by a number of studies, including a recent study of the effectiveness of EPR programs in driving product design changes in the electrical and electronic equipment sector (Tojo, 2004). Findings from the study indicated that in general, higher resource efficiency processes were undertaken where manufacturers had more control over downstream infrastructure, suggesting that producers should integrate into downstream resource recovery infrastructure. However, this may present limitations and a loss of efficiency from a system wide perspective, especially where producers replicate recovery systems for different brands of similar products.

The optimum balance is likely to be somewhere between recyclable products and provision of recovery infrastructure. The rate at which this change occurs will be determined by the priority that establishing communication linkages is given by both product designers and resource recoverers. Changing market economics to better reflect the true costs of production and consumption (internalisation of externalities) will create a commercial imperative to formalise such linkages where future product design is coupled with planning for future infrastructure. Strategies to realise such a “perfect world” potential for EPR and PS schemes, with associated sustainable energy and material flows, can be developed by applying the principles of value chain optimisation.

7. Next Stage in Evolution: Value Chain Optimisation

In a perfect world the level of integration between product designer and resource recovery provider would be such that adding value all the way along the value chain was the universal priority. This focus on value chain optimisation would result in sustainable flows of energy and materials. For some products this line of thinking would drive a 'servicising' approach, while for others the focus will be on design for resource recovery in a manner that returned the maximum amount of resource to the economy in a form that optimised resource efficiency.

7.1 Value chain optimisation

Value Chain Optimisation (VCO) refers to a design intent of maximising the value added to or retained with a product throughout all stages of the value chain. The overall structure of VCO and its integration with resource recovery is presented in Figure 7-1 overleaf. Once the "sustainability case" is made for a particular product (including a justification of the subsequent demands on eco-services on the basis of value provided), the design team has the greatest influence on the range of sustainability impacts the product will have as it moves off the drawing board, into the economy and then returned as a "renewed" resource via a planned end-of-life resource recovery pathway.

Traditionally the design team is focussed on maximising the sales potential of products under development by enhancing aspects of form and function. Value Chain Optimisation integrates designers into dialogue regarding:

» articulation of highest resource value pathway to deliver sustainable energy and material flows – optimum value balances (social, environmental and economic) achievable during:
  - manufacturing and production (material composition (renewable, recycled, recyclable and embodied energy considerations)
  - distribution and sale (packaging, weight, modes of transport, market pull or advertising push, ultimate value proposition)
  - service life (quality of product performance, resource impacts, direct human health impacts, environmental pollution, direct biodiversity impacts and life span)
  - end-of-life management (planned outcome, degree of value conservation, accessibility of reverse distribution infrastructure, accessibility of processing technology, consumer education and participation, markets for recovered products, recovery rates, leakage impacts)

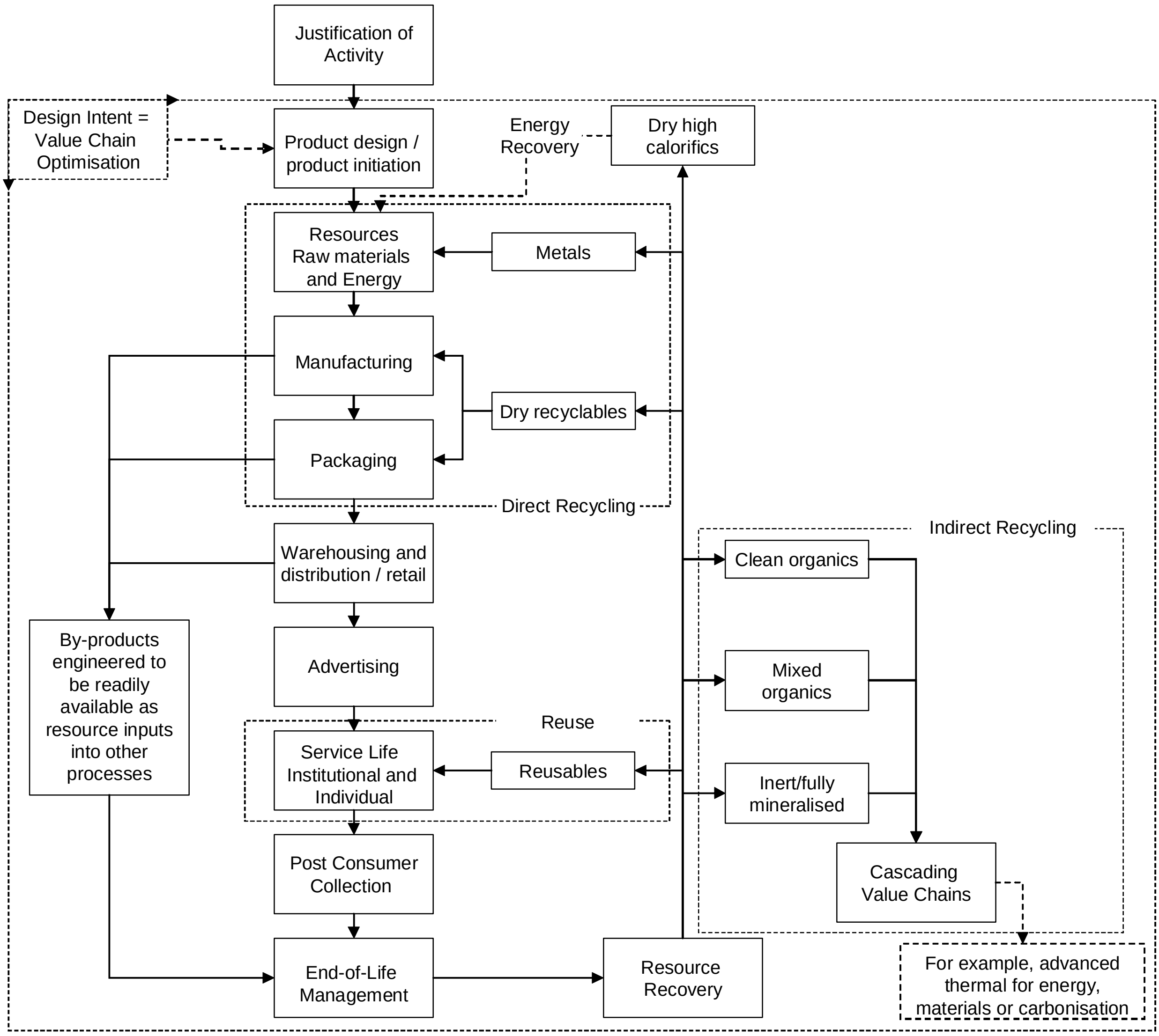


Figure 7-1 Value chain optimisation – integrating design intent with resource recovery

- overcoming market failures – the externalisation of costs onto the environment and communities is a critical market failure that rewards companies that pollute and exploit workers. VCO involves designers in the debate on market based instruments to improve sustainability outcomes
- development and sharing of reverse distribution infrastructure – continuous improvement of post consumer reverse distribution infrastructure such as community drop off facilities, mixed material and individual item collection services
- development of resource recovery processing technologies (services and capabilities) – ensuring technology for resource recovery (reuse, direct recycling, indirect recycling and energy recovery) matches developments in product technology

- education of consumers – improving ability of consumers to play their part in optimising value balances in product selection, service life and end-of-life recovery (for example identification of recyclables and understanding of recovery system operations to avoid contamination).

By engaging design intent with each stage in the value chain, the goal is to maximise the net present highest resource value of recovered materials as part delivering resource productivity within the economy. For example, VCO aims to deliver following outcomes through designer decisions and the provision of end-of-life management services that recover resources:

- sustainable energy and material flows
- profitable organisations in "fully internalised" markets
- low to no environmental pollution
- improved quality product offerings
- "bottom up" resource productivity.

Extended Producer Responsibility and Product Stewardship are useful levers to establish this kind of thinking for specific product types. The challenge is for VCO to become the standard business approach across all products and sectors. An important component of VCO is the transition to service based economies.

7.2 Transition to service based economies

The concept of product-service systems "*promotes a focus shift from selling just products to selling the utility, through a mix of products and services while fulfilling the same client demands with less environmental impact*" (Manzini et al, 2002). Consumers rarely wish to own a product, rather they desire the service that the product delivers.

The concept of a service based economy was popularised in the book by Hawkin, Lovins and Lovins (1999) "Natural Capitalism: The Next Industrial Revolution", with a focus on the delivery of a continuous flow of services, as opposed to the discrete sale of products. For example, few people actually want to own a car, but rather desire its services (transportation, comfort, safety and reliability). Similarly, it is the services of carpet (warmth, aesthetics and comfort) that is valued, as opposed to the material itself.

Under the proposed "servicising" model, companies would sell the services of products, while retaining ownership of the product itself. This would provide an incentive to drive towards greater durability and recyclability, in order to maximise the amount of services that could be sold from a single unit of resource. The services can then be delivered more cheaply, efficiently, and consistently with an associated reduction of inventories, revenue fluctuations and other risks.

Servicising was also advocated by Stahel (in Mont, 2000) who argued that under an industrial economy value is measured by the extent of product exchange. As the responsibility for product disposal is transferred to the customer at the point of sale, there is little incentive for the manufacturer to supply goods which have a long life or are reusable.

Alternatively under a service based economy, the customer would not be buying the product, but a service and system solution for its use and end-of-life management that minimises the environmental impacts of consumption (Mont, 2000).

The example below (Table 7-1) outlines the essential differences between product selling systems (traditional product sales) and product-service systems for the sale of a washing machine. In this example (from Manzini et al, 2002), disposal of a washing machine would be the responsibility of the consumer in a traditional product sales environment. Within a service based economy, the disposal service is provided by the manufacturer, and hence there is increased incentive for the manufacturer to maximize the product life, reuse components, and recycle materials. Thus material cycles are closed, and less waste is stored, incinerated, or landfilled.

Note that there are other examples of companies that have realised the potential benefits of adopting a product-service approach including both Xerox and Nokia. These companies are providing increased services either as an extension of their existing services to customers, as part delivery of their EPR obligations, or to obtain an edge over competitors.

Table 7-1 Comparison of a traditional product sales system versus product-service system for a washing machine (adapted from Manzini et al, 2002)

Traditional Product Sales	Extended Producer Ownership	Full Service Equation
Consumer buys a washing machine to clean clothes at home	Consumer rents a washing machine to clean clothes at home from original equipment manufacturer (OEM)	Client buys service from a company (laundry) to clean clothes (company determines best equipment and method based on client needs)
Consumer owns, uses and stores washing machine – is also responsible for maintenance and quality of clothes washing	OEM retains ownership of washing machine and is responsible for maintenance. Renter is responsible for use and quality of clothes washing	Company owns, maintains and stores cleaning equipment, including washing machine – is also responsible for quality of clothes washing
Considerable upfront investment for consumer	Consumer costs are spread over time – deposit is paid and either a per wash approach or weekly rent	Client costs are spread over time as payment is made on a per wash basis
Consumer ultimately disposes of washing machine and buys replacement	OEM responsible for disposal – has incentives to prolong use, reuse components and recycle materials	Company is responsible for disposal - has incentives to prolong use, reuse components and recycle materials

Under VCO the designer must not only consider the product development, but also the required service system (including product maintenance, replacement, recycling, and/or disposal) for that product. This requires integration of all stakeholders in each element of the life cycle framework, including the raw materials and energy suppliers, the producers, the retailers, the consumers/customers and the end-of-life managers. For example, design functions related to the washing machine include development of the washing machine, detergent, maintenance service systems for the machine, and recycling and disposal requirements for both the washing machine and detergent packaging.

The function that designers need to deliver under a value chain optimisation approach (related to establishing a product service system) includes (Manzini et al 2002 and Mont 2000):

- production – reducing size, making easy to recycle, preference for recyclables, reducing associated land use and reducing weight
- operation and maintenance – multifunctional capacity for multiple users and multiple use, self optimising systems, improved quality outputs, reduced weight of components and longevity
- post consumer – ensuring product fits into take back, reuse, refurbishment, remanufacturing, recycling pr energy recovery systems.

As companies engage with concepts of value chain optimisation and servicising, there is likely to be a level of vertical integration for those operations that see a business case in physically taking back products at the end of their service life (or do so in order to discharge their obligations under EPR / PS). These companies will be able to create a critical mass of resources that will in turn improve the efficiencies of the recovery process.

8. Conclusion

The need for change from “take-make-waste” mentality relying on disposal in “mass-dump” landfill or “mass-burn” incineration is well understood amongst OECD countries. Tools such as the Sustainability Guide for Energy from Waste Projects and Proposal, assessment of net present highest resource value, and Life Cycle Assessment are useful in supporting the drive toward sustainable resource productivity.

The influence that product design has on supply chain impacts is also well defined and the basis of Extended Producer Responsibility (EPR) and Product Stewardship (PS) Schemes. The implications for end-of-life management, however, are influenced not only by designer decisions, but also by the availability of post consumer services and capabilities (accepting that unavailability of these services is not an excuse for a producer to disregard their design responsibilities). The impacts of design along the value chain demonstrates the need to integrate design intent with resource recovery service provision and validates the central proposition of the first stage of IEA Bioenergy Task 36 Topic 1: Product Stewardship / Producer Responsibility.

The challenge that integration poses is how to better establish the relationship between product designers and providers of post consumer resource recovery services in order to provide a platform from which to plan for infrastructure requirements for resource recovery technologies. Changing market economics to better reflect the true costs of production and consumption (internalisation of externalities) will create a commercial imperative to link product design with infrastructure planning. Strategies can also be developed by applying the principles of Value Chain Optimisation (VCO), or the design intent of maximising value added or retained throughout all stages of the value chain.

Such an approach integrates designers into dialogue regarding: highest resource value pathways to deliver sustainable energy and material flows; overcoming market failures; development and sharing of reverse distribution infrastructure; development of resource recovery processing technologies; and education of consumers. The result is that design choices are improved in step with improvements made to post consumer resource recovery services.

Value Chain Optimisation thus provides not only a model for engagement and integration between product designers and resource recovery service providers, but also a planning platform for resource recovery infrastructure and technology requirements in general, and energy recovery in particular.

The second stage of IEA Bioenergy Task 36 Topic 1: Product Stewardship / Producer Responsibility (led by the EfW Division of the Waste Management Association of Australia) will review actual experience and outcomes of Extended Producer Responsibility / Product Stewardship in order to identify the existing level of integration between design intent and resource recovery. A comparison will then be made between tangible results and the potential for integration of design and resource recovery infrastructure suggested through the application of VCO principles.

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Appendix A

Decision Support Tools

Decision support tools are used to provide a formalised process for determining between options on the basis of multiple and often conflicting criteria. Without diverging into the well developed body of knowledge that is decision analysis and behavioural theory, three decision support tools are presented here with resource recovery applicability.

A.1.1 Sustainability Guide for Energy from Waste Projects and Proposals

The question of deciding when energy recovery presents as the most sustainable resource recovery option is both polarising and problematic. Energy from Waste (EfW) is "*an approach to resource recovery that focuses on maximising the amount of energy that can be recovered from materials that would otherwise be disposed of to landfill through a variety of energy recovery technologies*". It is contrasted against Waste to Energy (WtE), which "*is a waste management approach where the focus is on material destruction and where energy recovery is a by-product* (EfW Division WMAA 2005).

Stakeholder consultation undertaken as part of the Energy from Waste Sustainability Project, outlined the following concerns with energy recovery as an approach (Warnken ISE 2002):

- encouraging the generation of waste - if an Energy from Waste (EfW) facility is established it will create a large demand for feed material and this will reduce the drive toward minimising the generation of waste in the first instance
- best use of the material in question - EfW could be taking away resources from current recycling operations in addition to preventing innovative future recycling technologies from gaining access to a resource stream. For instance the debate about returning 'organic carbon' as compost to the land in order to reduce soil degradation and salinity. (This argument puts composting ahead of any EfW approach)
- control of emissions to air, water and land - for instance concerns regarding dioxin creation in stack gases and heavy metal contamination of ash.

In order to address stakeholder issues preventing EfW projects from making a bona-fide contribution to sustainable resource recovery, the Energy from Waste Division of the Waste Management Association of Australia produced a "Sustainability Guide for Energy from Waste Proposals and Projects" with funding from the Australian Greenhouse Office and other industry and government sponsors.

The purpose of the Guide was 'to address and define those elements in the general urban waste streams that are suitable for application as a sustainable source of energy and to present protocols for their appropriate conversion.' The main sources of energy are those materials that 'have no further practical value for reuse, recycling or reprocessing for the recovery of their inherent resource value' and 'have an inherent net energy value that could be beneficially recovered and that otherwise will be lost to simple disposal' (EfW Division WMAA 2005).

The main outcome of the Sustainability Guide was an assessment roadmap of six project scoping principles (PSPs) that are used as a tool to decide when the use of EfW is appropriate, based on profiling and assessing the sustainability of a proposal or project. The process is shown in Figure A-1.

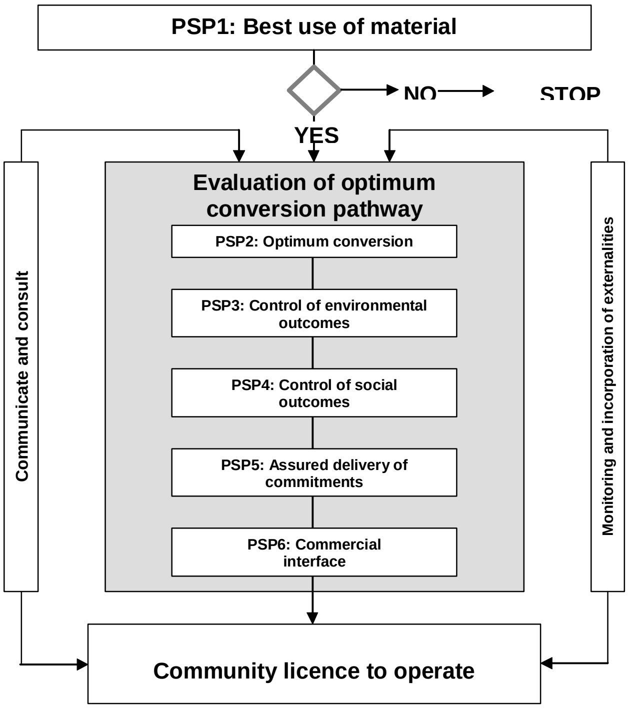

Figure A-1 Assessment roadmap of project scoping principles (WMAA EfW Division 2004)

PSP1 is an assessment to "demonstrate that the application of urban wastes being considered for conversion for their calorific value represents the most sustainable application of the resources". This is followed by an analysis to determine if the selected process and pathway are optimum for the available materials (PSP2). The measures to manage the environmental, social and economic impacts of the project are then assessed in PSP3 and 4.

The aim of PSP5 is "to demonstrate that the environmental, social and economic commitments defined at the initiation of the project are understood and delivered over the life of the project". The procedure is completed with PSP6 to assess if the project structure for achieving commercial viability does not compromise the inherent sustainability achieved by observance of the other PSPs (EfW Division WMAA 2005).

The main point of the Sustainability Guide is the importance of quality assurance and control to energy recovery. It is a process geared toward product manufacture and not waste management. As such the quality assurance and quality control (QA/QC) stages become integral to differentiating between bona fide energy recovery and incineration.

While the Sustainability Guide is specifically designed with decisions regarding energy from waste in mind, the structure of the decision-making process can be used to assess alternative resource recovery technologies that seek to recover the highest resource value of a material within the context of sustainability. A similar less formalised approach with this wider applicability is the concept of Net Present Highest Resource Value assessment.

A.1.2 Net Present Highest Resource Value

There are usually a number of recovery options for a given material. Therefore, it is important that the best option is selected to maximise the highest resource value of that material. Sometimes, the solution is intuitively clear. Warnken (2004) gives the example of recycled solid hardwood floor boards: it is clear from this analysis that it is better to turn the floorboards into a dining room table than to chip up the timber for fuel or landscape mulch. However, it is not as clear as to how to balance the issues with regard to composting and energy recovery for woody waste materials.

Ideally highest resource value would be used to determine between resource recovery options of reuse, direct recycling, indirect recycling and energy recovery as represented in Figure A-2. The main difficulty is distinguishing which option is best when they each have advantages and disadvantages with regard to economic, environmental and social impacts.

Net present highest resource value (NPHRV) is a means for assessing the range of resource recovery options available to any given material stream. The elements within this concept are as follows (Warnken 2004):

» net – captures both positive and negative impacts of the option. There will always be a series of tradeoffs when approving resource recovery activities, however it should be possible to present an argument of both the positives and negatives as a means of achieving the best "net" result.

» present – captures "current conditions". The question to be resolved is do we spend the next 10 – 15 years locking up a resource stream when in five years time a more efficient use of that recovered resource could emerge? However, this argument invariably delays decisions and serves to maintain the status quo. When considering resource recovery options, there is a need to compare options that are presently available as opposed to being under development.

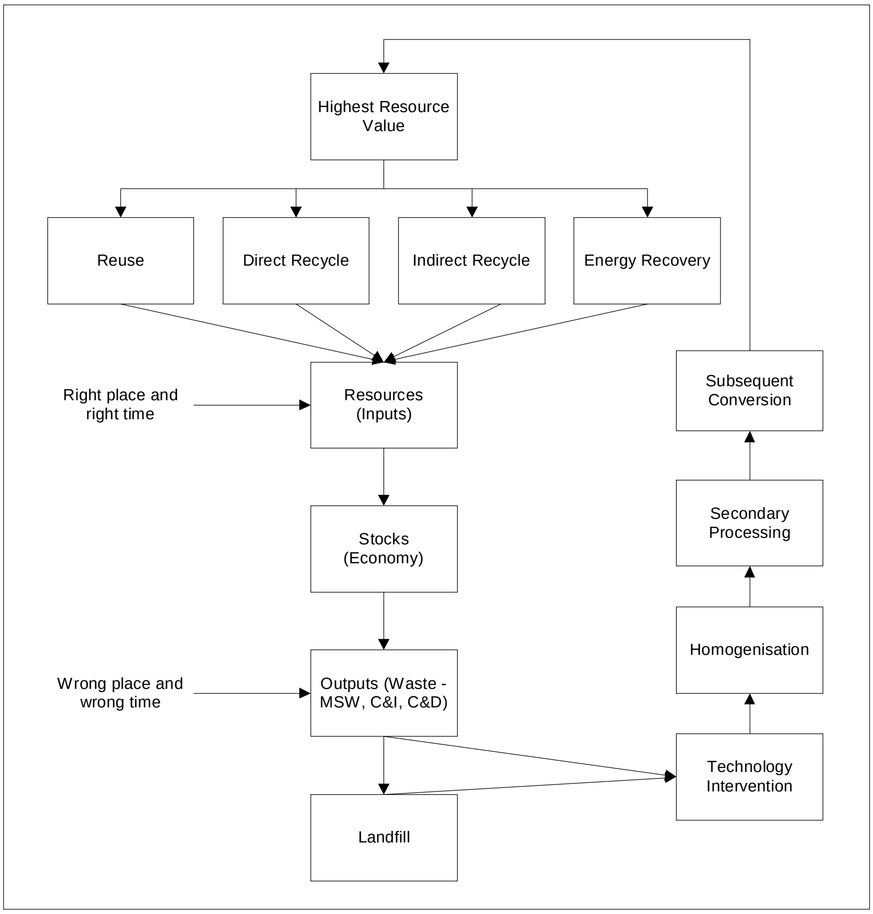

Figure A-2 System of resource recovery determined by highest resource value (Warnken 2004)

» highest – the point of differentiation between a range of alternatives. This concept in combination with "present," suggests the role of continuous improvement towards ideal performance.

» resource – moving away from the mind-set of waste management toward a focus on the inherent raw materials and an attitude of product manufacture. This involves a focus on quality assurance to control the material mix in the recovered resources so that it is possible to prepare a fit-for-purpose product.

» value – the combination of environmental, techno-economic and socio-political values. This includes aspects such as impacts on air, water and land, technical merit of a technology or process and the economics that surround that operation and community permission to operate a resource recovery operation in a given location.

Putting the elements of the concept together, the drive to recover the net present highest resource value of materials seeks to develop resource recovery operations that maximise the positive and minimise the negative relative environmental, techno-economic and socio-political impacts for the materials in question.

Net Present Highest Resource Value assessments attempt to qualitatively describe these concepts for a given material with differing recovery options. Table A-1 gives an example of how an assessment would be undertaken.

Table A-1 Assessment matrix to determine first order NPHRV (adapted from Warnken ISE 2004)

Assessment Criteria	Comments
What are the recovery options for the material in question?	This should include a listing of all the 'possible' options to ensure that as wide a net as possible has been cast to investigate opportunities.
How many of these are commercial at the present time?	Moving from the possible to the probable, what options currently exist as commercial operations?
What kind of recovery opportunity is it?	Reuse – another trip through the economy for the product as is Direct recycling – another trip through the economy for the material Indirect recycle – possibly the last use before dispersion back to the environment, for example compost Energy recovery – irrecoverable loss of material structure to capture energy content.
What is the planned and accessible end-of-life use for the recovered material?	Re-use, direct recycle, indirect recycle or energy recovery.
What is the economic case for the commercial recovery options?	An assessment of the business case for each recovery option as a traditional cost and benefit analysis, including a comment on market maturity and stability.
What is the environmental case for the commercial recovery options?	An overview of the environmental impacts (both positive and negative) including potential emissions to land. Also including offset benefits such as reduced need for virgin materials
What is the social case for the commercial recovery options?	An overview of the social impacts (both positive and negative) including local amenity
What are the prevailing local conditions?	An overview of pertinent factors that could influence the resource recovery choice

NPHRV is a new concept for assessing resource recovery options and some considerations need addressing further in order for NPHRV to be proved a successful decision support tool for sustainable resource recovery. One limitation is in its qualitative approach, which leaves the process of evaluation open to interpretation and ambiguity, in addition to the issue of indicator selection and measurement. One decision support tool developed explicitly to overcome these types of limitations and provide quantitative environmental comparisons between options is Life Cycle Assessment (LCA).

A.1.3 Life-cycle based analysis

Life Cycle Assessment (LCA) can be defined as:

'*a systematic inventory and comprehensive assessment of the environmental effects of two or more alternative activities involving a defined product in a defined space and time including all steps and co-products in its life cycle'* (Pederson 1993, cited in Kiely 1998)

If the assessment stage is omitted, the term 'life cycle analysis' can be used. LCA is an environmental decision support tool increasingly used to understand and compare how products or services are provided 'from cradle to grave'. It is widely used in waste management and resource recovery applications, with considerable international effort being put into providing access to life cycle inventory data as well as effective tools for performing LCAs. The phases of an LCA are shown in Figure A-3.

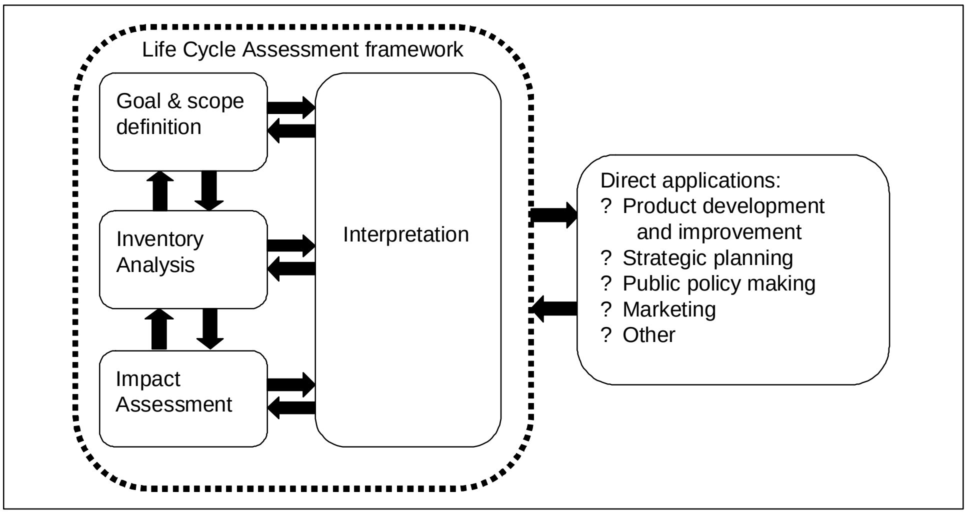

Figure A-3 Phases of an LCA (McDougall et al 2001

The phases include (McDougall et al 2001):

1. Goal definition - options to be compared, intended use of results, the functional unit[17] and system boundaries
2. Life cycle inventory analysis - account for all materials and energy, both inputs and outputs across the whole life cycle
3. Life cycle assessment - organises or classifies the life cycle inventory inputs and outputs into specific issues or categories and models the inputs and outputs for each category into an aggregate indicator
4. Life cycle interpretation - the process of balancing the importance of different effects. Here there is no agreed scientific method and more public debate is required.

[17] Functional unit – a measure of the performance of the functional outputs of the product system/service/technology. The functional unit is the basis on which the product/services/technologies will be compared in an LCA.

LCAs are sometimes used by industry in order to ascertain areas in which environmental improvements can be made. Hence, it can also be used as a tool in developing waste avoidance/minimisation strategies because it helps identify those stages in production processes which generate the most pollution or waste, and those which have heavy energy or material demands.

LCA techniques are also used for evaluating future resource recovery options for cities or regions. They provide a way to systematically assess the impacts of alternative technologies/processes as well as waste or recycling collection schemes. The assessment process is quite complex, and numerous assumptions are made to gain a result. The outputs of LCA studies thus need to be viewed in the context of the applicability of the life cycle inventory data to the particular situation being assessed.

An LCA of resource recovery options aims to (McDougall et al 2001):

» predict the comparative environmental performance of each option

» demonstrate the interactions that occur within each option – LCA attempts to model the whole system and hence the life cycle model will show how different parts of the system are inter-connected

» clarify the objectives of the overall system

» allow for 'what if…?' calculations – a number of hypothetical resource recovery options and their environmental burdens can be compared

» provide data on technologies, which can be used in life cycle studies of individual products and packages.

The main benefit of the life cycle approach is that it is an inclusive tool. Provided that an appropriate system boundary is chosen for the investigation, the inventory phase looks at all necessary inputs and outputs (such as emissions) in the various stages and operations of a waste management system/technology. It also includes indirect inputs and outputs and the analysis aggregates over time.

LCA attempts to address a broader range of environmental issues rather than focusing on one issue alone. The system mapping approach allows other environmental information and assessment tools to be used in conjunction with LCA, which "helps take some of the emotional element out of environmental debates" (McDougall et al 2001).

LCA aims to include the whole life cycle and all environmental issues associated with a waste management system or resource recovery technology, while relating this to a common functional unit that makes comparison between options possible. In this regard LCA is a quantitative tool and values (usually monetary) are assigned to each input and output in each of the stages and operations. Some of the inputs and outputs can be valued relatively easily, however others are problematic when assigning monetary values.

For example, while it is relatively easy to define the monetary value of energy as an output from energy from waste technologies or water from alternative waste technologies, the commercial prices of energy and water do not reflect the actual value that these resources might have to a society. In some countries the price of water and/or energy is highly undervalued. For instance, in Australia, the price of water is minimal when considering the scarcity of this resource. Hence, an LCA based on purely the commercial price of water may not place enough weighting on any water savings achieved by a certain option. It is also difficult to place monetary values on new or emerging technologies which have not been proven commercially before.

Furthermore, LCA is structured to employ an overall system balance which aggregates environmental impacts over time. Unfortunately it is not able to assess the environmental effects of a waste management system or resource recovery technology. That is, LCA does not predict actual impacts or assess safety, risks, or whether thresholds are exceeded (McDougall et al 2001). The actual environmental effects of the system or technology will depend on when, where and how the various outputs are released to the environment. Other assessment tools (such as risk assessment) and information is required to determine this.

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