Bilateral industrial symbiosis

An assessment of its potential in New South Wales to deal sustainably with manufacturing waste

Robin Clive Chimmo Branson

A thesis submitted in fulfilment of the requirements
for the degree of Doctor of Philosophy

School of Geosciences
The University of Sydney
September 2011

Abstract

Manufacturing takes place in NSW on sites that are dispersed throughout the state. They may be isolated, remote from one another and hence from likely users of their waste. This scenario is not conducive to industrial symbiosis which is conventionally understood to be a network of organisations in close geographic proximity that share resources, cascade energy and use each other's waste. Regulations governing the disposal of waste are stringent and associated costs are significant, largely due to the highest landfill levies anywhere in Australia. The state government's strategy is to increase levies to a level that 'induces' generators of waste to find alternatives to landfill. Responding to these challenges will necessitate a fundamental change in the approach to dealing with waste. The way in which manufactures might accomplish the change sustainably and systematically is the underlying issue addressed in this thesis.

The concept of physical bilateral symbiosis, specifically an arrangement between a generator of waste and its user, has been developed to suit geographic conditions in NSW. However, an attempt to establish trials of its autogenous form was unsuccessful. Nevertheless, results of the attempt indicated that broader issues should be investigated: managers' perceptions of waste disposal, their willingness and their capacity to meet the challenges imposed by government; collectively, what I have called a generator's internal infrastructure. These issues, in turn, led to an investigation of how third parties, that is, the external infrastructure, might be able to facilitate bilateral symbiosis.

The principal findings are that while some generators may develop uses for their waste others will simply not be able to do so. There is, in practice, no external infrastructure capable of facilitating systematic, bilateral symbiosis on behalf of a generator. Furthermore, government action, particularly in relation to policy on funding, is neither appropriate nor adequate for sustainable development in relation to waste. The overall conclusion is that much could be done by the private sector to increase the use of waste, if government policy were to support the effort. However, that support is expected to be very difficult to achieve, even in the form of appropriate legislation in NSW, let alone coordinated among the various jurisdictions in Australia. In regard to what actually happens in practice, the current scenario in general is unlikely to change significantly within the foreseeable future.

Statement of authorship

This thesis has not previously been submitted for a degree or diploma at any other university. To the best of my knowledge and belief, it does not contain any material created by another person, whether published or not, other than that which has been acknowledged by appropriate reference within the thesis itself.

Robin Branson

Acknowledgements

As I write these acknowledgements, I see with my mind's eye a gathering of the people who have contributed, Gaia like, to a project that, for me, has been an exhilarating and greatly enjoyed preoccupation for the last six years. At the centre of the gathering is my wife, Sarojah, whose instant support at its inception and unstinting encouragement ever since has been the bedrock of this enterprise. Arm-in-arm with her stands our daughter, Arsha, herself a student at the University of Sydney for much of that time, who was always willing and acutely able to comment on my efforts. Close by is my supervisor, Associate Professor Dr Phil McManus, who took on a sexagenarian for what must have seemed to him at the time a most unlikely proposition. His deft guidance, academic inspiration and great sense of humour have been invaluable and are greatly appreciated. Two other academics are also distinguished among the gathering. Dr Phil Matthews, formerly at the University of Queensland, challenged me to study for a PhD and was my original supervisor, until he left the university. His suggestion that I research the mineralisation of composting persuaded me, instantaneously, to focus on industrial waste. Dr Lou Vance at the Australian Nuclear Science and Technology Organisation agreed to become my co-supervisor with Phil Matthews. His encouragement continued after I transferred to Sydney University and has been unflagging ever since.

Also at the gathering are Jørgen Christensen and Mogens Olesen with their wives Edith and Elsebeth who so kindly welcomed me to Kalundborg, Denmark, on my first, fleeting, visit there in 2008. Jørgen and Mogens spent many hours on that occasion discussing the evolution of industrial symbiosis. When I visited again a year later, Jørgen introduced me to Inge Christensen, whose unique contribution to the field of industrial symbiosis is described in the thesis. Not so distinct individually, though nonetheless present in my mind, are the many people in industry who have cooperated with the research. Whether responding to a questionnaire, at interview or in some other way, their involvement has provided a sound basis for my thesis. Similarly among the gathering are my post-graduate colleagues and the academic staff in the School of Geosciences, whose challenging discourse, fulsome critiques and unreserved support all greatly enriched my pondering. The help given by the members of the school's administrative staff is also appreciated; each seemed to deal effortlessly with any issue whenever I sought their advice. Two weeks before printing, Dr Agata Mrva-Montoya of Sydney University Press undertook the role of a 'fresh pair of eyes', to proof-read the thesis before it slid irretrievably into the future. She ‘knocked it into shape’ with astonishing speed and attention to detail.

I acknowledge with profound gratitude and fervent thanks all those mentioned here who have contributed to this project; they shall remain at the gathering in my mind’s eye for so long as it is able to see.

Robin Branson

Contents

Preface

In September 1989 *Scientific American* published a paper by Robert Frosch and Nicholas Gallopoulos called 'Strategies for manufacturing'. The authors were executives with General Motors at the time and proposed a network of relationships among industrial organisations by which resources would be shared and waste used rather than dumped. They called the arrangement an 'industrial ecosystem'.

About two months later Dr Valdemar Christensen and his wife Inga were having dinner together at their home in the small industrial town of Kalundborg on the west coast of Jutland, Denmark. Dr Christensen was due to give a talk the following day about a phenomenon that had evolved during the previous 20 years or so. A project undertaken by a group of students at the local high school revealed a network of relationships between various industrial organisations in the district, established through unrelated bilateral agreements to share resources such as water and heat, and to use waste. Dr Christensen wanted a 'catchphrase' to describe the situation. Neither he nor Inga was aware of the article in *Scientific American*, which would have given him exactly the epithet he needed. Inga, being a biologist, suggested the network resembled a form of symbiosis: 'industrial symbiosis'. The phrase 'stuck' and has been used ever since.

About a month after Dr Christensen's talk on industrial symbiosis, half a world away in Sydney, Australia, I attended a meeting of the Kensington Club which had been set up in association with the University of New South Wales as a forum in which academics and managers in industry could meet informally with a view to fruitful collaboration. At that particular event I met an executive of an aluminium smelting company who had a problem with spent pot liner, a toxic industrial waste (see Chapter 1 vignette). We discussed an idea I had to fix the problem. Two years and about A$140,000 later I had a technically viable solution and a patent. Although commercial exploitation has not yet been successful the project introduced me to the extraordinary world of industrial waste. Extraordinary because so much waste was routinely dumped by manufacturers when it could easily have been used profitably. So it is that three unrelated events have led inexorably to this thesis.

In 1987 I started Qubator, a company intended to finance and manage the pre-commercial development of industrial technology. As a result of the project mentioned above, Qubator has specialised ever since in finding uses for waste, that is, bilateral industrial symbiosis. The regulatory environment with regard to industrial waste in NSW changed markedly during the early 2000s as did manufacturing practices. The exigencies of waste disposal focused the 'corporate mind' with ever greater intensity as the prospect of increasing costs and restrictions became reality. Manufacturers faced a particular problem: there seemed to be no structural, systematic way of finding a use for waste so that the cost and difficulties of dumping it could be mitigated. Materials such as scrap glass, paper, metal and some types of plastic could be sent to aggregators. Some organic waste such as sludge and effluent from processing food could be applied to improve soil and solid organic waste might be accepted for composting but there remained a wide variety of waste materials for which indefinite storage or dumping in registered landfill sites were the only legal options for disposal.

After almost 20 years of operation as a one-man business, it became clear that Qubator had very remote prospects of providing a systematic solution to this problem on a scale large enough to satisfy the general need, even though the business model has been successful at the scale of individual projects. Realising that a general solution to the problem is needed raised the question which underlies this research: What can be done systematically (rather than by happenstance) to use manufacturing waste instead of dumping it?

In September 2010, at the 2nd Australasian Industrial Ecology Conference in Sydney, I gave a presentation on 'Projects that went pear-shaped'. On the basis that one can probably learn as much from failure as from success, I talked about some of Qubator's projects that had failed, as a way of illustrating what the business of bilateral symbiosis is really like in practice. The particular significance of failure is that the company receives no remuneration at all until an arrangement is operating successfully and then only for as long as it continues. By way of parentheses to this thesis, I include vignettes of those projects as adjuncts to the general context of this research. At the beginning of each chapter there is a story of failure, except the last. The vignette for Chapter 9 is one of a few, long-lasting successes that have made life worthwhile and, like the many failures, endlessly fascinating.

Chapter 1

Introduction

Spent pot liner dumped in an open pit – pre-1995
Source: Alcan Aluminium, Kurri Kurri, NSW

The spent pot liner project

Spent pot liner (SPL) is a toxic waste that arises from the electrolytic process for smelting aluminium. The waste comprises a mixture of refractory brick and carbon cathode permeated by soluble species of fluoride and cyanide. It is toxic to the extent that if SPL becomes saturated with water, as it would in landfill, the fluoride and cyanide dissolve and leach into the environment. Disposal options in Australia, current when the project began in 1989, were either landfill or storage in sheds. There are six smelters operating in Australia: two in NSW, two in Victoria and one each in Queensland and Tasmania. Five were dumping SPL on their own land and one was storing it in sheds. All six sites currently (2011) store SPL in sheds. As now, the challenge then was to find a sustainable use for SPL.

Qubator instigated a project to develop a process to convert SPL into saleable products. The technology was based on the process for making Synroc, an artificial ceramic which prevented radioactive waste from leaching. The Australia Nuclear Science and Technology Organisation (ANSTO) at Lucas Heights, NSW had been developing the technology since the mid 1970s and agreed to do 'laboratory bench' research for this project. Qubator managed and funded initial research, in collaboration with the Alcan smelter at Kurri Kurri, in NSW. Subsequent stages were funded by Qubator, Alcan, Alcoa and Tomago (owned jointly at the time by Pechiney and CSR). This was said to be the first project anywhere in the world funded jointly by these three competitors.

The process involved crushing the raw SPL, mixing it with calcium sulphate and aluminosilicate, calcining the mixture, more crushing and grinding then forming the resulting grog into green product and sintering. The project 'spanned' four different sites, where various items of equipment were located, with the two furthest from each other being approximately 300 km. apart. Alcan's smelter at Kurri Kurri, about 180 km north of Sydney provided raw SPL and carried out several heating stages. The addition of 'ingredients', grinding and mixing were done by the Commonwealth Science and Industrial Research Organisation (CSIRO) in Sydney. Forming and firing products for trials were done by an industrial ceramics manufacturer in their product development facility, approximately 120 km south of Sydney. Logistics of the project were therefore protracted; it was not unusual for a single trial to take two round trips in a week. The project was managed in stages, each with its own objectives, scope of work, budget and funding.

Technically, the project was successful. Qubator was granted a patent for the process and the final products, made in the form of house bricks, intended to be used as filling for Gabion baskets and the like, still exist intact, more than 20 years after they were manufactured. The problem of leaching had been solved and a method of extracting reusable fluorides had been demonstrated. From a commercial perspective, the project demonstrated that costs of disposal at the time could be reduced by at least A$150/tonnes. A market for ceramic product was identified which would have generated revenue. By 1991 the recession at the time had sapped all enthusiasm for funding technology development so the project collapsed before a demonstration plant could be built.

The 'driver' for this project was to solve a problem of disposal, not necessarily to find a use for waste. However, it revealed the potential profitability of finding uses for waste, which Qubator has done ever since. Characteristics of the Australian industrial scenario highlighted by this project include the long distances between sites, the lack of technical infrastructure suitable for developing uses for waste and the vulnerability of such development to the vagaries of funding.

1.1 The subject of this thesis

The academic study of industrial symbiosis relates to industrial ecosystems, notionally, group of organisations in close geographic proximity that might share resources, cascade energy and especially use each other's waste (Subsection 2.3.1). This thesis is about using manufacturing waste generated by organisations that are *not* associated with an industrial ecosystem. The study concentrates on manufacturing in the state of New South Wales (NSW), Australia in which only one, small, industrial ecosystem has been identified, as noted below. Manufacturing sites are dispersed throughout the state, some are remote or isolated. Environmental regulations are stringent and deliberately exert pressure on manufacturers to find uses for their waste. This scenario creates particular difficulties addressed in this research.

Dumping waste as landfill squanders resources and, theoretically, is unsustainable in the long term. A tenet of this research is that using waste is economically and environmentally preferable to dumping it. Another tenet is that what actually happens in practice is the critical determinant of sustainable development. Accordingly, the bearing this research has on practice is emphasised in various ways throughout the thesis. In academic literature, the topic of industrial waste lies predominantly in the field of industrial symbiosis (Section 2.4). The conventional scenario, which characterises industrial symbiosis, depicts a network of relationships between more than two participants in close geographic proximity that share resources, cascade energy and use one another's waste (Subsection 2.4.1). Much of the manufacturing in NSW does not conform to this scenario (Section 1.2), particularly geographic proximity. This research, therefore, explores the potential of industrial symbiosis to facilitate the effective use of waste under atypical conditions. It centres on a basic form of industrial symbiosis comprising a single relationship between two principals, that is, bilateral industrial symbiosis or simply bilateral symbiosis. Its role in the evolution of established industrial ecosystems (Subsection 2.4.1) is recognised in academic literature but as a strategy for sustainable development, bilateral symbiosis deployed in circumstances such as exist in NSW has not been researched.

The issue of waste disposal rests on the horns of a dilemma. Maximising profit in the private sector mandates minimising the costs of waste disposal. Left untrammelled by environmental regulations, least cost options for manufacturers, such as dumping on their own sites or in landfill, typically pollute the natural environment. On behalf of society at large, governments regulate to protect and preserve the environment. When regulations become more stringent, as they are legislated to do in NSW, compliance becomes more costly and so the dilemma is magnified as manufacturers confront increasingly intractable situations (Section 8.5). It transpires from this research that the dilemma has not been resolved in NSW and if other jurisdictions introduce similar environmental legislation, the dilemma might proliferate and induce unintended consequences (Sections 1.4 and 9.2).

1.2 Manufacturing in NSW

The NSW Department of Trade and Investment NSW reported that manufacturing in the state accounted for 32% of national production and in 2007–2008 contributed A$35.1 billion to the state economy. The state is strong in food and beverage production, metal manufacturing, electrical and electronic equipment manufacturing, publishing and printing.[1]

There are several industrial areas in Australia that resemble the conventional scenario, modelled on Kalundborg in Denmark, where industrial sites are within close geographical proximity to one another (Subsection 2.4.1). Those studied by academics include Kwinana in Western Australia, Gladstone in Queensland (e.g. van Berkel 2005) and Synergy Park, west of Brisbane in Queensland (Roberts 2004). An 'eco-industrial park' was established in the late 1990s at Botany, near Sydney airport, comprising the disaggregated Imperial Chemical Industries (ICI) businesses.[2] Botany Industrial Park (BIP) is currently owned and operated by three different companies: Orica, which in 1998 acquired the operation of ICI Plc. in Australia and New Zealand; Qenos, a joint venture between Orica and ExxonMobil which was subsequently sold to China National Chemical Corporation in 2005 and Huntsman, which bought the surfactants business from Orica. This site is particularly interesting in the context of dissimilar industries constituting industrial symbiosis (Subsection 2.4.1). Symbiosis at the BIP is gradually increasing but only within the existing site.

Heavy industry in NSW is located predominantly in the substate regions of Illawarra, Hunter and greater Sydney (Figure 1.1). It may be feasible to develop conventional industrial ecosystems in these regions but as indicated below, even within them, sites are rarely close enough to operate (economic) fluid reticulation systems.[3] Manufacturing also occurs outside these regions, generally in the vicinity of 'transport hubs'; towns such as Albury, Orange and Dubbo but also in smaller country towns where there

1 NSW Department of Trade and Investment, 'Invest in NSW' at www.business.nsw.gov.au/invest-in-nsw.

2 www.oricabotanytransformation.com/?page=3.

3 The infrastructure of pipes conveying steam and water is a dominant feature of the situation in Kalundborg.

may be only one large enterprise, such as in Kurri Kurri[4] and Tomago (aluminium smelting) or Tumut (chip board production) or Berrima (cement clinker production). Just as significantly, the principal generic uses for waste, such as stock feed rations, soil conditioning, cement kilns and rehabilitating mine sites, are typically remote from the sources of waste.

Figure 1.1 – Substate regions and principal towns in NSW
Source: Google images

An indication of the likely distances involved is given in Figure 1.2. Road transport, preferably backloading[5] is invariably the only viable means of transport available for bilateral symbiosis. Rutherford et al. (1966) noted the steadily increasing importance of road transport, even though it was, in the 1960s, the most expensive mode over long distances.

4 This is not a 'typo'! Some place names in Australia have duplicate words, reflecting usage in the local Aboriginal languages. Kurri Kurri comes from the Awabakal language meaning 'the beginning' or 'the first'. Other examples in NSW are Wagga Wagga meaning 'the place of many crows' in the Wiradjuri language, which repeats a word to indicate plural and Woy Woy, believed to be a corruption of the Darkinjung language reputedly meaning 'big lagoon' or 'much water'.

5 Trucks that have delivered cargo on an outward journey, e.g. from the depot in a country town to Sydney, will often take a load back to their country depot for a lower rate that the outward journey, rather than returning empty.

Neither the Australian Bureau of Statistics nor any other source of similar information gathers data on manufacturing at the substate level, which could be used to support the empirical view that manufacturing sites in NSW are dispersed, isolated and in some instances, remote. However, industrial geographers studying trends in manufacturing after the Second World War provide insights to how the current situation developed.

Figure 1.2 Distances (km) between cities and major towns in NSW
Source: Hema Maps Pty Ltd 1997

Distance Grid

	Wagga Wagga	Tamworth	Sydney	Newcastle	Mildura	Grafton	Goulburn	Dubbo	Canberra	Broken Hill	Bathurst	Armidale	Albury
Albury													
Armidale													1006
Bathurst												527	466
Broken Hill											953	1136	913
Canberra										1104	292	853	345
Dubbo									447	751	202	453	553
Goulburn								360	93	1131	199	760	372
Grafton							842	658	935	1341	855	205	1214
Mildura						1457	832	809	805	299	819	1262	614
Newcastle					1201	473	369	430	462	1150	382	391	741
Sydney				174	1027	647	195	410	288	1161	208	565	567
Tamworth			455	281	1152	316	650	343	743	1026	417	110	896
Wagga Wagga		739	470	644	557	1117	275	423	248	901	322	876	130
Wollongong	416	536	81	255	973	728	141	491	234	1276	289	646	458

Rich (in Cardew et al. 1982) alludes to dispersion etc. in commenting on the inefficient organisation of manufacturing in Australia, due in part to spatial disaggregation. He discusses the influence of corporate headquarters based in Sydney or Melbourne and notes that they 'control the operations of branch establishments scattered across the country' (Cardew et al. 1982, p101).

Rutherford et al. (1966) note that processing industries are located close to the supplies of raw materials, particularly if those goods are perishable or significant weight is lost in processing. They mention that 'Because of these considerations, processing industries are widespread through the country towns of Australia' (Rutherford et al. 1966, p59).

These authors noted two other points, which are particularly significant in relation to bilateral symbiosis. Owing principally to relatively small domestic markets, there is a propensity for regional specialisation in manufacturing, notwithstanding the cost of long-distance road transport. Perhaps more significantly, they note a high degree of monopoly in the Australian economy 'for specialisation in a particular region may be due to the location there of the only manufacturer in the industry' (Rutherford et al. 1966, p366).

The concentration of ownership in transnational corporations (Cardew et al. 1982) is another trend that significantly affects manufacturing in NSW. These authors note that by the mid 1970s, approximately one third of all manufacturing in Australia was controlled by interests overseas. A consequence of this concentration is increasing vulnerability to closure in response to (economic) conditions in other parts of the world. Perhaps the most recent observations on the spatial organisation of manufacturing in NSW are made by Fagan (in Connell 2000), albeit in the relatively restricted context of the greater Sydney region. He notes, for example, that during the period 1950–70, manufacturing dispersed from the inner city suburbs, typically within about 10 km of Sydney's central business district (CBD), where it had been ensconced since the mid 1800s and where closer proximity might have been more conducive to industrial symbiosis. Outer 'industrial zones' were populated by industries needing the large sites that were available for expansion. These zones are typically 30–40 km from the CBD and separated from one another by similar distances. By the mid 1990s, these zones had become so densely developed that manufacturing dispersed once again but this time, to locations that in some cases are at least 100 km from the CBD.

These insights to trends in location, ownership and specialisation provide a theoretical basis for understanding how the current circumstances of manufacturing in NSW came about. A particularly significant feature, from the perspective of bilateral symbiosis, is that categories of manufacturing in NSW are generally represented by few participants. For example, there are two producers of soy milk, approximately 600 km apart; there is one manufacturer of yeast, two manufacturers of fibre cement building products and one cement kiln, in a rural town 100 km from Sydney. Opportunities are rare to consolidate waste from various sources to achieve critical mass for use. An effect of 'globalisation' is that the range of manufacturing in Australia is diminishing (in line with trends observed by Cardew et al. 1982). Labour-intensive industries in particular are being moved offshore to countries that have lower labour costs.[6] This trend

6 For examples, at the end of May 2011, Heinz announced the closure of its fruit processing plants in Victoria, NSW and Queensland. Approximately 340 jobs will be lost and the operations moved to New Zealand where labour rates are lower. In April 2010, Bridgestone closed the last remaining tyre

diminishes opportunities in manufacturing to use waste. It seems logical to correlate less waste with less manufacturing. While this may be true of *production* waste, it is not true of waste overall. Consumption continues as usual but materials and products are increasingly imported to replace lost domestic production. Other forms of waste therefore increase, such as packaging. A particular example is the flexible intermediate bulk carrier (FIBC),[7] which has a capacity of approximately a cubic meter and is used to transport any dry material. They are made of polypropylene, nylon and polyethylene in various combinations. When market prices of such materials are high enough, used FIBCs are re-exported to countries like China for re-use; otherwise they are dumped, as is currently (2011) the case because they cannot be re-used economically in Australia.

1.3 Government regulation of waste

There are six state governments in Australia, two territory governments and one federal government. Each state and territory government enacts environmental legislation with respect to its own jurisdiction. Appendix 1 illustrates the variation between jurisdictions, using respective definitions of waste as an example. The federal government has no environmental jurisdiction over the states or territories.[8] It does have limited powers in its federal jurisdiction to 'facilitate' national initiatives such as producer responsibility for e-waste, but only in cooperation with the states and territories (Australian Government National Waste Policy 2011). Regulation in NSW is the most stringent of any jurisdiction in Australia. It may restrict the options for disposal[9] and imposes the highest costs for landfill. The levy in the Sydney Metropolitan Region (July 2011) for dry landfill is A$82.20/tonne and for the extended regulated regions such as the Illawarra and Hunter (Figure 1.1) the levy is A$78.60/tonne. The levy for traceable liquid is currently A$64.50/tonne.[10] Levies in NSW have been legislated to increase by approximately 10% compounded every July until 2015. All levies in NSW are paid into consolidated revenue rather than being allocated directly to initiatives that facilitate using waste, although programs such as Sustainability Advantage are supported (Subsection 7.4.2). In comparison, levies in Victoria for

---

manufacturing plant in Australia at the cost of 600 jobs because the business was uncompetitive internationally.

7 Commonly called a 'bulk-a-bag'.

8 However, in accordance with s109 of the Australian Constitution, Commonwealth legislation will prevail over that of the states in circumstances where valid jurisdictions overlap.

9 For example, green waste (vegetation) and other organic waste may be banned as landfill.

10 Current information available at: www.environment.nsw.gov.au/wr/index.htm.

industrial waste are A$38.50–44/tonne depending on location.[11] All revenue from levies in Victoria is allocated directly to initiatives that facilitate the use of waste and to similar environmental projects. On 1 July 2011, Queensland introduced a levy of A$35/tonne on industrial waste; there will be no levy for municipal waste.[12]

An explicit objective of the NSW government's strategy on industrial waste is to create an incentive for manufacturers to find uses for their waste. The pressure is exerted by continually increasing the levies for dumping. The underlying assumption is that manufacturing is analogous to a natural ecosystem, as suggested by the metaphor of industrial ecology, and as such, is generally interpreted to mean that all waste can be used. This interpretation has created perhaps one of the most insidious and intractable problems for manufacturers. In contrast to the interpretation, not all waste produced in nature is used. For example, iron ore, fossil fuels and chalk are the waste products of ancient ecosystems (Ayres 2004). It may not be possible technically to use *all* the waste arising from manufacturing, let alone to do so effectively or before 2015 when the current legislation will be reviewed. Nevertheless, there will be no reprieve from the levy for waste that simply cannot be used, given current knowledge and practice; a truly intractable problem for manufacturers!

Government attention to industrial waste has the effect of converting the environmental problem into an economic one. Unless dumping waste is avoided, the increasing costs of waste disposal will diminish profits and hence impair the competitiveness of manufacturing. In view of the responsibility on generators to deal with their waste, their position and attitudes are germane to solving the problems of its disposal. My experience has been that manufacturers have generally not regarded waste disposal as part of their core business. Given the relatively low cost and ease of waste disposal historically, they choose not to allocate the people or capital required for any other purpose than to 'outsource' the function to waste management contractors and the like. However, prospects for the future are likely to stimulate new strategies. One, for example, is to re-locate to a state in which the regulations are less stringent or overseas where the advantage might be enhanced by cheaper labour. Others are to minimise the generation of waste and/or find uses for what is produced, both entirely within the purview of industrial ecology (Section 2.3). In practice, if not in theory, there will likely be a limit to the extent that some waste streams can be minimised so a premise of this research is that generators will continue indefinitely to produce waste for which they will need to find a use, or face increasing restrictions on disposal and associated costs.

11 Current information available at: www.epa.vic.gov.au/waste/landfill_levies.asp.

12 Current information available at: www.derm.qld.gov.au/services_resources/item_details.php?item_id=205878.

The issue of using waste was approached originally from the perspective of its generator, being the agent of its creation and responsible for its disposal. As research progressed, it became apparent that the perspective of other actors who have the potential to achieve satisfactory results by operating in place of, or on behalf of, the generator should also be understood. What began as applied research (Chapter 3) transfused into an assessment of the conditions necessary for instigating effective bilateral symbiosis.

1.4 The problems of waste disposal

Legally disposing of manufacturing waste generally entails dumping solid materials and substances as landfill or discharging liquid to sewer. Some intractable waste may be stored indefinitely pending an acceptable means of disposal. Principal factors influencing disposal can be identified from the perspectives of government, manufacturing, the waste disposal industry and society at large. They are summarised here in relation to NSW and discussed in Sections 8.3–8.5.

The *Protection of the Environment Operations Act 1997* (*POEO*) and its amendments in 2005 and 2008, confer on the Department of Environment, Climate Change and Water (DECCW)[13] a statutory obligation to protect the environment. In DECCW the Waste Management Section of the Environment Protection and Regulation Group (the regulator) is primarily responsible for meeting the obligation. In attempting to control the disposal of waste, the regulator has defined waste (Appendix 1) to include every conceivable form of 'matter'. Notwithstanding some 'matter' can be used, it is nevertheless included in the definition of waste. The strategy is to categorise the waste, set regulations pertaining to each category and specify general exemptions from the regulations for materials and substances that are not considered injurious to the environment. A manufacturer may apply for a specific exemption of its waste from the regulations under a provision known as a 'resource recovery exemption'. Anecdotal evidence from both the regulator (Section 6.2) and from industry (Subsection 7.3.4) indicates the procedure is protracted, expensive and frustrating for both sides. There is also within DECCW the Sustainability Programs Division, whose mandate includes implementing measures that enhance the efficiency and longevity of manufacturing in the state. A program has been established under the mandate called Sustainability Advantage, which provides services to large and medium size organisations.[14] The program is not oriented specifically towards using waste but assistance, limited to

13 With the change of state government in March 2011, DECCW became the Office of Heritage and Environment in the Department of Premier and Cabinet (see last paragraph of this chapter). This note is reiterated, as a reminder, in other parts of the thesis.

14 Defined as having a workforce of at least 40 employees.

consulting services, could be provided (Subsection 7.4.2). As mentioned in Section 1.3, landfill levies are paid into consolidated revenue. The government perspective on waste is seen to be inherently conflicted. The regulator within DECCW is protective, controlling and resists change. The treasury is acquisitive, parsimonious and resists change which might reduce revenue. Programs run by the Sustainability Division of DECCW are intended to instigate change which will likely reduce revenue from landfill levies. The division cooperates proactively with manufacturers to mitigate environmental damage, which is atypical of the regulator or the Treasury.

The perspective of manufacturers is seemingly uncomplicated in principle but is fraught with difficulties in practice. They must comply with the regulations and minimise costs. Manufacturers must also be cognisant of how they impact local neighbourhoods and society more generally. With regard to minimising costs, waste reduction[15] and improving operations such as handling, processing and storing waste on site are primary strategies. Transportation costs might be reduced by de-watering, drying, compacting and segregating waste. However, most strategies have disadvantages such as increased management burden and the exigencies of capital funding (e.g. Subsection 8.3.2). Managers tend to focus on daily operations, to the detriment of ancillary projects, medium-term planning and innovation. There is a propensity to 'outsource' capability. So, in the case of waste, the problems are passed on to another company, most likely a waste management contractor (Subsection 8.3.3) and management capacity to address them 'in-house' is reduced accordingly. These conditions represent a paradox: notwithstanding corporate rhetoric about increasing shareholders' wealth, managers in practice are more likely to *increase costs*, by outsourcing than they are to increase their *workload* by undertaking tasks, 'in-house'. If this were true generally, the 'finding' has a significant bearing on the systematic deployment of bilateral symbiosis.

Waste management companies are an indispensable component of disposal systems in Australia and their influence is significant. Those most relevant to this research comprise the four national operators whose principal interest continues to be earning revenue from *transporting* waste (Subsection 6.3.1). Some own tip sites and infrastructure[16] but the 'main game' is transport and associated services such as bin hire. As recipients of manufacturers' problems mentioned above, these companies have no formal capacity and scant informal capacity to deal with waste, other than to dump it (Section 6.4). Furthermore, none plan to exploit opportunities to instigate bilateral

15 Waste reduction, for example by designing for the environment or dematerialisation (Section 2.3.1) is a broad topic in its own right and is beyond the scope of this research.

16 Which is practically all of it since the NSW government sold Waste Services NSW to SITA at the end of 2010 (Section 6.3.1).

symbiosis (Section 6.4). An inference from these perspectives of the private sector is that the type of organisation manufacturers are most likely to enlist for assistance in minimising their costs of waste disposal has vested interests which militate against doing so.

The social dimension of the general problem with waste is still emerging but its influence is already a significant consideration when determining its fate. The NIMBY[17] syndrome influences what can be done with waste. Producer responsibility[18] imposes long-term contingent liabilities on manufacturers that may require them to re-possess products which then constitute waste. Product recall[19] can be particularly devastating if it is on a sufficiently large scale.[20]

Summarising circumstances in NSW from the manufacturers' perspective: they have a burgeoning problem disposing of waste; options are restricted; dumping costs will increase, expressly to stimulate alternative uses but there are apparently no effective resources available to do so.

1.5 Approach to solving the problem

The circumstances summarised above raise the question of what can be done to systematically use waste instead of dumping it. One possibility considered originally was that each generator would solve its own problems, given the wherewithal to do so. Another was that similar results could be achieved by intermediaries acting to facilitate bilateral symbiosis, as Qubator had done but on a larger scale.[21] In conjunction with each of these approaches, academia was canvassed for a solution. Literature on industrial ecology is broad and the topic of industrial symbiosis is especially apposite. Other

---

17 NIMBY – 'not in my back yard'.

18 A manufacturer's obligation to ensure satisfactory disposal of their products once they are taken out of service.

19 Products that are discovered after sale to be defective may have to be 'recalled' by the manufacturer. They may be returned to the manufacturer's custody or otherwise destroyed, at the manufacture's expense.

20 For example, in March 2000, as a result of criminal contamination beyond its control, Heron Pharmaceuticals recalled lines of capsules nationwide and ceased production for three months while a new production line was installed.

21 It is noted that this research began in the same year (2005) as the National Industrial Symbiosis Programme (NISP) in the UK (Section 7.4.1) was set up nationally. NISP is now a preeminent example of facilitated bilateral symbiosis but in 2005 it was relatively unknown and neither sufficiently well established nor developed to be a model for the approach (see Environmental Technologies Action Plan Newsletter Issue 12, September 2008.).

possibilities which emerged during the period of this research are the Sustainability Advantage program run by the NSW government (Subsection 7.4.2) and the Australasian Industrial Ecology Network (Subsection 7.4.3).

1.5.1 Hypothesis – Phase 1

The original aim of this research was to test three hypotheses emanating from the first of these approaches and based on the proposition that it represented a least cost option. The first hypothesis is that manufacturers would find uses for their own waste, using the strategy of bilateral symbiosis, provided they had the necessary knowledge and skills, in house. The strategic implication being that if such ad hoc arrangements were undertaken ubiquitously at the organisational level of day-to-day operations then the results would in effect be systematic throughout the state. A corollary is that if this approach were successful in NSW then it might be applicable in other jurisdictions with similar conditions. The second hypothesis is that bilateral symbiosis can be facilitated successfully by an intermediary.[22] The third hypothesis is that government, through regulation, exerts a dominant influence on the feasibility of bilateral symbiosis. Phase 1 of this research addressed the first of these hypotheses. The intention was to subsequently test the second in a similar way and the third by means of a survey. No organisation agreed to participate in fieldwork so Phase 1 was abandoned at the end of 2007 (Section 3.3 *et seq.*). As a result, research was redirected towards a collective perspective rather than the operations of individual manufacturers. The second and third hypotheses were converted into research questions about the views and circumstances of generators in relation to the legislative environment in which they operate and the facilities available to them for instigating bilateral symbiosis. The methodology changed correspondingly from case studies to other, fundamentally different, research techniques in human geography.

1.5.2 Research questions – Phase 2

The principal question underlying Phase 2 is whether or not a systematic[23] process is feasible in NSW by which dumping waste can be avoided. Four dimensions of 'feasible' are noted in this context. From the generator's viewpoint the regulatory and the financial dimensions dominate (Section 6.2). The dimensions of environmental and of social acceptability are gaining increasing sway over corporate behaviour[24] but are

22 An organisation involved in the 'transaction' (as a facilitator, rather than as a transporter) other than the principals i.e. the generator and the user.

23 Systematic as distinct from ad hoc or opportunistic.

24 Consideration of environmental and social factors may feature in corporate rhetoric but they do

seemingly not yet strongly influential factors. A focal question addressed in this phase is: can theoretical industrial symbiosis be adapted to provide a practical process, given the particular conditions prevailing in NSW? One possible answer is facilitated bilateral symbiosis but this in turn raises questions about regulations conducive to the process, the capacity of manufacturers to participate and their incentives to do so (Section 4.2).

1.6 Scope of research

This research relates to solid or fluid manufacturing waste which is dumped as landfill or discharged to sewer or stored pending an approved means of permanent disposal. The cost of these options is likely to be high enough to induce a generator to avoid them and hence resort to bilateral symbiosis for disposal. However, results might also apply to other waste, such as involuntary emissions of heat to the atmosphere, provided the benefits are sufficient. Similarly, they might apply to a generator who dumps waste illegally but considers bilateral symbiosis a better strategy than incurring penalties if discovered by the authorities. The positionality of manufacturers and the regulator is a focal issue because they are the dominant actors in the context of using waste. Interviews were conducted with representatives of major waste management contractors because their business strongly influences the fate of waste. The scope does not include social issues relating, for example, to the influence of community values on waste disposal[25] or the conundrum of what causes a manager to be strongly sympathetic towards the environment while 'at home' yet be nonchalant about it at work (Section 9.4). The scope also excludes such issues as the implications of life cycle analysis on using waste (Subsection 2.3.2). Other researchers have dealt with such topics and my business experience is that manufacturers' decisions are rarely influenced by environmental or social considerations so it was decided to concentrate resources on factors known to strongly influence management decisions.

1.7 Conceptualising waste

Waste from manufacturing is conceptualised for this research in terms of its definition, its typology, its use and the sustainability of use. Definitions are derived from different perspectives for various reasons. As noted previously, examples are given in Appendix 2 to illustrate the diversity of meanings and purposes. As Knight points out:

---

not seem to significantly influence what happens in practice at the management level where day-to-day decisions are made about waste disposal. At this level, complying with regulations and minimising costs are all that matter.

25 For example: the debate about engineered fuels versus incineration.

> There is a plethora of physical, social and legal definitions of waste. Wastes may be identified by their physical properties, the way they were created, where they were created, their impact on the environment, or their lack of purpose. At the simplest level, waste is *unwanted material* (matter or energy) that is *discarded.* (Knight 2009, p423, original emphasis)

Manufacturers might use epithets for waste such as 'byproduct', 'recoverable resource' and 'residue' in an attempt to avoid attention or the burden of disposal imposed by regulators, a futile subterfuge given the comprehensive definitions of industrial waste used by regulators (Appendix 1). The definition that *really* matters to manufacturers in NSW is that given in the regulator's guidelines. This concludes with the statement that:

> A substance is not precluded from being waste for the purposes of this Act merely because it can be reprocessed, re-used or recycled. (NSW Government DECC – Waste Guidelines 2007, p117)

In the context of this research, waste is designated as such specifically and exclusively from the perspective of the generator; notionally the manager responsible for the site where waste is held. From this perspective, waste is defined along the lines suggested by Knight (2009). It is taken to mean any form of substance, matter or thing possessed by the generator that is not wanted and is to be discarded from site. This definition is intended to include a substance etc. which cannot be used or is allowed to escape from the site or the regulations require it to be removed from the site. The physical (legal) boundary of the site controlled by the generator *does not* represent the spatial limit of this definition. That is to say, waste designated within the site boundary continues to be waste beyond the boundary until custody is transferred to a user (Subsection 1.7.1). Crossing the site boundary represents a point at which the character of waste may change (Subsection 1.7.1). The generator is (deemed to be) responsible for custody of the waste and must exercise a duty of care in its creation and disposal.

This definition is thought to be generally consistent with responsibilities that might be imposed on generators as occurs for example in the UK.[26] Two characteristics of this definition are noted. One is that waste is personal; a person designates it as such, a person is responsible for its (safe) custody and a person decides its fate. Waste is essentially a personal issue, even though people may be employed by an organisation in which responsibility is amorphous and anonymous. The other characteristic is that the origin and nature of a substance etc. that entered the site have no bearing on its subsequent designation as waste. This means, for example, that an input to a process,

26 NetRegs at www.netregs.gov.uk.

which may have been treated as waste by the organisation from which it was obtained, would not be classified as such by the user, merely because it was previously so classified. It would only become waste again if the user subsequently wanted to discard it. These characteristics are relevant to the classification and uses of waste, outlined below.

Two categories of waste are identified within this definition: *voluntary* waste is deliberately discarded by the generator. It might include, for example, raw material that is surplus or out of specification, scrap arising during production, finished product that has been condemned before shipment to market, and obsolete or condemned product returned to the manufacturer after market. Voluntary waste might also include equipment and machinery that has been taken out of service. *Involuntary* waste is any form of matter[27] or energy such as heat or sound which is emitted into the atmosphere or otherwise escapes from the site into the environment, beyond the control of the generator. This category includes accidental as well as operationally normal, though unavoidable occurrences. This research concentrates specifically on voluntary waste because it is more likely to be usable than involuntary waste, given the dispersed nature of manufacturing in NSW.

1.7.1 Typology of waste

From the perspective of the generator, waste may be conceived as having a commercial dimension represented by three notions of value. One is the notion of a 'negative' value, in effect, the costs of disposal incurred by the generator. Another is the 'intangible' value which the generator might perceive to be derived from a particular course of action, such as enhanced reputation for environmentally responsible behaviour. The third is the notion of market value that is the price a user would be willing to pay for the waste. Whereas waste has been defined from the perspective of the generator, this typology invokes the perspective of a *user*. The typological criterion is *demand*, represented by the extent to which waste can be actually or potentially *traded*. In this context, 'traded' means that payment is made by one party to another, so that the waste is used, as distinct, for example, from merely being processed in preparation for dumping. The user might pay nothing for the waste or might even be paid to receive it but one way or another, payment is made, according to the notional values mentioned above. The notion of an established market simply means there is at least one recognised use for the waste, which is proven to be satisfactory. On this basis:

- *Un-tradeable* waste has no known potential for or possibility of being used, given the technologies currently available. Its disposal is financed by its negative value.

27 Generally a fluid or a suspension of solids in a fluid such as smoke.

- *Tradeable waste* could possibly be used, given the technologies currently available but it is nevertheless dumped because the negative and intangible values are not sufficient to finance its use.
- *Narrowly traded* waste is supplied in an established market comprising only a few users, if more than one. The trade may have to be financed but there is at least a use for the waste which avoids dumping and reduces the generator's costs of disposal.
- *Widely traded* waste is supplied in an established market comprising many users. Although the waste may have market value, it might not be sufficient to finance supply so, like narrowly traded waste, the trade may have to be subsidised.
- *A byproduct* is waste for which there is a continuous demand and for which the market value exceeds the cost of supply. The trade in byproducts does not have to be subsidised in order for it to take place.

1.7.2 Typology of use

Recycling has become what might be regarded as a generic term for using waste, which encompasses several fundamentally different activities. Segregating these provides a more precise understanding of what might be done with manufacturing waste.

Recycling occurs when waste is used in an unchanged (chemical) form in the same process from which it arose. Examples are crushed glass containers (cullet) used to make new glass containers and scrap metal used in foundries.

Re-use occurs when waste is used in an unchanged (chemical) form in a process from which it did not arise originally. Examples are crushed glass containers used to manufacture glass wool insulation or as 'manufactured' sand, granulated waste polypropylene containers used to make clothing.

Use occurs when the (chemical) form of waste is changed either before or during the process into which it is introduced. Examples are carbohydrate waste used to produce ethanol and effluent used as a soil conditioner.

Non-use occurs when waste cannot be used in any form and is consequently dumped in landfill or is stored indefinitely until an alternative means of permanent disposal is arranged.

1.7.3 Sustainability of use

Since the overarching context of this research is sustainability, the issue arises of what this means with respect to using manufacturing waste. From a practical perspective the meaning is an unambiguous, relative, finite concept, albeit indeterminate with respect to time. A sustainable 'arrangement' for using waste need only endure for so long as the waste is generated. The arrangement may comprise elements which cease to participate in the arrangement, before the waste ceases to arise, but provided there are adequate substitutes for those elements or they can be replaced so the arrangement can function indefinitely, it is sustainable with respect to that particular waste stream. From this interpretation of sustainability a proposition permeating this thesis is that achieving a sustainable use for manufacturing waste is a realistic prospect in practice.

1.8 Contribution to theory

Academic work on industrial waste concentrates on concepts and issues derived predominantly from studies of circumstances in north-west Europe and the USA (e.g. Gertler 1995; Schwartz & Steiniger 1997; Korhonen et al. 1999; Heeres 2004; Jacobsen 2006 and Posch 2010). Some characteristics of the industrial ecosystems in these locations differ critically from circumstances typical of manufacturing in Australia. The absence of close geographic proximity and anything even approximating the conventional concept of a network are examples of significant points of difference. Consequently, the conventional view of industrial symbiosis applies to a relatively few opportunities in Australia such as Kwinana or Gladstone (van Berkel 2005) and the Botany Industrial Park (Section 1.2) which has not yet been written about academically. By reverting to the basic mechanism by which long-established industrial ecosystems such as Kalundborg and Styria evolved (Subsection 2.5.5 *et seq.*) and applying that mechanism to manufacturing in NSW, this research shows that industrial symbiosis theory can be relevant to situations other than conventional industrial ecosystems. Factors were identified that are not canvassed prominently in academic literature but nevertheless exert a dominant influence on the fate of waste, for example, the role of the regulator and regulations (Sections 8.2 and 8.5), corporate capacity (Subsection 8.3.3), managerial agency, as distinct from corporate agency, (Subsection 8.3.4), and the external infrastructure (Section 8.4). The results of this study are likely to be relevant to countries where circumstances are similar to those in Australia, particularly developing economies comprising widely dispersed, small- and medium-sized enterprises (SMEs). This research is situated at the interface between theory and practice. It is thought that by linking the two through bilateral symbiosis, the former can assist the latter make a worthwhile contribution to sustainable development.

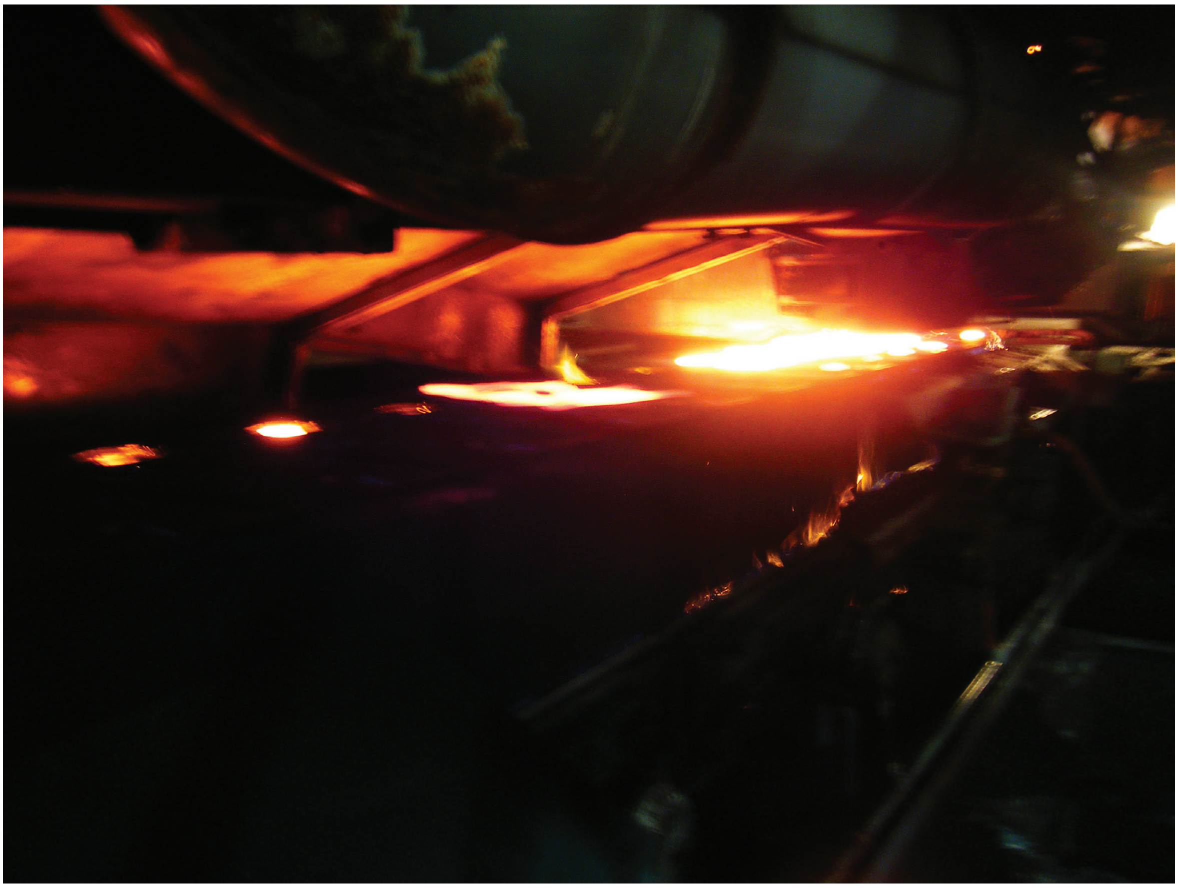
1.9 Structure of this thesis

Chapter 2 presents a general survey of the literature on sustainability and industrial ecology, as the underlying context for this research, followed by a more focused summary of industrial symbiosis, which is the topic most directly relevant to the study. Chapter 3 describes Phase 1 of the research; it sets out the methodology used to develop and test a set of procedures intended to be a rubric for implementing (autogenous) bilateral symbiosis. It presents the results of attempting to test the procedures and a discussion of those results. Chapters 4–7 cover Phase 2 in which more fundamental issues were studied than in Phase 1. Chapter 4 describes the various research techniques that were integrated to form the methodology. Chapters 5–7 present the results of applying those techniques. Chapter 8 presents a discussion of the results from both phases and the findings. Chapter 9 summarises the conclusions drawn from this research and suggests topics for further study.

During the six-year span of this research, the name of some organisations has changed. The name used in this thesis was current when the relevant research was being conducted. Where appropriate, a footnote elucidates the change.

Chapter 2

Literature review



Steel casting in the Automatic DISA Foundry, Sydney
Source: Qubator Pty Ltd

BTR engineering – DISA dust

Although the SPL project described in the vignette for Chapter 1 alerted me to the business potential inherent in arranging bilateral industrial symbiosis, it was not in itself typical. Eighteen months after that project collapsed, during which time Qubator had been unable to earn any revenue at all, the first opportunity to arrange true bilateral symbiosis was offered to me in September 1993, by the procurement manager of BTR Engineering (as it was known at the time) who was keen to reduce the disposal costs of their baghouse dust. The company is a steel foundry in Sydney, which uses the entirely automated DISA process to produce parts for automotive manufacturers. The plant creates a fine dust comprising mainly silica and carbon from the casting sand and various forms of iron from the castings. It also contained traces of some heavy metals. The material arose from dust collectors and was being dumped in landfill at the rate of about 20 tonnes per week. Significantly, it has a higher bulk density that would have been expected for such material.

One of the ironies of this project is that the procurement manager actually suggested to me how he thought the material might be used. I immediately canvassed his suggestion and within six weeks, having completed trials, arranged transport (for the first time in my life) and negotiated commercial terms, supplies began to a site about 30 minutes from the foundry, door-to-door. I did not understand at the time why the procurement manager had not made these arrangements himself, particularly as Qubator was paid by the foundry to dispose of the waste and also by the user for supplying it. With a little more experience, I came to realise why he, like many other managers in manufacturing, preferred such arrangements to be made on their behalf. Some of the most salient reasons are canvassed in later chapters of this thesis.

The company using DISA dust was Dynamic Lifter, a successful, privately owned company, which specialised in collecting chicken litter from egg producers and converting it into pelletised fertiliser. Their interest in the dust was as a filler for exported product: they could increase their container loading capacity from 18 tonnes to 20 tonnes, at very little extra cost but for a significant increase in profit. This application was so successful from their point of view that I was asked to find similar material in Western Australia for their operation in Perth. However, it transpired that while these arrangements were being established, the sale of Dynamic Lifter was being negotiated secretly with Yates Ltd, a national conglomerate dominant in the agricultural, horticultural and domestic gardening markets. The purchase was completed by the end of December 1993 and supplies of DISA dust were suspended on 15 January 1994. Yates had established a ‘marketing pitch’ along the lines that its products, which now included Dynamic Lifter, were 100% organic. Since DISA dust is predominantly inorganic, it could no longer be used as a filler. The project collapsed instantly – almost. A week after supplies were suspended the new general manager of Dynamic Lifter called to ask me what I wanted done with the stockpile of more than 140 tonnes of DISA dust the previous owners had accumulated! I explained that it was all his, since the material had been paid for but I would be willing to find a use for it. We negotiated a fee for Qubator and within a month the entire stockpile had been transferred to a composter. However, the opportunity did not end there; the composter wanted to know what he should do with 140 empty bulk bags, which had contained the DISA dust. Having by then embarked on another project to find a use for stainless steel swarf from BHP Steel at Port Kembla, about 150 km south of Sydney, I sold the bulk bags to a scrap metal merchant to whom I was supplying the swarf for export to Japan. By that stage the DISA project really was dead; though perhaps not a complete failure.

2.1 Introduction

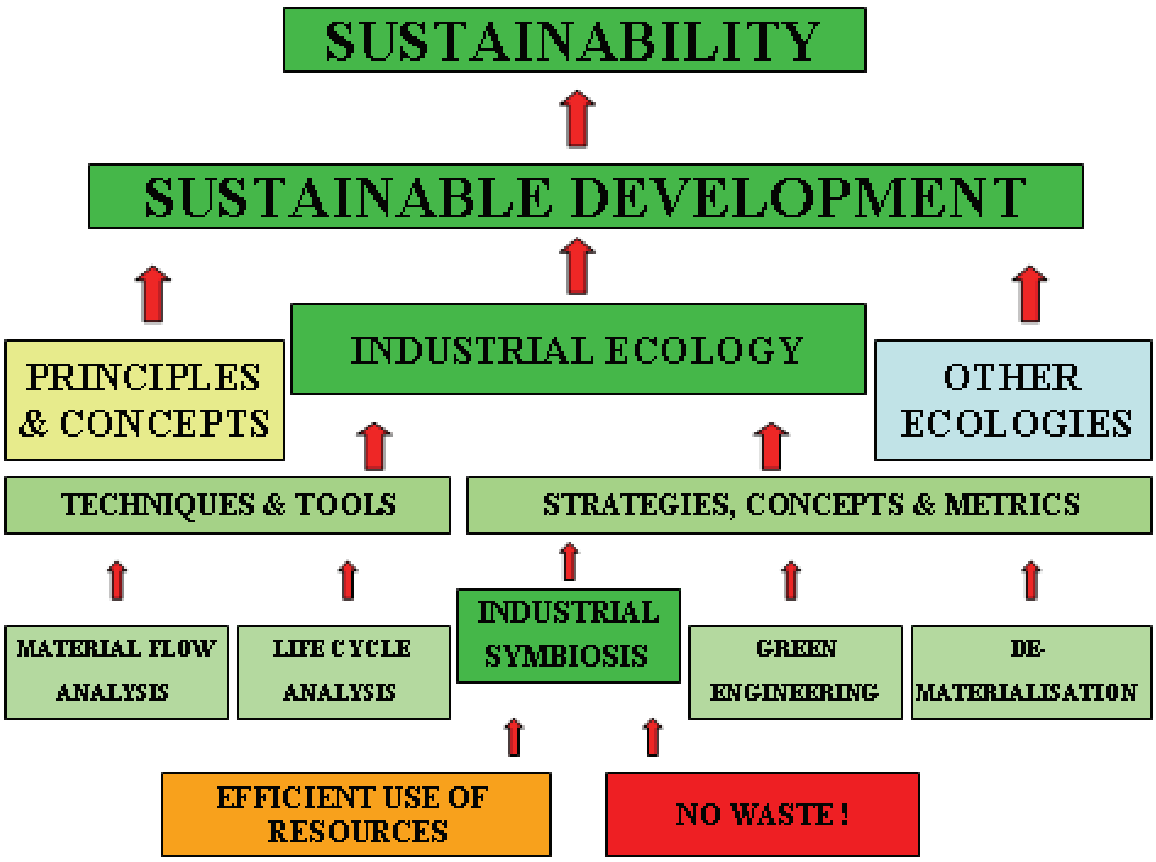
A central issue of this thesis is how manufacturers in NSW might meet the challenge of finding uses for their waste; a task imposed by the environmental regulator (Section 1.4) apparently without regard to how it might be achieved in practice. The issue guided a search for theory and other academic work that could contribute to its resolution. In this respect, reviewing the literature in 2005 was undertaken primarily to discover knowledge that might contribute to solving a problem in practice, which in turn might then contribute to theory, rather than to identify an opportunity per se to augment existing knowledge. An initial review of the literature concentrated on government regulations, to establish the scope of the problem and strategies for dealing with waste within the ambit of recycling and industrial symbiosis. Methods, such as systems analysis, for developing and testing the procedures in Phase 1 were also reviewed. The transition to Phase 2 at the end of 2007 broadened the range of topics brought into the purview of this research. From a theoretical perspective issues arose such as corporate behaviour, trust and the capacity of a 'society' in general to facilitate the use of waste. From a methodological point of view, the techniques used in human geography for gathering and analysing data were applied in Phase 2 which represented a radical change from the methodology used in Phase 1.

From an academic perspective, three topics are at the core of literature relating to industrial waste. Ultimately the issue is anthropocentric sustainability, achieved notionally by sustainable development. Industrial ecology contributes to sustainable development from the standpoint of industry. Studies from the standpoint of other perspectives such as political ecology, urban ecology, environmental economics and demography also contribute to sustainable development, as do various general principles and concepts. The literature on recycling and industrial symbiosis comes within the ambit of industrial ecology and is more directly relevant to the issue of waste. All three topics are relatively young, none being prominent in the literature or in practice until the 1970s, which may account for the apparent lack of coherence among them. These and the ancillary topics which impinge on this research and surveyed in this chapter form, conceptually, a 'nimbus' of knowledge for which no integrating structure has emerged from the literature itself. The topics are therefore organised in two groups: the core topics mentioned above in one group are followed by the ancillary topics in the other. This review of the literature has a chronological dimension which relates it to events that occurred during the six years of this study. A case in point is the emergence of the National Industrial Symbiosis Programme (NISP) in the UK (Subsection 7.4.1). After a pilot trial in 2003, a national roll-out started in 2005, the year this research began. Academic literature about NISP became available in 2004 (Mirata 2004) and a comprehensive account of its success was made available in a publication by NISP, itself: 'The pathway to a low carbon sustainable economy' (Laybourn & Morissey 2009). Had this information been available five years earlier, the focus of this research may well have been different, though the principal findings would have been much the same because they relate to fundamental conditions rather than transitory events.

The major topics of sustainability, industrial ecology and industrial symbiosis are presented below, in sections comprising an overview of the concept, a brief history of its evolution, its salient characteristics and relevant issues. Section 2.5 is a discussion of the literature that integrates these three sections and considers their implications for my original research.

The relationships suggested in this review between the three core topics are depicted in Figure 2.1.

Figure 2.1 – Elements contributing to sustainability



2.2 Sustainability

Sustainable development may be viewed as the primary purpose of industrial ecology. Certainly, notions of sustainability underlie the relevant environmental laws and regulations in NSW that set the options for disposing of manufacturing waste. It seems appropriate, therefore, to give a synopsis of sustainability before reviewing the literature on industrial ecology and industrial symbiosis. The term 'sustainability' means also 'sustainable development' in this chapter, except where a distinction has to be made in a particular context. Where they are differentiated, Harding's explanation (2006) applies: ' "sustainability" refers to the ultimate goal or destination … "sustainable development" is the path or framework followed to achieve it' (Harding 2006, p233).

2.2.1 Conceptualising sustainability

There seems to be no generally accepted explanation of what sustainability actually is. There are myriad definitions (e.g. Murcott 1997; Garde et al. 2007) but scant commonality beyond a vague understanding that the natural environment cannot cope with the current exigencies of human activity. Perhaps the most cited source is a report by the World Commission on Environment and Development (WCED): *Our common future* which contains the following passage:

> Humanity has the ability to make development sustainable – to ensure that it meets the needs of the present without compromising the ability of future generation to meet their own needs. (Brundtland 1987, p8)

This passage has been quoted by myriad academic, political, professional and corporate authors as *the* definition of sustainable development. The passage continues:

> The concept of sustainable development does imply limits – not absolute limits but limitations imposed by the present state of technology and social organisation on environmental resources and by the ability of the biosphere to absorb the effects of human activities. (Brundtland 1987, p8)

The complete paragraph seems more a statement of human ability and environmental capacity than a definition of sustainable development. Nevertheless, the first passage cited above seemingly initiated awareness, globally, of the inalienable relationship between the environment and sustainable development (e.g. Erkman 1997).

Kidd (1992) points out that the literature on sustainability 'is so voluminous that full analysis is not practical. And if it were, it would probably not be worth the effort'

(Kidd 1992, p3). Nevertheless, the notion of sustainability is fundamental to so much academic thinking about industrial ecology that at least an attempt to conceptualise it is necessary. Accordingly, the approach in this review is to examine the origin of definitions, rather than attempting, for example, to compile an annotated, representative catalogue. Important articles by Mebratu (1998), Kidd (1992) and Faber et al. (2005)[1] have been selected for this task. Each explains an approach to conceptualising sustainability and when grouped together, they appear to summarise a wide range of contemporary views. Definitions are central in each approach, probably because, as Faber et al, noted 'On the one hand, definitions form the foundation of reasoning. On the other, definitions can seriously limit its scope' (Faber et al. 2005, p13).

Mebratu gives an historical context for modern approaches to sustainability. In recent history, he identifies a 'conceptual breakthrough' made in 1980 by the International Union for the Conservation of Nature (IUCN) which formulated its World Conservation Strategy: *Living resource conservation for sustainable development*. This work introduced the dimension of time to the debate on conservation. The next major event for sustainability, according to Mebratu, was the WCED (Brundtland) Report in 1987.

Mebratu traces the evolution of thinking about sustainability by categorising definitions according to the source of a problem or crisis, the core approach to dealing with it, the scale at which it is addressed, what he calls the 'solution platform', the key instrument for the solution and the main drivers of the conceptualisation effort. One category is the 'institutional version' which includes definitions by WCED, the International Institute of Environment and Development (IIED) and the World Business Council for Sustainable Development (WBCSD). These exemplify the exigence of satisfying human needs construed in a wide spectrum of interpretations and established interests. Another category comprises definitions which Mebratu suggests are derived from ideological perspectives; predominantly the environmental versions of classical ideologies such as liberation theology, radical feminism and Marxism. He also identifies hybrid theoretical positions derived from these, including ecofeminism, ecosocialism and ecotheology. Mebratu concludes that despite these hybrids having different roots in liberation theory, the structure of their various definitions is similar: they identify a cause of the problem, there is an ideological basis for a solution and a clear perception of which groups of actors (should) provide leadership in dealing with sustainability.

Mebratu's third category comprises definitions from academic perspectives, represented mostly by conceptualisations in economics, ecology and sociology. The economic perspective is based on neoclassical theory, which treats the environment as

1 Except for specific passages, further references to these articles will be by name only for brevity.

a commodity that can be analysed like any other conventional commodity. The principle underlying this approach is that, historically, using the environment for economic purposes has been free of (monetary) cost or substantively undervalued. As a result, the environment has been abused and degraded. Rectifying this situation requires theoretical determination of an appropriate value for environmental 'products and services' which then are transformed into real-life prices by means such as taxation, subsidising environmental improvement or creating markets for environmental goods and services.

The ecological perspective is based on the assumptions that if unperturbed by humans, ecosystems exist in homeostasis and that humans attempt to secure 'environmental goods and services' through deterministic intervention. Mebratu identifies two domains within the ambit of ecological theorising. Shallow ecology treats the problems without necessarily addressing the underlying causes or challenging the philosophical foundations of economic and political thinking. Deep ecology attempts to deal with these issues from the standpoint of biocentric egalitarianism rather than anthropocentricity.

Mebratu categorises definitions in relation to problems whereas Kidd takes a somewhat different approach, although there are underlying similarities. Kidd identifies six 'roots of sustainability' from which many definitions are derived. Three roots relate to the earth's capacity to support human life, the rest relate to development. For Kidd, the *ecological root* is arguably the most significant because ecologists have always maintained that the environmental consequences of human behaviour are potentially disastrous. Any given ecosystem can sustain a maximum population of the various species within it; exceeding a maximum will cause the system to return the population to sustainable levels. This root is epitomised by the concept of carrying capacity (Subsection 2.3.2).

The *resource/environment root* derives from the ever-growing demand for resources and the environment's capacity to provide the 'goods and services' required by increasing populations. Kidd's view is that emphasis shifted during the late 1960s from Malthusian considerations to concerns about environmental quality. This shift intensified during the 1970s. The issue of capacity is extended further to encompass the entire planet in formulating the *biosphere root*. As industrialisation progresses, focus has increased on global rather than local effects. The concept of 'intergenerational equity' (Brundtland 1987) emerged from this root.

The *critique of technology root* represents what Kidd sees as a counter-technology movement centred on a tenet that the predominant effect of technology is dehumanising and disorganising. Some observers in the late 1960s began stressing the pernicious effects of exporting technologies from industrialised to developing countries. Such initiatives supplanted long-established agricultural systems that required simple technologies, little energy and supported enduring social structures.

Concern about accumulating wealth and material possessions underlies the '*no growth – slow growth' root*. The exigencies of capitalism and accelerating (western) economic growth during the 19th century generated (social) values, attitudes and human costs that were increasingly questioned. Writers alluded to achieving sustainability by maintaining static populations and capital, which would not inhibit cultural, moral and social progress. This proposition was boosted during the 1970s by commentators including Nicholas Georgescu-Roegen (*The entropy law and the economic process,* 1971) who showed how the laws of thermodynamics mandate a steady state economy and Meadows et al. (*The limits of growth,* 1972) who forecast an environmental collapse globally brought about by overpopulation and degradation of the environment generally. Such prognoses were contested. Nevertheless, this genre of thinking was widely embraced, according to Kidd, and based on two assumptions: that there is a limit to growth and that a no-growth economy would promote superior ethical values and social goals. The sixth root is *ecodevelopment,* the essence of which conflates the social agenda and the political agenda with sustainability. The underlying idea is that social values are an inherent factor of sustainability.

Recognising the centrality of organisations in the industrially developed world, it seemed apposite to review a relevant perspective on sustainability. The contribution by Faber et al. was selected because they develop a fundamentally different approach to those of Mebratu and Kidd and one that discusses ideas, which are, I think, more broadly useful than simply for corporate analysis. Definitions[2] of sustainability relating to corporations are analysed rationally to yield insights on the formation of corporate policy, management practices and social behaviour. The authors developed a framework comprising three parameters. An *artefact* parameter describes *what* is to be sustained. It may be either an entity having tangible form or a concept. This dichotomy enables abstract notions such as relationships, mores and values to be considered as defining elements of sustainability. *Goal orientation – absolute/relative* relates to the type of sustainability being considered. It may be an abstract notion or a pragmatic alternative of relative sustainability. Faber et al. postulate that abstract thinking relates to some point on a continuum between circumstances that are un-sustainable and those assumed to be sustainable but are unknowable until the end point of the continuum. This interpretation of sustainability is the guiding principle for some commentators who advocate (discrete) action towards a series of objectives, imagined to lead

2 The authors mention that over 50 existed when they started the project in 2001.

ultimately to sustainability. Since the end state is unknowable, other commentators advocate achieving sustainability by incremental steps with the aim of improving conditions, relative to their previous state. The parameter of *behaviour interaction – static/dynamic* facilitates an assessment of how a definition of sustainability treats the various relationships between an artefact and its environment. Each relationship can change independently resulting from exogenous or endogenous forces or a combination of both. The authors assert that interaction between an artefact and its environment is an inalienable feature of sustainability which requires the artefact to adapt continuously within the limitations of its environment in order to be sustainable.

Contemplating this feature with regard to anthropocentric sustainability raises questions about what the relevant environment is for the artefact 'human species' and how that artefact should adapt. Answers might be drawn from diverse perspectives beyond the scope of this thesis but the precautionary principle (e.g. O'Riordan & Cameron 1994) is relevant to this research and is discussed below.

2.2.2 The precautionary principle

As implied above, the interaction between humans and the environment is intensifying with accelerating growth in populations and becoming more diverse with globalisation. Management of the interaction has to be increasingly coordinated around the world to be effective; the 'how' raised implicitly by Faber et al. (2005). In a sense, the precautionary principle provides a framework for coordination. Its underlying tenet of wise care and practice was established by the German socio-legal tradition rooted in the democratic socialism of the 1930s. By the end of the 1980s, six basic concepts had become enshrined in the precautionary principle. They are: preventative anticipation, safeguarding ecological space, proportionality of response or cost effectiveness of margins of error, duty of care or onus of proof on those who propose change, promoting the cause of intrinsic natural rights and paying for past ecological debt (O'Riordan & Cameron 1994). These authors point out that the principle is:

> rather a shambolic concept muddled in policy advice and subject to whims of international diplomacy and the unpredictable public mood over the true cost of sustainable living. (O'Riordan & Cameron 1994, p12)

Nevertheless, the precautionary principle focuses thinking on the environment as a system and the services it provides to support life. The precautionary principle rejects notions that such services are free, abundant and indestructible. It is inextricably intertwined with sustainability and, correspondingly, takes several forms. Strong sustainability puts great emphasis on adapting human behavior to the earth's natural systems. The corresponding strong form of the precautionary principle is exercised in total empathy with the natural world. The benefits derived from adversely effecting the environment are clearly seen as not justifying the resulting degradation so society pays a financial premium for being cautious. Weak sustainability assumes that human attributes such as technology, innovation and adaptation will compensate for environmental degradation but may include safeguards for irrecoverable ecological and biochemical processes. A correspondingly weak precautionary approach would rely on negotiation, based on the merits of 'playing it safe' and emphasising the attitude of 'wait and see' rather than imposing extra financial costs (O'Riordan & Cameron 1994, p21). The principle is generally invoked by government legislation or regulation at national or supernational level such as the European Union. Being multidimensional and ill-defined, the principle is applied in many different ways so its interpretation varies greatly. For example, the USA and Japan have seen it as a threat to free markets and innovation (Bodanski in O'Riordan & Cameron 1994); the European Union was ambivalent in that the principle is supported rhetorically but is not substantively reflected in legislation. Germany is an exception; the principle there is seen as an opportunity for greater federal government involvement in the social market economy and for developing new markets for such things as low-waste technologies, remediation, waste to energy and monitoring environmental conditions (Haigh in O'Riordan & Cameron 1994). As suggested in Figure 2.1, a theoretical framework by which industry can comply with these principles and contribute to sustainability may be provided by industrial ecology, depending on what that field of study is defined to be. This and related issues are canvassed in the next section.

2.3 Industrial ecology

The extent of literature on industrial ecology depends on how authors define the subject. Some suggest essentially a technical view, alluding to industrial metabolism, material flows and life cycles as the core of industrial ecology (e.g. Culaba & Purvis 1999; den Hond 2000; Bringezu in Bourg & Erkman 2003; Bailey et al. 2004). In this sense, the scope is relatively limited; however, other views such as those of Erkman (2001) perhaps led Seager and Theis (2002) to comment that:

> A broad review of the historical origins of the term shows that a myriad of [sic] definitions, descriptions and new terms have appeared, disappeared or reappeared in the literature – only to confuse experts and neophytes alike … a comprehensive literature review shows that there has been considerable uncertainty as to what IE is or should be. (Seager & Theis 2002, p225)

The phrase 'industrial ecology' invokes the question of what actually constitutes 'industry'. Texts about material flow analysis, eco-industrial systems and the like imply that 'industry' means manufacturing or a process such as generating power. Others extended the meaning to include extractive industries, agriculture, forestry or fisheries and even beyond those to tourism and transport (e.g. Erkman 2001). A comprehensive view is logical given that research on topics like carrying capacity, de-carbonisation and input/output analysis is typically done at a national or higher level. This review concentrates on the narrow meaning, given the research focuses on manufacturing waste.

In this research, industrial ecology is construed to be the study of human interaction with the natural environment, considered from the perspective of industry (derived from Seager & Theis 2002). Consequently, concepts relevant to the subject are diverse. The structure for organising this part of the review is modelled on Kidd's approach to categorisation but based on the idea of themes instead of his notion of *roots.* During the short history[3] of (modern) industrial ecology, four 'themes' have emerged. Demarcation between themes is flexible and the commentators might deal with several themes. For the purposes of elucidation, however, these themes are considered individually in this section. First, the theoretical theme covers concepts, insights from various metaphors, systems theory, dematerialisation and latterly,[4] complexity theory. Second, the utilitarian theme includes applications, case studies and organisation, design, policy formation and promulgating sustainability. Third, the quantification theme deals with metrics and data; finally the holistic theme includes literature reflecting the multidisciplinary nature of industrial ecology.

2.3.1 Theoretical theme

Metaphors

Industrial ecology grew from the work of systems ecologists in the 1950s that treated industry as part of the biogeochemical cycles (Kronenberg 2006). In 1989 Frosch and Gallopoulos invoked the metaphor of a biological ecosystem:

---

3 Generally recognised to have begun in the late 1980s, particularly with the work of Frosch and Gallopoulos, *Strategies for manufacturing* (1989).

4 A literature search done on 17 January 2011 of Wiley Online Library for articles about complexity in industrial ecology yielded 147 results of which less than 10% predated 2000. Complexity featured in a set of sessions at the conference of the International Society for Industrial Ecology in 2007 and a special issue of the *Journal of Industrial Ecology* in 2009 was devoted to the topic (Dijkema & Basson 2009).

> the traditional model of industrial activity … should be transformed into a more integrated model: an industrial ecosystem. In such a system the consumption of energy and materials is optimized, waste generation is minimized and the effluents of one process … serve as the raw materials for another process. (Frosch & Gallopoulos 1989, p144)

An industrial ecosystem became a generic concept as subsequent literature referred to precepts derived from the metaphor. For example, Harper and Graedel commented that:

> Considerable effort in IE focuses upon developing analogies between biological and industrial ecosystems … accordingly the cyclic use of nutrients in biological ecosystems is a quality often used as a vision for industrial ecosystems. (Harper & Graedel 2004, p435)

Some authors suggest that biological metabolism is the underlying metaphor and the gamut of industrial ecology (e.g. Bringezu in Bourg & Erkman 2003). The concept of industrial metabolism (e.g. Ayres 2004) is thought to provide insights to manufacturing sustainability by considering the uptake of energy and the flow of substances through an industrial system as comparable to a biological ecosystem absorbing solar energy and metabolising nutrients. Erkman points out though:

> Industrial ecology goes further; the idea is first to understand how the industrial system works, how it is regulated and its interactions with the Biosphere; then, on the basis of what we know about ecosystems, to determine how it could be restructured to make it compatible with the natural ecosystems function. (Erkman 2001, p531)

Korhonen (2001) uses the word *roundput* to connote the metaphorical process of biological ecosystems by which matter is recycled and energy is cascaded. As he discusses in his paper: 'the ecosystem principles that are considered in the IE analogy include *roundput*, *diversity*, *locality* and *gradual change*'. (Korhonen 2001, p254, original emphasis).

The biological metaphor has been criticised from several points of view. Ayres (2003) criticises it on the economic grounds of labour, markets and currency, none of which have any counterpart in nature. Tansey (2006) is similarly critical of the ecological metaphor in terms of the restrictions it imposes on development. He contends that emphasis on design is the more crucial factor (Subsection 2.3.2). A somewhat different line of enquiry is taken by McManus and Gibbs (2008) in their analysis of the tropes relating to industrial ecology. They consider the practical implementation of industrial ecology, as manifested in the form of eco-industrial parks and examine the extent to which development of the latter may have been inhibited by misinterpretation or inappropriate application of the former. They reach the conclusion that:

> there is a substantial gulf between the perceived potential of this concept [industrial ecology] and its implementation (Gibbs & Deutz 2007). This disjunction occurs because the tropes are flawed, and we would argue that their benefits in the development of theory are overshadowed by their weaknesses. (McManus & Gibbs 2008, p536)

It is noted that the ambit of industrial ecology suggested by McManus and Gibbs seems more akin to the notion of industrial symbiosis (Section 2.4) than to the concept of industrial ecology outlined in this review. Nevertheless, these insights accord with some observations on apparent trends in thinking about industrial symbiosis (Section 8.8) and are particularly interesting, given their reflection on what happens in practice, which is a principal focus of my research.

Wells (2006) questions the validity of using the metaphor to imply that humans are embedded in the natural world when they alter it to the extent they do. An unusual aspect of Wells' critique illustrates how the metaphor is used selectively. For example, parsimony is an underlying tenet arising from the metaphor construed to imply that resources should be optimised and waste minimised. However, profligacy is the basis of some ecosystems that would not exist without it. Wells cites the range of life supported by the chronic excess of acorns produced by an oak tree and suggests that on this basis, a logical inference of the metaphor is that waste should become institutionalised. He criticises industrial ecology more generally. From an economic perspective, he points out that it has not tackled the issue of 'structure, ownership and control of financial capital'. He states that 'There is nothing within industrial ecology that allows economic rationality to be challenged' (Wells 2006, p123).

Wells also raises the issue of the detrimental influence that scientific rationalism has on industrial ecology. For several centuries the physical world has been studied in arbitrarily separated disciplines which results in fragmented knowledge. The schema inhibits an understanding of interconnectedness, which is fundamental to the metaphor of industrial ecology. For example, it does not permit the assimilation of contributions from other systems of knowledge such as the emotional and spiritual aspects of human relationships with the natural environment derived from Christian theology (e.g. Maxwell 2003) or the principle of unity, the intellectual foundation of Islamic philosophy (e.g. Nasr 1981) or from the wisdom of an oriental culture, which is able to conflate feminism with nature in opposition to 'mal-development' by the west (e.g. Shiva 1997).

Systems theory

Enquiry using systems theory includes logistics, medicine, engineering, physics, biological sciences, information and communications. Rapoport characterises the relevant literature in these terms:

> one finds wide divergence on definitions of systems, in criteria of classification and in the evaluation of the systemic approach as a contribution to knowledge, understanding or pursuit of specific practical goals. (Rapoport 1986, p1)

His view is that such diversity is partly epistemological and partly due to the orientation of values. Broadly stated, the theory may be expressed in the mathematical form of an equation or in graphical form comprising 'boxes' representing elements of the system joined by 'lines' representing relationships between them. Industrial ecology draws predominantly on the graphical representation of the epistemological dimension. The theory provides analogues and methodologies for understanding both biological ecosystems and industrial arrangements. It addresses the three basic elements of a system, namely its structure, organisation and evolution, what Rapoport calls goal-directedness. Systems theory is seen to be a fundamental part of industrial ecology (e.g. Diwekar 2005; Dijkema & Basson 2009) and is used in myriad ways. A novel example is provided by Diwekar (2005) who suggests that industrial ecology is part of a methodological progression from green chemistry to sustainability. She deals with the notion of time and a need to predict and forecast by adapting methods borrowed from the finance industry. The core of her approach is an application of systems analysis which she develops as a technique for coordinating all the elements of the continuum she postulates. Beyond the boundaries of a single site, the continuum might include, for example, interactions between other manufacturing plants in the region, between them and their communities of customers or neighbours, with supply chains and sources of inputs. The scenario would likely involve a complex array of management decisions, amenable to Diwekar's technique, such as might be encountered in attempting dematerialization; a topic addressed in the next subsection.

Dematerialisation

The theoretical principle of dematerialisation and the closely related concept of decarbonisation (Nakicenovic 1996), is simple: humans must reduce the resources they use if their existence is to be sustainable. There the simplicity ends because interpretation and application vary widely. A comprehensive synopsis of dematerialisation is given by Ayres and van den Bergh (2005). They state that resource and labour productivity must increase simultaneously but not the consumption of natural resources.

> The mechanism for achieving this result can only be to add value to, and extend the useful life of, durable products while simultaneously reducing use of fossil fuels and other dissipative intermediates. This strategy can be characterised as 'dematerialisation'. It also includes reuse, renovation, remanufacturing and recycling on various levels. (Ayres & van den Bergh 2005, p101)

Ausubel (1994) lists industrial ecology, dematerialisation and decarbonisation as the environmental technologies which he regards as the tools for long-term green evolution.[5] Sun (2000) illustrates the range of views on dematerialisation in citing definitions by:

> Herman et al. as 'a change in the amount of waste generated per unit of industrial product'; by Carrelli '… that it takes place whenever a unit good or a unit services can be produced and consumed with less material than before' and by Bernardini & Galli as 'the reduction of raw material (energy and material) intensity of economic activities, measured as a ratio of material (or energy) consumption in physical terms to gross domestic product in deflated constant terms. (Sun 2000, p142)

Sun proposes a framework for analysis comprising two parts, each of which introduces a temporal dimension. In one part dematerialisation is defined as:

> the real change of material and energy use (or carbon emissions) in an observation year, if that is less than the trend based on the levels of a given base year of an observation period, and if this process occurred throughout the whole observation period. (Sun 2000, p143)

The other part is deintensification which he defines in a circular way as the decrease in intensity over a given period. Sun maintains this is the main cause of dematerialisation. Cleveland and Ruth (1998) discuss the notion of intensity of use (IU), which they defined as 'the ratio of materials use to the value added, which in the case of an economy is equivalent to gross domestic product (GDP)' (Cleveland & Ruth 1998, p17).

This measure underlies Sun's reference to deintensification and is a central issue in the debate about dematerialisation, much of which is concerned with metrics. The

5 The context of Ausubel's paper suggests that by 'green evolution' he means a gradual improvement in the environmental performance of industrial processes; seemingly it is a euphemism for sustainable development.

amount of material is measured in terms of weight but this has been questioned as an appropriate indication of environmental impact and hence sustainability (e.g. van der Voet et al. 2005). Using GDP as the denominator is also flawed (Bartelmus 2003, pp63–64). Dematerialisation is typically assessed on the level of a national economy, at which scale its relevance to sustainability is tenuous (Bartelmus 2003). Assessments have been made for subnational regions and for specific industries (e.g. Dobers & Wolff 1999) but owing to the incompatibility of different variables, aggregation to inform national policy, for example, is highly problematic (e.g. van der Voet et al. 2005, p133).

A strong form of dematerialisation considers absolute reductions in materials. A weak form assesses relative reductions in materials per unit of output and could, in reality, produce a result that is unsustainable if, for example, growth in population or exports caused the absolute consumption of materials also to increase. This type of scenario underlies the proposition that use of materials and energy must be 'de-coupled' from the drivers of consumption, if absolute dematerialisation is to be achieved (Naes & Hoyer 2009).

Another concept borrowed from economics treats environmental goods and services as natural capital (Ayres & van den Bergh 2005) so their contribution to an economy can be analysed according to the prevailing theories. Hinterberger et al. (1997) summarise the approach writing that:

> capital enables us to produce goods and services which in turn provide us with wealth and well-being … Besides man-made [sic] capital, 'natural capital' plays a crucial role in the view of the world as a macroeconomic production process. (Hinterberger et al. 1997, p2)

These authors reject natural capital as a valid metric and propose instead an approach to dematerialisation using material input per unit of service (MIPS) as the appropriate measure. They suggest that the 'service' is a proxy for human wellbeing and distinguish their stance from that of others in these terms:

> According to the view held by Pearce/Turner and other authors, we have to keep 'natural capital' intact in order to avoid a decline in well-being. From our perspective, the physical flow from the ecosphere into the economy (the material input) has to be reduced by a factor of 10 over the next 40–50 years, which does not imply declining well-being if we utilize all opportunities to de-link well-being from mi [sic].[6]

6 Hinterberger et al. 1997, p11. To judge from the context, 'mi' appears to be an abbreviation of 'material input'.

A factor of 10 mentioned in this quote refers to an objective to be met by OECD countries if global sustainability is to be achieved. The underlying reasoning is that by means of de-coupling, human wellbeing can be increased over time by a given factor while simultaneously reducing material consumption by the same factor. The objective was set by Schmidt-Bleek, based on his conclusions that OECD countries can and must achieve a fivefold increase in wellbeing while concurrently achieving a fivefold dematerialisation of the economy. In other words, sustainable material flows worldwide cannot be achieved unless the material intensity of OECD countries is reduced by a factor of 10. Schmidt-Bleek established the Factor 10 Club in 1994, the first meeting of which took place at Carnoules, south of France in October that year. The principles by which the objective could be achieved were set out by members of the club in the Carnoules Declaration of October 1994; a document that was reported to have been immediately influential among officials at the European Commission (Weizsacker et al. 1997).

Bartelmus (2003) refers to Factor 4, a similar target provided by a report to the Club of Rome in 1997:

> The best-known overall target for the use of materials in economic activity is possibly the Factor-4 standard (von Weizsacker et al., 1997). It calls for halving material input into the economy while doubling 'wealth'. At a global level Factor 4 is derived from the goal of long-term ecological equilibrium of the planet and an anticipated, desirable or unavoidable, economic growth rate over the next three to five decades. (Bartelmus 2003, p69)

The focal tenet of this report is that humans can achieve twice the output currently generated for half the resources currently used. A corollary is that humans can achieve twice the wealth yet halve environmental stress. Accounting for environmental stress, carrying capacity,[7] ecological rucksack[8] and analysis of human behaviour such as the notion of rebound[9] all suggest that dematerialisation transcends the notional boundaries of traditional industrial ecology. Studies now intersect with economics, behavioural science, politics, policy formation and particularly complexity; a condition which pervades the natural environmental but has only recently been introduced to industrial ecology.

7 The amount of human activity the environment can support.

8 A recognition of all the environmental goods and services that are otherwise regarded as 'externalities' from an accounting perspective.

9 Consumers buying more when prices fall, due to dematerialisation, increases the absolute demand for environmental goods and services – the antithesis of what is intended.

Complexity

Traditional industrial ecology sometimes involves studying *complicated* arrangements represented by constructs of 'knowable' relationships. In theory, such constructs can be used for prediction with definable levels of confidence. They are characteristically *closed* systems, essentially mechanistic, static, singular representations of 'real life'. However, some industrial ecologists recognise that 'real life' is dynamic and *complex*; that its course may be determined by irrational decisions and is inherently unpredictable. Complexity theory attempts to model the randomness in life, using the techniques and insights of cybernetics (Rapoport 1986), information technology (Prokopenko et al. 2008) and biology (Corning 1995).

Summarising these authors' views of cybernetics, it can be said that the systems are *open*; they exchange influences with their environment, i.e. other systems. They are autonomous; they react randomly to exchanges rather than anticipating them. They are self-organising; relationships within a system change according to constraints imposed by the system itself and they are hierarchical in that levels of organisation result from these relationships. Finally, systems are adaptive; they have a capacity through feedback mechanisms to 'learn' and so evolve. Academic interest in complexity is burgeoning; sessions on the topic featured in the International Society for Industrial Ecology conference in 2007 and were the subject of a workshop immediately following it. A special edition of the *Journal of Industrial Ecology* (vol. 13, no. 2, April 2009) records transactions at these events and consolidates the current status of complexity in relation to industrial ecology (Dijkema & Basson 2009).

2.3.2 Utilitarian theme

Applications of industrial ecology

Techniques used for analysing the flows and consumption of substances, materials and energy at various scales constitute the applications of industrial ecology. For example, life cycle analysis or life cycle assessment (LCA) can be used to assess environmental impact of any sequence of related events such as the creation, use and disposal of a particular product. Factors are calculated for the environmental impact of discrete events;[10] many are standardised and routinely used in professional practice (e.g. Culaba & Purvis 1999), typically to understand the environmental impact of specific products

10 Such as the energy consumed in winning a unit mass of virgin aluminium or the amount of carbon emitted to the atmosphere per litre of diesel fuelling long-haul transport.

(e.g. Blengini & Busto 2009). Professional use of LCA is governed by ISO 14040:2006[11] which sets out the principles, requirements, guidelines and a framework for its use. Academics, however, have used LCA in a variety of applications.[12]

Materials flow analysis (MFA) relates to industrial metabolism: the flow of energy, substances and materials through an industrial system. Such a system may be bounded at the level of a product, or in relation to a corporation, an industrial sector, a geographic region or at the level of a national economy (e.g. Bringezu in Bourg & Erkman 2003; Binder 2007). MFA is generally more versatile than LCA but choosing the scope, scale and the boundaries of study is challenging in both applications.

Notwithstanding the versatility of MFA, Binder (2007) notes it is not influential in policy formation. Reasons she suggests are methodological: no general framework, scant or uncertain data, an inadequate structure for interpreting results and no capacity to include management information relevant to the objects of analysis.

Input/output analysis is used to develop measures of sustainability for various phenomena or as a method for comparison (e.g. Lenzen et al. 2006). The technique is closely related to MFA and has been used in conjunction with it (Bailey et al. 2004). It has been used at a subnational regional level (e.g. Lenzen et al. 2004) and at the aggregate level of a national economy (e.g. Wood & Lenzen 2009). In this context the aim is to produce an overall measure of sustainability, determined on the basis of national economic statistics.

A conceptually different type of application gauges the extent human existence is supported by the earth's resources. Carrying capacity is an example: biologically, it is the maximum population of a species that can be perpetually supported by a given habitat without it being degraded (e.g. Rees 1996). Human carrying capacity is a similar concept but includes the influences of human attributes such as technology, economics, standards of living and cultures (e.g. Arrow et al. 1995; Cohen 1997). Ecological footprint analysis is another example of the genera. It illustrates variation in human consumption around the world (e.g. York et al. 2003) but Ayers is dismissive of it as merely another way of stating what is already known (Ayres 2000). Notwithstanding

11 International Organisation for Standardisation.

12 A search of academic papers listed by Wiley Online Library (18 January 2001) produced more than 11,000 results for life cycle analysis in the title, published since 1990. They included a comparison of fruit juice packaging in Turkey (2008), cost analysis of reinforced concrete in Greece (2007), cost analysis of road pavements in India (2010), assessing future photovoltaic systems in the UK (2010) and the cost analysis of hydrogen life cycle in China (2010).

any limitations, the technique is applied on a national level to inform policymakers; some academics put considerable effort into improving the methodology (Kitzes et al. 2009).

Case studies

This category comprises studies of eco-industrial systems and associated commentary on the sustainable management of environmental resources and energy. The category includes industrial symbiosis but owing to its direct and specific relevance to the subject of this thesis, it is reviewed separately in Section 2.4. The ranges of scale, scope, geographic location and purpose of case studies are wide. Examples include: industrial ecology in relation to the island of Puerto Rico (Deschenes & Chertow 2004); eco-industrial park development in Asia (Chiu 2004); the potential of eco-industrial development as a paradigm for local and regional economic development (Gibbs et al. 2005; Deutz & Lyons 2008); the long-term development of an eco-industrial district at Carole Park, in Queensland, Australia (Roberts 2004); environmental improvement of established industrial complexes at Ulsan in South Korea (Park et al. 2008). There seems that little can be gained by reviewing such a large body of work without a suitable framework for aggregating information, which appears not to be yet available. The practical value of any particular study, therefore, is likely limited to the specific case(s) considered and closely similar situations.

Design

The design mode of industrial ecology is epitomised in green chemistry and green engineering. Beach et al. (2009) introduce their paper with the following definition, suggested originally by Anastas et al. in (2000): 'Green Chemistry is *the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances*' (Beach et al. 2009, p1308, original italics).

Their view is that green chemistry has evolved since the late 1980s into a global initiative aimed at achieving sustainable economic, social and environmental performance. Kirchhoff (2005) describes its role as preventing pollution by using innovative processes to provide society with the products it consumes. His prerequisite for sustainability arguably pertains to the gamut of industrial ecology: 'The collaborative efforts of academia, industry and government are needed to advance sustainability through the adoption of green chemistry' (Kirchhoff 2005, p238).

Anastas and Breen (1997, p97) suggest the centrepiece of industrial ecology comprises green chemistry and the Design for the Environment program established by the US

Environmental Protection Agency.[13] The concept of 'designing for the environment' introduces the idea of green engineering, which some authors suggest is an inclusive approach to achieving sustainability. For instance, Diwekar (2005) states that:

> Computer aided simulation and other design tools allow engineers to design, simulate and optimize chemical processes. However, there is a critical need to incorporate green engineering into the design of these processes. This calls for extending the breadth of the design process to incorporate ecological and sustainability issues. (Diwekar 2005, pp215–16)

The Sandestin Conference (Abraham & Nguyen 2003), convened to discuss the principles of green engineering, indicates its eclectic tendencies. Delegates represented the disciplines of mechanical, civil, environmental and chemical engineering. Writing by McDonough et al. (2003) and McDonough and Braungart (2002), advocating a 'cradle–to–cradle' philosophy of design for just about anything, also illustrates the beneficial attributes of green engineering. Vesilind et al. (2007) refer to green engineering as a revolution and examine why it is taking place. They canvas the views of senior executives in eight leading firms that have adopted proactive environmental policies. They conclude that:

> the reasons for embracing the principles of green engineering are often self-serving, resulting in material gains for the firm or for the individual. But we also argue that there are those engineers who do the right thing, with or without others knowing of their work, simply because it gives them pleasure to do so. (Vesilin et al. 2007, p290)

It often happens in the literature on industrial ecology that the prescience of John Ehrenfeld goes right to the core of an issue, as indeed it did with regard to the role of industrial ecology in design. In a paper which antedates all but one of the articles mentioned above, Ehrenfeld (1997) discusses the need to change what he calls the current 'dominant social paradigm' to one that is more conducive to attaining sustainability such that industrial ecology:

> offers a learning [sic], guiding framework that can move from the present base to a more sustainable world … In this new framework, product design and the policy framework that impacts design assume a central role, guiding the flows of materials in and out of the environment, and, at the same time, reflecting their social, economic importance. (Ehrenfeld 1997, p91)

---

13 In light of the literature cited in this review, their view resembles Kalnienk Vision.

Promulgation

Part of the corpus on industrial ecology relates specifically to promulgating its role in sustainable development. Education is a core component of promulgation and is seen by some authors to be crucial (e.g. Erkman 1997). In a direct, functional way Lenzen and various co-authors identify deficiencies in Australian tertiary curricula for training teachers and practitioners of industrial ecology and provide educational materials accordingly (Lenzen & Smith 2000; Lenzen & Murray 2001a; Lenzen et al. 2001b). Part of the mission statement of the National Pollution Prevention Centre for Higher Education at the University of Michigan, USA[14] is to educate student, academics and professionals, to create educational materials and establish a national network of educators (Garner & Keoleian 1995).

It might be argued that industrial ecology is promulgated by all its literature. This may be so in academia but much of it is likely beyond the understanding of lay people.[15] Publications intended for a broader readership include the Factor 4 report, (Weizsacker et al. 1997) sponsored by the Club of Rome (Subsection 2.3.1). Industrial ecology is also promulgated by literature relating to conference proceedings (e.g. Socolow et al. 1994) and by commentary (e.g. Lifset 2007; Lifset 2009). Although the focus of industrial ecologists on promulgation may not be as intense as some might wish, a preoccupation with quantification is widely represented by the relevant literature, summarised in the next section.

2.3.3 Quantification theme

The present dominant social paradigm (Ehrenfeld 1997) requires that phenomena are quantified. Accordingly, some authors have worked on developing suitable abstract or general methodologies for quantification, as distinct from specific, detailed applications such as life cycle analysis (Subsection 2.3.2). Some authors have explored the laws of thermodynamics. Dewulf and Van Langenhove (2005) apply the second law of thermodynamics to the mass and energy flows associated with technology to quantify its effect on the environment. They suggest that the concepts of clean technology, green chemistry and industrial ecology all provide guidelines for the sustainable integration of technology with the environment.

14 An antecedent of the current Centre for Sustainable Systems.

15 My corporate and government colleagues on the committee of the Australian Industrial Ecology Network have no understanding of what industrial ecology is (their view of it is actually practical bilateral industrial symbiosis) and virtually none of my corporate clients have even heard of the phrase.

The difficulties associated with data, their collection, quality, conservation and dissemination also have a bearing on quantification. Lenzen et al. (2006, p190) conducted a comparative, multivariate analysis of household energy consumption in five different countries, which illustrates some of the problems that can arise. For particular variables data was not available for all countries, data were inconsistent and aggregated values had to be estimated. Davis et al. (2010) canvas opportunities to use the World Wide Web and information and communications technology (ICT) to overcome difficulties brought about by the evolving complexity[16] of industrial ecology. The crux of the problem in their view is that technological (quantitative) data and knowledge must be amalgamated with different types of (qualitative) data derived from a social or environmental perspective.

Work on quantification is fundamentally important because it facilitates effective communication. The exigence for generally comprehensible, widely applicable metrics increases as industrial ecology evolves inexorably into a holistic, collaborative approach to sustainable development, involving researchers from diverse disciplines. Literature reflecting this trend is summarised in the next section.

2.3.4 Holistic theme

Much of the literature mentioned so far can be viewed as emanating from work with a technological perspective which attempts to define the topic of interest quantitatively, it is bounded arbitrarily in space and time, and it is studied using a rational science such as physics and mathematics. Some authors locate industrial ecology beyond this technological perspective; their views express or imply an inherently[17] holistic characteristic of industrial ecology. Frosch and Gallopoulos (1989) foresaw this characteristic in advocating progress towards ideal industrial ecosystems. Allenby (2009) describes a scenario for industrial ecology created by nanotechnology, biotechnology, robotics, information and communication technology and applied cognitive science. Allenby views these as the 'five horsemen' of the next 'Kondratiev wave'[18] of innovation, a construct of economic historians who would not previously have been heard by industrial ecologists. Holistic perspectives include sociology (Ashton

16 Their word, used in the colloquial sense of being very complicated rather than used in the cybernetic sense (see theoretical theme).

17 By virtue of the Gaia principle (e.g. Margulis 1997) holism must be inherent.

18 Nikolai Kondratiev (1892–1938) was a Russian economist and director of the Institute for the Study of Business Activity in the Soviet Union. His book, *The major economic cycles* (1925), brought to international attention long-term cycles of (modern) economic activity having frequencies of 40–60 years. His book was seen by the Soviet regime as a criticism of Stalin's policies at the time. He was sent to the Gulag in 1928 and received a death penalty in 1938.

2008), environmental policy and regulation (Deutz 2009), ethics (Randles 2007) and politics (Cohen & Howard 2006). Instead of reviewing these and other contribution here, Appendix 3 gives annotated references that serve the purpose of this section, which is to illustrate the holism of industrial ecology.

2.4 Industrial symbiosis

Industrial symbiosis is that part of industrial ecology which deals with waste specifically. Rather than providing a context as done in previous sections for sustainable development and industrial ecology, the aim of this section is to review only the literature which relates directly to the theoretical basis of my research. For example, case studies of industrial ecosystems such as Rotterdam Harbour in the Netherlands (Baas 2008), the Jyvaskyla region in Finland (Korhonen et al. 1999), Ulsan in South Korea (Park et al. 2008) or the Nanning Sugar Company in China (Yang & Feng 2008) are not reviewed because they represent situations that do not correspond with conditions in which manufacturing is typically carried out in Australia (Section 1.2). The exception is Kalundborg in Denmark because it is the origin of modern thinking about industrial symbiosis.

The structure of this section is in five subsections. The first covers literature on Kalundborg and industrial symbiosis from its inception in 1989 to 1997, an arbitrary demarcation being the year in which the *Journal of Industrial Symbiosis* was first published. The second subsection reviews the literature from 1997 to circa 2006, the period of initial review selected when this project began. The third subsection deals with literature published after 2006 which had a direct bearing on this research. The fourth subsection is about the distinction between industrial symbiosis and conventional recycling, which does not have the same potential for dealing with industrial waste. The final subsection critiques the literature and sets out the theoretical direction for this research. It is noted that some of the literature relating to using industrial waste which preceded the advent of industrial symbiosis was published under the general heading of industrial ecology or under more specific headings such as industrial metabolism and dematerialisation, which have been reviewed in previous sections.

2.4.1 Literature before 1997

The phrase 'industrial symbiosis' was originally used circa 1989 in relation to the evolution since 1961 of arrangements for using waste and resources in and around the industrial town of Kalundborg in Denmark. A history and deconstruction of these arrangements is given in Section 7.2. With regard to the literature, an article in the local press in Kalundborg late in 1989 brought to the attention of the Danish national press a school project which first identified the collection of arrangements between the various industrial organisations in the town. The story was featured superficially in articles published by the *Financial Times* in London (Knight 1990; Barnes 1992) but possibly the first academic study of Kalundborg was done in 1993 by Engberg, a professor at the Stern School of Business, New York University (Engberg 1993).[19] This study describes the relationships extant at the time, which Engberg refers to interchangeably as an industrial ecosystem and industrial symbiosis. He attributes original use of the latter phrase to Valdemar Christensen, then production manager at Asnaes Power Station. Industrial symbiosis is defined as:

> A co-operation between different industries by which the presence of each increases the viability of the other(s) and by which the demands of society for resource savings and environmental protection are considered. (Engberg 1993, p27)

Engberg describes Kalundborg as 'unique', suggesting that the arrangements occurred as a result of particular characteristics associated with industrial symbiosis and therefore represent a special example of an industrial ecosystem. Engberg states that 'The key to an industrial ecosystem is the conceptualization of industrial wastes as raw materials that can be used as inputs in other industrial processes' (Engberg 1993, p1).

In this perspective, the characteristics conducive to industrial symbiosis described by Engberg include: dissimilar participants so waste from one can by used by other; close geographic proximity (less than 10 km) so water and low-grade energy can be transported economically; close mental proximity, that is, managers of the various participants understand each other's business operations and trust one another. Engberg alludes to two overarching factors that drove the industrial symbiosis at Kalundborg. First, government environmental regulation was influential in prompting participants to take action. Second, accepting the exigencies of responding to regulatory pressure, each transaction had to be justified financially.

Engberg described the state of the industrial ecosystem in 1993 and portrayed it in several figures (Engberg 1993, Figs. 2 & 3) as what he called an extant network of exchanges. Importantly, he did not record how it evolved. This point was noted by Nicholas Gertler who visited Kalundborg in July 1994, as a guest of Asnaes Power

19 I understand the paper was one of 13 case studies on various topics that were assembled in one collection in 1993, as an internal record of work done at the school. I obtained an electronically scanned copy directly from the Stern School of Business, NYU.

Station, a principal participant in the arrangements, specifically to research industrial symbiosis for his unpublished Master's thesis on industrial ecosystems (Gertler 1995). Gertler set out to document the dynamics of its development. His fieldwork included five days conducting interviews in Kalundborg, on the basis of which he provided essentially the same, though more detailed, descriptions of the various transactions as had Engberg. He also used Engberg's chronological record but Gertler did not actually describe the process by which the commercial arrangements accumulated, that is, the dynamics of evolution.[20] Gertler did, however, comment on certain aspects which provide further insights for this current research. He noted that:

> close geographic proximity is not an absolute requirement even in Kalundborg … [the] example indicates that geographical closeness is very important for the sharing of physical energy, such as heat and pressure and only helpful in the transportation of material resources. (Gertler 1995, p40)

He commented that business managers are profit seekers but as individuals, they are environmentalists. He emphasises the influence of environmental regulations in motivating corporate action, in being conducive to satisfactory results and the role of regulators in cooperating with organisations to achieve their objectives. More significantly still for this research, Gertler notes that, referring to the influence of regulations: 'Such external signals are not sufficient, however, since innovative and pioneering cooperation is required among companies for symbiosis to occur' (Gertler 1995, p42).

A paper by Gertler and John Ehrenfeld, his thesis supervisor published in the February/ March issue of *Technology Review*, covered the same topics as the master's thesis but in less detail (Gertler & Ehrenfeld 1996). It would, however, likely have made the industrial ecosystem at Kalundborg more widely know than either of the two unpublished academic papers mentioned so far. Engberg cites a paper: 'Production at Kalundborg ends where it begins', published in *BioTimes,* no. 2 (1990) and Jørgen Christensen, Vice President, Administration at Novo Nordisk, a principal participant in eco-industrial system at Kalundborg, presented a paper at the International Industry Conference for Sustainable Development in Rio de Janeiro in 1992. Proceedings of the Air & Water Management Association's 89th Annual Meeting in June 1996 contain the abstract of a presentation by Michael Nisbet (affiliation unknown) on the role of cement plants in industrial ecosystems. Nisbet states that:

---

20 They may be inferred from Engberg's chronology but the process of accumulation is, I believe, a critical feature of industrial symbiosis, as discussed in Subsection 2.4.5.

> The well known Kalundborg case is used to identify the technical, economic and regulatory factors which contribute to successful dev elopement of contiguous industrial ecosystems where the components are in close proximity and non-contiguous systems where the components must be joined by efficient transportation links. (Nisbet 1996)

From the standpoint of this research, the typology of contiguous and non-contiguous industrial ecosystems is particularly useful (Subsection 2.5.5). Given the scope and nature of the literature on Kalundborg apparently available by 1996, reference in Nisbet's abstract to Kalundborg being well known suggests that other work on industrial symbiosis had been published in one form or another by that time. I have been unable to obtain the full text of Nisbet's presentation so his sources are not reviewed here but no reference to industrial symbiosis or Kalundborg is made in either Socolow et al. (1994) or Allenby and Richards (1994), two influential books of the period on industrial ecology. Whatever may have existed by 1996, writing about Kalundborg and industrial symbiosis more generally proliferated during the ensuing 10 years[21] and some authors, such as Marion Chertow, became widely recognised.

2.4.2 Literature 1997–2006

The inaugural issue of the *Journal of Industrial Ecology* in January 1997 contained an article (Ehrenfeld & Gertler 1997), which drew extensively from Gertler's Master's thesis (1995) including the chronological development of the industrial ecosystem at Kalundborg given by Engberg in 1993. The article considers the viability of industrial symbiosis in other settings and discusses factors identified at Kalundborg which influence the development of industrial ecosystems. As in previous writing, the authors depict the system graphically, seemingly as a complete network of relationships but they add what I believe to be a crucial detail:

> Each link in the system was negotiated … as an independent business deal and was established only if it was [sic] expected to be economically beneficial. (Ehrenfeld & Gertler 1997, p73)

This is possibly the first explicit recognition of the bilateral nature of industrial symbiosis at Kalundborg. It is mentioned subsequently, for example, in Chertow (1999) and in Jacobsen (2006) but it seems that examining the role of bilateral arrangements, as the

21 For example, an online search of the principal databases for environmental sciences (Compedex, GEOBASE and Georef) on 13 February 2011 gave a single result (Gertler & Ehrenfeld 1996) for 'industrial symbiosis' in the 'subject/title/abstract' field between 1989 and 1996. An identical search for the period 1997 to 2006 produced approximately 50 relevant results.

basic mechanism of evolution, is not prominent in the literature on industrial symbiosis. Studies of eco-industrial systems in other parts of the world also reveal similar forms of 'organic' growth over decades but in a similarly understated way. Examples are Heeres et al. (2004), comparing eco-industrial parks in the USA and in the Netherlands; Schwarz and Steininger (1997), an account of an extensive eco-industrial system in the Styria region of Austria; and Korhonen et al. (1999), a description of an eco-industrial system centred on optimising the use of timber and other waste as fuel at Jyväskylä in Finland. The significance of bilateral evolution is discussed in (Subsection 2.5.6).

Apart from Gertler's thesis (1995) and a paper by Mogens Olesen, General Manager of Asnaes power station (Olesen 1999), it is unclear from these early texts whether the authors visited Kalundborg themselves to carry out their research or whether they relied on the secondary sources with Ehrenfeld and Gertler (1997), being the only known published account of the phenomenon at the time and which itself was based on Gertler's thesis of 1995. Whatever the sources, it seems that no subsequent study of industrial symbiosis has provided a significantly different assessment of the arrangements at Kalundborg than were recorded in Ehrenfeld and Gertler (1997). Some authors may not have described particular arrangements accurately (e.g. Desrochers 2002a, p30) but it appears that none has challenged the general arrangements or the factors such as geographic proximity and mental closeness, which are stated by almost all subsequent authors to be necessary for its evolution.

The literature on industrial symbiosis developed in various directions after 1997. One of the more prolific directions was the study of eco-industrial systems, often described as eco-industrial parks and suggested by some authors to be synonymous with industrial symbiosis (e.g. Mirata 2004). Such arrangements invariably feature co-location or at most, close geographic proximity of the participants, which is taken to be a prerequisite for industrial symbiosis. Kalundborg is the archetypical example and has influenced much of the work which comprised case studies (e.g. Schwarz & Steininger 1997; Korhonen et al. 1997; Chertow 2000; Heeres et al. 2004; van Berkel 2005). Generally stated, results of case studies aimed to provide insights to the character of eco-industrial systems and observations on how their development might be accelerated. Work in this direction was stimulated in the USA by the President's Council on Sustainable Development, established in 1995 by President Bill Clinton and chaired by Kathleen McGinty, also the then first ever chairwoman of the Council of Environmental Quality. There, as in other parts of the world, attention became focused on developing 'tools' for identifying potential or nascent opportunities and applying the principles of industrial symbiosis, oriented always towards the notion of eco-industrial parks (e.g. Gibbs & Deutz 2005; Mirata & Emtairah 2005; Altman & van Berkel 2004; Roberts 2004; Chiu

2004). Examining the benefits or otherwise of industrial symbiosis, again manifested as eco-industrial parks, constituted another direction of research during the decade after 1997 (e.g. Jacobsen 2006; Chertow & Lombardi 2005). The overall conclusions appear to be favourable. Jacobsen reports environmental and economic benefits but they need to be understood at a collective scale as well as a company level. Chertow and Lombardi (2005) find uneven distribution of benefits and suggest that policy intervention would be a viable means of improving the results of industrial symbiosis.

It was mentioned in the introduction to this section that literature on eco-industrial parks is peripheral to my research, however, two articles were useful. One was Chertow's typology of industrial symbiosis (Chertow 2000). Her Type 5 symbiosis, in which relationships between firms exist over a broad region, is characteristic of the predominant scenario in Australia where industry is typically dispersed and may be both isolated and remote. However, I contest the notion that firms are organised 'virtually', as if to imply a fundamental difference between remote and contiguous relationships. As implied by discussions in the following section, there is nothing 'virtual' about arrangements between remote participants. The other article is Lyons' analysis of 'intermediaries' in the waste recycling industry (Lyons 2005). He concluded that until society, as a whole, fundamentally changes the way resources are consumed, that is, the way products are designed, manufactured, marketed and consumed, such intermediaries are unlikely to play a significant role in 'closing the loop'. Lyons' observations suggest that conventional recycling processes may not offer viable routes for using the variety of waste generated by manufacturers in Australia, typically in relatively small amounts.

Two other articles from this period were particularly useful in demonstrating the potential for bilateral arrangements to extend beyond the constraints of close geographic proximity, as imposed for example by eco-industrial parks. One was by Kincaid and Overcash (2001) who reported on a project established in the late 1990s to identify potential opportunities for bilateral industrial symbiosis throughout an area comprising six counties in North Carolina, USA and having a combined population of approximately one million people. The project lasted for two years during which 343 organisations were contacted. From these contacts, 186 opportunities were identified. Staff explored the potential of 49 partnerships, of which 12 could have been instigated in the short term. The project was intended to demonstrate what could be done to further industrial sustainability. There do not appear to be any subsequent reports on the aftermath of this project so I do not know if any of these initiatives came to fruition. The other is an article by Mirata (2004) which described the origins and early development of the National Industrial Symbiosis Programme (NISP) in the UK.[22] It also described pilot projects undertaken in the (subnational) regions of Scotland, West Midlands, the River Mersey and the River Humber which demonstrated the viability of establishing bilateral industrial symbiosis through formal 'third-party' intermediation. These projects resembled Kincaid's work in North Carolina and the way my own business operates, except for a very significant distinction. The projects in the USA and the UK were entirely funded by the public sector. This crucial factor is missing in the Australia context. It and other features of NISP in the UK are discussed in Subsections 7.4.1 and 8.4.1.

2.4.3 Literature after 2006

The scrutiny of eco-industrial systems continued after 2006, in some instances as case studies per se (e.g. Wolf & Petersson 2007; Yang & Feng 2008; van Berkel et al. 2009) but other authors have broadened the range of enquiry beyond merely observing a particular situation. Chertow illustrates the trend in aiming to accelerate the proliferation of industrial symbiosis. She indicates that efforts to establish planned eco-industrial systems have been largely unsuccessful, a view expressed also by Gibbs & Deutz (2007) and that further work needed to be done on developing tools by which existing, though hitherto unrecognised, opportunities could be uncovered (Chertow 2007). She states the basis for her approach to this task is:

> To distinguish industrial symbiosis from other types of exchanges, my colleagues and I have adopted a '3–2 Heuristic' as a minimum criterion. Thus, at least three different entities must be involved in exchanging at least two different resources to be counted as a basic type of industrial symbiosis. (Chertow 2007, p12)

This heuristic may define an embryonic eco-industrial system, as an 'entity' but as I argue in Section 2.6, it is too limiting when construed as the origin of industrial symbiosis as a process.

The possibilities for regional development by means of industrial symbiosis have been considered by some authors, such as Ristola and Mirata (2007), and Deutz and Gibbs (2008), sometimes with a geopolitical orientation (Jackson 2008) but generally having in mind some form of industrial ecosystem predicated on geographic proximity. In a recent article, Posch (2010) finds from his studies in parts of Styria, Austria and Oldenburger Münsterland in Germany that industrial symbiosis does not contribute more to broader sustainability-oriented cooperation than normal inter-company

22 Formally established as a nationwide program in 2005.

relationships. He reports also that inter-company recycling activities are 'regarded by company representatives as bilateral market transaction, not as collaborative network activities' (Posch 2010, p242).

Given the structure of manufacturing in NSW (Section 1.4), the relevance of such studies is moot but examination after 2006 of the socio-cultural aspects of industrial symbiosis is apposite to this research. Confidence, usually manifested as risk and trust, is one topic that must be addressed (Subsection 2.5.7) because it is seen to be critical for the success of industrial symbiosis but is also assumed to be derived from geographic proximity, that is, a particular characteristic of eco-industrial parks. Other socio-cultural topics of specific interest are the nature of networks, the role of a project champion, the response of corporations to regulation and the facilitation of industrial symbiosis. These topics transcend the notional construct of eco-industrial parks and some have antecedent literature before 2006 so they are reviewed separately in the following subsection.

2.4.4 Socio-cultural research

Jørgen Christensen is a retired senior executive at Novo Nordisk in Kalundborg who attributes success of the industrial symbiosis there, in part, to a 'close mental distance' between the managers who participated in its development (personal communication). The metaphor underlies the trust that emerges from geographic proximity and is deemed to be necessary among managers participating in eco-industrial systems of the type exemplified by Kalundborg. Gibbs summed up the issue as follows:

> The concept of eco-industrial parks has as its basis inter-firm collaboration and networking, based upon trust and reciprocal relations. Without those, an eco-industrial park does not exist, save as a thematic collection of environmentally-related firms. (Gibb 2003, p230)

In his paper Gibbs draws from the literature on economic geography, regional economics and sociology to examine eco-industrial parks other than from a techno-structural standpoint. He associates with trust characteristics such as cooperation, willingness to exchange information and reciprocity more generally; all regarded as part of the foundation for effective negotiations. Hewes and Lyons (2008) draw on a similar body of literature plus organisational theory to canvas the issue of trust and extend the range of associated characteristics to include the concept of embeddedness, which they relate to the role of interpersonal relations in generating trust and discouraging delinquency. Their research studied the work of two project champions, one for eco-industrial developments at Devens in the USA and another for those at Komsomolske and

Cherkassey in the Ukraine. They conclude that social embeddedness and geographic proximity of a project champion is crucial to gaining trust. Baas and Huisingh (2008) contribute a broader understanding of embeddedness to the debate on eco-industrial development. As part of their research on the industrial complex at Rotterdam harbour in Holland they discuss the cognitive, cultural, and spatial forms of embeddedness in relation to trust. They, too, suggest that trust is crucial for communication between partners and hence to successful industrial symbiosis. Others have written about trust from different perspectives, for example, Ristola and Mirata (2007) suggest that elevated levels of trust can improve the economic performance of industrial symbiosis by lowering transactional and control costs. These and similar observations appear to assume a general understanding of trust but there is scant literature on industrial symbiosis that details what actually constitutes trust and how it operates to influence decisions. Jensen et al. (2011) come to a contrary view of close mental proximity and trust from their analysis of distances between participants in arrangements created by NISP (Subsections 2.4.2 and 7.4.1). Their data set comprised 792 'synergies' in which the find that 50% of all resources are used within a distance of 36.2 km from the source and 75% are used within 62.6 km of the source. The authors state that:

> Due to the way the Programme operates, it is thus argued that trust oriented mental distances are not the primary factor dictating the short resource movement distances presented within this article. (Jensen et al. 2011, p711)

It is noted, however, that their argument relates to circumstances in which arrangements are facilitated by an independent coordinator as distinct from occurring by happenstance.

The risks of industrial symbiosis have also been canvassed in the literature. An insidious form is alluded to by Gibbs et al. (2005) who suggested that initially satisfactory arrangements need to be adaptable over time. There is otherwise a danger that restrictions imposed by contractual or other exigencies of industrial symbiosis will subsequently inhibit the evolution of better practices. However, it is not clear from the literature how the risks associated with industrial symbiosis are different from those of normal commerce (Subsection 2.5.7).

The construct of a network, however, is particularly relevant because it is almost invariably depicted in the literature as being the structural manifestation of industrial symbiosis. The most widely cited example is Kalundborg but others around the world such as Kwinana in Western Australia (Altman & van Berkel 2004), Styria in Austria (Schwarz & Steininger 1997), Landskrona in Sweden (Mirata & Emtairah 2005) and

Ulsan in South Korea (Park et al. 2008) are also described as comprising a network. Even Chertow's 3-2 heuristic for embryonic industrial symbiosis constitutes a network (Chertow 2007).

As with trust, the geographic dispersion and isolation of manufacturing in NSW would normally inhibit the formation of such networks. It is apposite, therefore, to discover which aspects of a network, if any, are indispensable to the operation of industrial symbiosis, if it is to be considered as a viable strategy for using manufacturing waste in this state. The issue is discussed in Subsection 2.5.5, based on the following ideas.

An abstract concept of a network is analogous to a system in which its elements (nodes) are connected by relationships (links) between them. In examining the notion of constancy amid change, which Rapoport states is implied by almost every definition of a system, he contends that 'it is the network of relations, not the nature of the elements that defines something as a system of a given type' (Rapoport 1986, p79)

In business networks, a relationship between elements can be construed as a flux of 'agency' (Choi et al. 2001), which may involve materials, knowledge or influence. In the context of industrial symbiosis, two distinct types of network can be identified notionally from Rapoport's standpoint on relationships. One type involves reciprocating flux, an *exchange* of agency. Simsek et al. (2003) allude to this type of network, for example, in discussing the significance of embeddedness on entrepreneurial behaviour:

> *Relational* embeddedness refers to the quality of dyadic exchanges, including the degree to which parties consider one another's needs and goals as well as the behaviors that they exhibit towards one another, such as trust, norms, reputation, sanctions and obligations. (Simsek et al. 2003, p430)

This passage refers to the dyadic nature of relationships in a network, a characteristic which pervades their entire discussion of embeddedness. Such relationships are examined specifically by Anderson et al. (1994) who postulate a 'focal' dyadic relationship between a supplier and a buyer as embedded in an arbitrarily bounded business network and consider how this relationship is influenced by the network. The concept of a supplier/buyer relationship is segue to the other type of network relating to industrial symbiosis; one that involves a uni-directional flow of material or substance, typical of supply chains generally. As Choi et al. (2001) argue, supply networks should be managed as complex adaptive systems that may involve an exchange of knowledge, which is an element of reciprocity but the predominant agency is unidirectional from supplier to buyer.

Theoretical discussion of issues canvassed in this review, such as the design of eco-industrial parks versus their organic evolution, the various benefits conferred by them or the social dimensions of their existence, seldom emphasises the reality that industrial symbiosis does not 'just happen' in practice. It almost invariably results from some form of dedicated agency, human activity committed to motivating and managing the development of a particular project (e.g. Mirata 2004). The agent might be a single person, a 'champion' whose involvement may be intensely personalised and essential for a successful project (e.g. Hewes & Lyons 2008). An example of a different form of agent is given by Baas and Huisingh (2008) who describe the role of Deltalings in the development of industrial symbiosis at Rotterdam. Deltalings is essentially a committee, the capacities of which remain intact, potentially indefinitely and accumulate although its membership might change. Even the evolution at Kalundborg was driven by champions – individual managers like Mogens Olesen and Valdemar Christensen at Asnaes Power station and Jørgen Christensen at Nova Nordisk (personal communication). The paper by Kincaid and Overcash (2001) described a different pathway for agency (Subsection 2.4.2). The significance of this project is not so much its success as that it suggested the concept of 'third-party' agency that had seemingly not been described previously in the academic literature. Whereas the nature of a champion or a committee such as Deltalings connotes a characteristic of agency as being an embedded part of a project and inextricable from it, third-party agency is essentially external to the project. It is performed by an 'outsider' whose function is to initiate and perhaps also manage the process of bilateral industrial symbiosis between principals, being a supplier and a user of waste.

This approach was taken by the National Industrial Symbiosis Programme (NISP) in the UK (Subsection 2.4.2). NISP provides an integrated, standardised service based on arranging 'workshops' to which organisations registered with the program are invited to discuss among themselves potential projects. Participants are selected for each workshop according to research done by NISP on the waste they might have available and potential uses for it. Attendees are encouraged in various ways to pursue opportunities but except for especially large projects, there is generally no follow-up by NISP to manage or monitor the progress of an opportunity (personal correspondence). A critical part of NISP is seen to be its role as an independent, impartial repository for information distributed to participants in the scheme (Mirata 2004; see Subsection 7.4.1). The program has developed as intended and continues to be successful (Laybourn & Morissey 2009; personal correspondence), a result that might have been foreseen in the light of another study in the UK by Watts et al. 2001. A particularly significant feature of NISP is that it is funded entirely by government. Participation in the program is free to all comers and no revenue is derived by NISP for its services in facilitating projects (Laybourn & Morissey 2009; personal correspondence).

2.5 Discussion of the literature

The conventional scenario for industrial symbiosis described in the relevant literature is rare in Australia, particularly manufacturing in NSW. Authors describe eco-industrial systems as comprising participants in close geographic proximity, at least one of which would be the focal enterprise or 'anchor' for the system. Arrangements are portrayed as networks, which involve social factors, such as 'close mental proximity', embeddedness and trust as much as they do technological compatibility. Diagrammatically, networks are depicted fully formed, as if they had come instantly into existence, which tends to obscure the process of their evolution. In an essay on taxonomy, Margulis[23] commented that:

> taxonomy, or placing organisms into categories, is not just an exercise in science – it promotes a frame of mind that pervades our thinking, colors our values and affects our actions. Furthermore, the frame of mind may persist even when the classification system becomes obsolete. (Margulis 1997, p75)

Reference to a persistent frame of mind suggests the possibility that if elements of conventional industrial symbiosis were viewed differently, a theoretical approach might be developed that would lead to its systematic, sustainable deployment among manufacturers in NSW. The purpose of this discussion is to examine nine elements of conventional industrial symbiosis that seem most likely to constitute such an approach. Accordingly, this section is divided into subsections dealing with sustainability and the use of waste, metaphor and simile, networks, Kalundborg, trust and risk, bilateral industrial symbiosis as distinct from recycling and the importance of project champions. The next subsection sets the philosophical perspective in relation to the origin of industrial symbiosis as a concept.

2.5.1 Understanding sustainability

Charles Kidd (Subsection 2.2.1) states that his paper

> is intended to demonstrate that there is not, and should not be, any single definition of sustainability that is more logical and productive than other definitions. The

23 Lyn Margulis is a renowned microbiologist and author who developed the theory of symbiogenisis, which some regard as equivalent in scientific significance to Darwin's theory of evolution.

> central point of the paper is that those who use the term 'sustainability' should always state precisely what they mean by the term. (Kidd 1992, p3)

Accordingly, in the context of using industrial waste, the meanings of 'sustainability' and its related epithets are explained principally from a practical perspective. However, these meanings depend in turn on particular definitions of the words themselves. The word 'sustainable' can mean 'to maintain or support' some thing or state of being. It can also mean 'to prolong' (e.g. *Chambers dictionary,* 1972), which implies the quality of durability. The meaning 'to prolong' is intended in this discussion, specifically the notion of 'prolonging in perpetuity' with respect to what is being or must be sustained. Development is construed to mean some idea of improved efficiency that is, achieving more with fewer resources or decreasing embodied energy. If development were construed to mean growth then the concept of growth in perpetuity seems an absurdity in a finite world.

- Bearing in mind the primacy of the generator's perspective, being the actor responsible for dealing with waste, a disposal strategy could be considered sustainable if it satisfies simultaneously the following conditions:
- Sustainability: the options for use exist for as long as the waste is actually generated or could potentially be generated. For example, a factory that generates waste may close completely or a particular production line may be closed down permanently. In each case, disposal ceases to be an issue as the associated waste ceases to arise and may reasonably be assumed never to arise again. If the factory is 'mothballed' or production ceases temporarily then the disposal strategy must remain intact in case waste arises again in the future.

Robustness: the disposal strategy is sufficiently resilient to avoid dumping waste (or otherwise allowing it to harm the environment) in the face of perturbations in the arrangements. For example, there may only be one user of the waste in which case the strategy is potentially unsustainable, unless it includes sustainable contingency plans if the user ceases to accept the waste.

The notion of sustainability has two dimensions. One is intrinsic to the materials and processes associated with the use of waste and the other is, basically, a function of human behaviour. The intrinsic dimension relates to the fact that processes used to combine particular materials will always produce the same result by virtue of the physical properties involved. For example, silica mixed with a specific selection of other ingredients and heated to a certain temperature under defined conditions will always produce a given form of glass. A waste material that can be substituted for one of the ingredients without changing the end product can therefore be used sustainably in this way. If, however, the glass factory closes down or the products it manufactures are changed then the waste material may no longer be used for this purpose, in which case the situation with respect to using the waste is unsustainable. This is an example of the behavioural dimension of sustainability. These examples suggest the concept of a continuum from unsustainable to sustainable, according to which the sustainability of a particular waste disposal strategy could be assessed. This idea is developed further in the following subsection.

2.5.2 Assessing sustainability

One approach to assessing sustainability is to consider the risk that some action, strategy or thing is unsustainable in relation to any one of three distinct scenarios: technical, commercial or longevity. The technical scenario relates to the durability of a process that might be used to deal with waste. A few technical details of the SPL project (Chapter 1 vignette) illustrate he scenario. For as long as calcium sulphate and clay are mixed with SPL ash, the fluoride will become insoluble and the resulting material will be environmentally benign for ever. Ceramics technology does that job very well so one can reasonable say that the process is technically sustainable. The availability of calcium sulphate and clay relates to the commercial scenario. In the SPL project the calcium sulphate used was itself a waste material arising in Sydney. However, the chemical factory producing it closed down couple of years after the project ended. If the ingredient were not available from another source or a substitute could not have been found, the strategy would have been unsustainable but for commercial reasons, rather than for technical reasons. The commercial scenario also includes the issue of what happens to the waste, after it has been discarded by the generator. From an environmental perspective, it is probable that dumping is not sustainable while demand in a free market economy could be adversely influenced by almost anything that might happen. This suggests that any disposal strategy which depends solely on free market forces is inherently unsustainable. Longevity is perhaps the most salient characteristic of sustainability and here again there is a dichotomy. Although it may appear that a disposal strategy will only be required for as long as the waste is being generated, it is fundamental to the whole concept of sustainability that no material ever poses a threat to the biosphere. For example, if it were possible for fluoride to become leachable again sometime in the future then with respect to the biosphere, SPL ceramic would not be durable in perpetuity and hence the strategy could not be regarded as sustainable.

2.5.3 Weak and strong strategies

The notions of a weak and strong may be used to locate strategies, at least in relative terms, in the continuum of sustainability. Referring again to the SPL project, if the refractory component as well as the carbon component of SPL could be used in making cement, then doing so would probably be a permanent means of disposal. Even if it were, however, sustainability is not at all certain, principally because the generator's disposal strategy depends entirely on third parties. Being entities 'at arm's length', the generator is unable to guarantee the continuing existence of those third parties for the duration of its own commercial life. In the sense of being sustainable, this waste disposal strategy is weak. A countervailing scenario is where the generator retains control over the entire system of disposal. For example, the SPL process was designed to be operated by each aluminium smelter, on site where the waste arises, as if it were an integral part of normal operations. The ceramic could have been used on site or sold as a finished product. This is a much stronger strategy and has a correspondingly better potential for achieving sustainability.

Assessing the sustainability of a disposal strategy in theory is one thing; actually finding uses for industrial waste in practice is another matter. My experience is that simply being able to rescue waste from landfill or the sewer is difficult enough without having to cope also with the exigencies of sustainability. Nevertheless, sustainability is undoubtedly what has to be achieved in practice, even though it may not be accomplished at the first attempt. In the business of organising bilateral symbiosis, I have always assumed that a particular solution to a given problem is unlikely to be the ultimate solution. It is axiomatic that there will probably be a better way of using waste than the current one. In this context, sustainable development is taken to be a continuing process to improve the status quo.

2.5.4 Tropes

The metaphor of industrial symbiosis has been adopted by researchers as the organising principle for eco-industrial systems, especially those comprising participants in close geographic proximity with one another which share various resources, cascade energy and water, and use waste. In view of the circumstances in which manufacturing occurs in NSW, this construction of industrial symbiosis is rarely applicable, which raises the issue of its validity as a general principle.

In the first instance, the phrase 'industrial symbiosis' was used as a simile, not as a metaphor or analogy. It was explained to me by Inge and Valdemar Christensen, in person (Kalundborg, June 2009), that during dinner the night before Valdemar was due to make a speech in late 1989, the pair were trying to think of a word to describe the situation that had recently been discovered at Kalundborg by the high school project. Inga, being a biologist, thought it looked like what she called an 'industrial symbiosis'. Jørgen Christensen observed 'that this account of events has never been challenged' (personal correspondence, 2008). The phrase was intended merely as a 'name' for an entity, not a metaphor for its development or its existence.[24] Nevertheless, 'industrial symbiosis' variously interpreted as a metaphor has only attained currency among academics in the form known as mutualism in which both symbions benefit (Appendix 4). In relation to mitigating environmental impact, I contend that two other forms of symbiosis are apposite: commensalism, in which one symbion benefits while the other is unaffected and neutralism, in which neither symbion is affected. In the absence of economic motivation, this contention leads to the idea of altruism in industry, in the sense of a willingness to 'act in the interest of others for the greater good' rather than the behaviour of an entity which increases the welfare of another at the expense of its own (Dawkins 1989). From the standpoint of mitigating environmental impact in practice, arrangements that are not detrimental to either symbion should come within the ambit of industrial symbiosis, whether or not they confer any financial benefit.

2.5.5 Networks

The perception of eco-industrial systems as networks is almost universal among academics, exemplified by a typical depiction of Kalundborg (Chapter 7, Figure 7.1) as the archetype of industrial symbiosis cited ubiquitously in the literature. Drawing on Rapoport's discussion of system theory relating to organisations (Rapoport 1986, especially pp153–54), the simplest construct of a network, that is its most basic element, requires a minimum of two nodes (actors) connected by one link (relationship). The general form of a network is characterised by the notion of a *reciprocal* flow of agency[25] along a link as, for example, conversation during a telephone conference and railway rolling stock. In some specific types of network, flows of agency occur in one direction only, for example in management decision charts and product supply chains. When the agency flowing in either direction is the same or similar, for example, in the case of digital data transmitted electronically or vehicles using a road system, the operation

24 Although conjecture on both our parts, Jørgen Christensen concurred with my view that had Valdemar read the paper by Frosch and Gallopoulos (1989), published approximately two months before his speech, he would have referred to Kalundborg as an eco-industrial system.

25 As mentioned in subsection 2.4.4, 'agency' in this context is an abstract notion of an attribute, something that flows or passes along a link between one actor and the other. An attribute might be tangible materials or goods, it might be information in various forms or it might be influence.

of a reciprocal network may be described notionally as an exchange. When the agency flowing in a reciprocal network is dissimilar, such as payment for product supplied or the flow of agency is always in the same direction, then the operation is notionally a transfer, rather than an exchange. Although this distinction may be subtle, it facilitates a more refined understanding of industrial symbiosis than is typically represented in the literature and perhaps more significantly, the circumstances in which the strategy might be deployed in practice. This point is taken up again specifically in relation to Kalundborg (Subsection 8.6.1). It can be inferred from Rapoport's discussion of network organisation (Rapoport 1986, p154) that complicated networks (as distinct from complex systems) may be viewed and analysed as accumulations of the basic elements mentioned above. This is analogous to how an eco-industrial system may be perceived, whether it be characterised or not by close geographic proximity of the participants. A corollary is that accumulation of bilateral arrangements is the process by which eco-industrial systems develop. Researchers have identified this process, for example, in Styria (Posch 2010) and Kalundborg where, as Chertow observed 'Not even the mother of all eco-industrial parks, Kalundborg, sprung from its creator fully formed' (Chertow 1999, p9).

The typical depiction of eco-industrial systems as being fully formed segues to the issue of how they develop in practice. The two basic mechanisms identified in the literature are evolution and design. Various studies cited in this review indicate that most existing systems evolved, typically over relatively long periods, some dating from the early 1960s. The eco-industrial system at Kalundborg is the archetypical example; it is the origin of the phrase 'industrial symbiosis' and almost every author who has written about the topic refers to it. The idea of designing eco-industrial systems attracted attention during the 1990s, partly stimulated in the USA by the President's Council for Sustainable Development. Research focused conceptually on a collection of contiguous enterprises within an area described as an eco-industrial park or similar epithet. Notionally, a defining feature of an eco-industrial park is the existence of multiple relationships between the participants. Accelerating the evolution of eco-industrial systems or increasing their abundance seems to have been the motivation for design but success in practice has been elusive (e.g. Chertow 2007). One possible reason is that the design concept has been a network of more than two organisations. I argue that bilateral relationships are the actual basis of industrial symbiosis (Subsection 8.6.1) and are likely a more useful model than a network for developing the concept in practice.

A hybrid of the evolutionary and the design mechanisms is suggested by Chertow's 3-2 heuristic (Chertow 2007, p12) although she does not refer to it as such. Her approach is to seek out embryonic systems (defined by her heuristic) and suggest that attempts be made to develop them by identifying opportunities for expansion. At the time of writing (March 2011), there does not appear to be an account of any empirical attempt to use this particular approach. However, it is unlikely to overcome an inherent feature of eco-industrial systems: the more participants they involve, the more difficult they are to establish. Chertow notes that ‘it would be difficult to underestimate the complexity of developing multi-party relationships where the advantages to each party are not necessarily well understood’ (Chertow 2000, p328).[26]

Ehrenfeld and Gertler (1997) make much the same observation in relation to the likelihood of two firms simultaneously having positive environmental, technical and economic linkages that comprise the basis of a relationship. They use combinational theory to show that the overall probability of such an occurrence producing a favourable outcome is 1 in 64 (Ehrenfeld & Gertler 1997, p77) and that adding more firms to a combination further reduces the probability of a successful symbiosis.

In light of such comments and the limited success in establishing designed eco-industrial parks (e.g. Chertow 2007), insights to the practical value of networks may be gained from considering what intrinsic characteristics, if any, they have that confer benefits which cannot be derived from bilateral arrangements. Reciprocal networks comprising three or more organisations (nodes) which facilitate flows of similar influence would seem to confer particular benefits by virtue of the way they operate. This type of network is seen as typical of social interaction among contiguous firms. However, with respect to operations, eco-industrial systems are based on either reciprocal networks with flows of dissimilar influence or, more commonly, on uni-directional networks such as a supply chain providing goods to a supermarket. The issue of dependency then becomes a defining factor. If an arrangement (link) between two organisations (nodes) in a network is operationally dependant on arrangements with other organisations then a more complicated network than a bilateral arrangement is necessary. If there is no such dependence, then the (operational) relationship is essentially bilateral, irrespective of what social relationships might exist.

This reasoning leads to the questions: can existing eco-industrial systems be analysed as (an agglomeration of) bilateral arrangements and, if so, could new systems be designed on that basis? The likely benefits of this approach would include an extension

26 From 22 years of experience in arranging bilateral industrial symbiosis, my view is that even when the advantages are well understood by each party, it is nevertheless inordinately difficult to establish a functioning arrangement.

of industrial symbiosis beyond the notional boundaries of close geographic proximity and a diminution in the difficulty of establishing eco-industrial systems in practice. This question is addressed in relation to the industrial symbiosis at Kalundborg, discussed in the next subsection.

2.5.6 Kalundborg

Early descriptions of the industrial symbiosis at Kalundborg, particularly those by Gertler (1995), Ehrenfeld and Gertler (1997) give detailed descriptions of the various relationships and in the case of Christensen (e.g. Christensen 2006 and personal communication), a chronology of their accumulation. Several features of the system emerge from studying this body of work that are relevant to the aim of this research. The system at Kalundborg, like almost every other eco-industrial system recorded in the literature, is invariably *depicted* as a network, implying reciprocal arrangements (Subsection 7.2.1), though not necessarily stating as much. Notwithstanding this depiction, these and other authors note that the situation at Kalundborg evolved by the accumulation of bilateral arrangements. Whereas the notion of a network might represent the state of the system at a particular time, I argue that it does not adequately represent the actual process of its evolution (Subsection 9.3.4) and that deconstructing the temporal dimension may yield a different understanding of industrial symbiosis.

Examining the transfers of materials, substances and energy throughout the system at Kalundborg is concomitant with deconstructing its chronological evolution. The predominant scenario portrayed in the literature involves materials described as waste, which arises from four (heavy industrial) generators located on three sites[27] in close geographic proximity. Transfers within the system are typically homogenous, bulk 'commodities' requiring dedicated infrastructure. These are not typical features of manufacturing in NSW, however, Gertler (1995) mentions transfers that took place beyond the immediate neighbourhood of these participants. His observation suggests that useful insights might be gained from a detailed analysis of what the transfers actually involve and the nature of their interdependence.

Kalundborg is the archetypical example of industrial symbiosis and is continually referred to in literature on the topic (e.g. Costa et al. 2010; Bain et al. 2010). In view of its significant influence and the possibility of still being able to access original sources of information, it is the pre-eminent case to study in the issue of evolution and the characteristic of dependency. Other eco-industrial systems such as in Styria, Austria (Posch 2010) have evolved in a similar way and study of them might enhance the

27 Asnaes power station, Statoil oil refinery and the Novo Nordisk/Novozymes site.

general validity of bilateral industrial symbiosis but for the purpose of this research, only the situation at Kalundborg will be deconstructed (Sections 4.5, 7.2 & 8.4).

2.5.7 Trust and risk

The notion of trust recurs throughout this chapter in contexts that indicate a significant disparity between the physical conditions of dispersed manufacturing in NSW and those thought to be necessary for industrial symbiosis, especially the various attributes of embeddedness. The types of trust alluded to in the literature, predicated on close geographic proximity, can rarely, if ever, exist in the circumstances prevailing in NSW so the issue needs to be addressed in this review. Trust was mentioned by Engberg (1993) cited in Subsection 2.4.1 and, as noted in Subsection 2.4.4, it was a focal issue for some authors, notably Gibbs (2003), Baas and Huisingh (2008), and Hewes and Lyons (2008). They and others write about trust as an integral feature of industrial symbiosis; that it is strongly correlated with close geographic proximity and attributes such as cognitive, social and cultural embeddedness. However, I make the point, also in Subsection 2.4.4, that while an understanding of trust, as a vague sense of general dependability, seems to be assumed, it is not clear from the literature what is actually meant by trust. For example, Domenech and Davies (2009, Table 1) list a definition of trust that is actually a summary of the circumstances suggested by other authors, which engender trust. Uzzi (1997) is more specific. In his analysis of inter-firm networks and associated embeddedness, he explained an understanding of trust, expressed by his interviewees as being:

> an explicit and primary feature of their embedded ties. It was expressed as the belief that an exchange partner could not act in self-interest at another's expense and appeared to operate not like calculated risk but like a heuristic – a predilection to assume the best when interpreting another's motives and actions. (Uzzi 1997, p43)

This remains a general, if somewhat altruistic, interpretation of trust, as associated with the notion of a network based on reciprocity and recurring interactions. Nevertheless, it does tend to emphasise the inference that without trust, the probability of industrial symbiosis occurring is low, if not vanishingly small. Reflecting on observations by Gibbs and Deutz (2007), two dimensions of trust seem relevant to the issue. There is personal trust between actors, as individuals, which engenders social interaction, sharing information, informally discussing ideas and generally cultivating favourable dispositions among one and another. There is also the business dimension of trust, or lack of it, which is associated with commercial transactions. While social interaction might make commercial transactions easier to consummate, it is not a prerequisite. Business is routinely conducted in the absence of personal trust. All the relevant studies cited in this review support the notion that industrial symbiosis is, fundamentally, a business arrangement, undertaken for commercial reasons, whether they are economic, social, environmental or a combination of these. Normal business transactions are based on some form of contract, memorandum of understanding or verbal agreement, as the case may be, according to the level of business trust between parties. There is no apparent reason why industrial symbiosis could not be established on a basis[28] that has a degree of reliability similar to other commercial transaction. Research by Jensen et al. (2011) on the arrangements made by NISP in the UK supports this view, that surrogates for trust are used routinely in arranging industrial symbiosis.

Industrial symbiosis is perceived to involve significant business risk associated with material specification and continuity of supply (e.g. Deutz & Gibbs 2008). From a theoretical perspective it can be argued that using waste is no different to using any other input to a process with regard to specification or supply. Irrespective of where inputs come from in the normal course of business or who supplies them, users are responsible for specifying their requirements and making contingency plans to access alternative sources. Suppliers are responsible for meeting specifications and contract performance generally. As in the case of trust, there is no apparent theoretical reason why industrial symbiosis should be regarded differently from normal business transactions. Management decisions in practice might be prejudiced or irrational but that is a matter of experience. There is, however, a dimension of risk that relates to liability; the extent to which a corporation might have to compensate unknown parties for future, indeterminate, contingent adverse circumstances caused by its actions. The topic is studied extensively in the context of corporate valuation, for example Kennedy and Mitchell (1998) in relation to the phenomenon of 'anchoring' assessment of contingent environmental liabilities and Harvey and Lusch (1999) who examine intangible liabilities associated with various forms of intellectual capital. The difficulties inherent in assessing contingent liabilities outlined in relation to corporate evaluation also confront managers contemplating bilateral symbiosis, as discussed in the context of a corporation's capacity to engage in bilateral symbiosis (Subsection 8.3.3).

2.5.8 Bilateral symbiosis versus recycling

The colloquial concept of conventional recycling is different from bilateral symbiosis in ways that make the former an unsuitable strategy for dealing with manufacturing waste. Concepts described as Type 5 industrial symbiosis and green twinning or byproduct

28 It is certainly my experience that bilateral industrial symbiosis is organised and established in exactly the same way as a normal commercial transaction.

synergy (Chertow 2000) might be conflated with recycling if not for the crucial concept of a market. Waste recycled conventionally such as metal, glass, paper and plastics pass through established market systems. In general terms, these systems comprise a (large) number of accumulators such as municipal councils and scrap merchants who obtain relatively homogeneous streams of waste from a wide range of sources. The waste is sorted to some extent and may then be supplied to end users or to an intermediate processor who creates recyclates fit for purpose, which are eventually sold to multiple users (e.g. Watts et al. 2001). The use of recyclates may be actual and widely known about, as for some metals, paper and plastic or it may not yet be actual, as in is the case for about 90% of electronic waste in Australia (Federal government – discussion paper 2011) and much of the timber not mulched or composted. Such wastes are nevertheless collected, processed and the resulting recyclates stockpiled pending actual use. Except for genuine byproducts[29] such as spent grain or excess yeast from brewers, which are typically supplied directly to a user,[30] there appears to be no market systems in Australia for manufacturing waste comparable to those for conventional recycling.

There are many varieties of waste from manufacturing. They are typically highly differentiated from one another; they arise in relatively small quantities compared with conventional recyclates and generally at a single site within a state or substate region. Significantly, there will likely be no identified use for the waste, which therefore has to be established for each particular waste stream. Developing and maintaining uses for manufacturing waste through bilateral symbiosis involves, among other tasks, finding a potential use for the waste, demonstrating technical, economic and environmental viability, negotiating contractual arrangements, establishing and managing operations. This process is fundamentally distinct from conventional recycling; apart from being highly specific to each waste stream, it requires a particular set of abilities that are not thought to be necessary for conventional recycling. It appears from the literature that there is scant analysis of the interface between industrial symbiosis and manufacturing practice. Generally, the focus is on theorising social factors such as actor participation (e.g. Domenech & Davies 2009) rather than analysing the broader operational aspects of implementation. However, some authors have examined the role of a project champion. Their articles indicate that a particular aspect of the topic is relevant to this research and as such, is discussed in the next subsection.

---

29 As explained elsewhere in this thesis, being an incidental product of manufacturing for which there is a demand and hence is traded.

30 And the periodic export of waste such a spent pot liner from smelting aluminium to Italy or bulk bags to China.

2.5.9 Project champion versus outsourcing

The function of a project champion appears to be critical for successful industrial symbiosis. The typical notion of a champion is a single individual whose personal enthusiasm provides inspiration and impetus for the project and whose abilities maintain its progress to fruition. Conceptually, a similar function can be performed by a group of people such the coordinating body mentioned by Mirata and Emtairah (2005, p994) and the industry catalyst, Synergy Trust, mentioned by Roberts (2004, p1008). Similarly, development of the eco-industrial system at Rotterdam reported by Baas and Huisingh (2008, p418) was facilitated professionally by various related groups throughout the 12-year period of the authors' study. Heeres et al. (2004) compared Dutch eco-industrial parks with those in the USA and noted that the local entrepreneurs'/employers' association in Holland performed the role of a champion.

The literature on Kalundborg does not address the issue of project champions, possibly because authors such as Engberg (1993), Gertler (1995), and Ehrenfeld and Gertler (1997) focused on other issues. However, Hewes and Lyons (2008) do write about Valdemar Christensen who was an original champion of the industrial symbiosis at Kalundborg. It may be surmised that individual managers within participating organisations adopted the role of a project champion in the course of performing their normal management duties. If this were in fact the case, then it raises the question of whether the champion driving a project is an individual within a company, or should the company itself be regarded as the champion (Chertow 2007, p25) In any case, the underlying 'message' from the literature is that a champion in some form is indispensible.

Mention of groups substituting for a project champion raises the concept of outsourcing as an alternative to dealing with waste in house. There is an extensive body of academic literature dealing with the subject in relation to non-core business (e.g. Heikkila & Cordon 2002; McIvor 2000; Barthelemy 2003). These authors point out that strategy is problematic when applied to the gamut of corporate activities but in the context of developing bilateral symbiosis as a broad-based, systematic strategy for dealing with waste, outsourcing would appear to be a viable option. This is what the National Industrial Symbiosis Programme (NISP) appears to be doing successfully in the UK (Subsection 7.4.1). Theoretically, an independent organisation like NISP could offer particular benefits: it would accumulate knowledge and expertise that would not be available to an individual; it would have a significantly wider sphere of operation and could provide services indefinitely whereas an individual may depart the organisation and take their accumulated knowledge with them. Outsourcing is discussed in Subsection 8.3.3.

2.5.10 A note about other literature

Discussing the results of this research (Chapter 8) has introduced topics that were thought to elucidate a particular finding or issue but are not seen to be at the core of this thesis, as is the literature reviewed in this chapter. For example, articles about business management have been cited on leadership and corporate culture, corporate social responsibility, ethics and consumer-citizen behaviour. Accordingly, where this occurs, the relevant literature is reviewed when it is introduced, as appropriate in the context in which it is used.

2.6 Conclusions

The conventional concept of industrial symbiosis is not suitable as a general model from which to develop a systematic, sustainable strategy for using manufacturing waste in NSW. Some elements of the concept, when viewed differently may, however, form the basis of a viable approach. They are summarised in this section.

Although the phrase 'industrial symbiosis' was originally used as a simile, it has been construed in the literature as a metaphor and as such, makes a deficient contribution to the concept of an eco-industrial system. Its guiding principle seems to be somewhat usurped by the overarching metaphor of a biological ecosystem. In the literature industrial symbiosis is construed to mean only mutualism. Biological symbiosis, however, also includes commensalism and altruism, each of which is potentially viable in the context of environmental protection and also non-financial corporate benefit.

The validity of depicting industrial symbiosis as necessarily comprising a network involving multiple participants with multiple relationships is questionable in view of the way in which long-established examples of the scenario evolved. Arrangements described in the literature as *exchanges* can in reality be viewed as transfers: discreet, one-way flows of energy, materials or water between two parties only. Various case studies mentioned in this review indicate that bilateral relationships would be an appropriate unit of study, rather than an entire network or its 'kernel' represented by Chertow's 3-2 heuristic (Chertow 2007).

Benefits associated with conventional industrial symbiosis discussed in the literature include those attributed to the social implications of close geographic proximity, principally the various manifestations of embeddedness. Among these attributes, close 'mental distance' and the development of trust between participants is seen as crucial to the success of an arrangement. It may be deduced from considering the dispersion of manufacturing in NSW that the social aspects of conventional industrial symbiosis will not materialise from bilateral arrangements. However, as Jensen et al. (2011) have found, these attributes are not essential. I contend that contracts and similar legally binding instruments between organisations are a surrogate for what is conventionally held to be the crucial element of trust between individuals in facilitating transactions. In as much as industrial symbiosis is ultimately a commercial undertaking, these instruments would likely suffice in practice.

There are sufficient case studies of industrial symbiosis and other relevant commentaries in the literature to indicate that the role of a project champion is also crucial for the success of an arrangement. It is evident that the role can be performed as effectively by a group of people, such as a committee, or by an independent facilitator, as it can by a single individual but the role must be performed.

Kalundborg is the iconic manifestation of conventional industrial symbiosis, described invariably as a network having particular attributes which exists in specific circumstances and is depicted as 'a state of being'. A different set of ideas about industrial symbiosis in relation to manufacturing in NSW has evolved from this review of the literature. It is thought that examining Kalundborg from the standpoint of its evolution would validate these ideas as a viable basis for this research. It is apparent that the role of project champion was performed by managers employed by the various companies involved with the arrangements at Kalundborg, all but one of which were bilateral. This suggests that manufacturers in NSW might take a similar approach. That is, they would be willing to undertake bilateral industrial symbiosis on their own behalf, rather than having it arranged for them by a third party such as NISP in the UK.

I argue that forming bilateral relationships is the basic process by which eco-industrial systems evolve. However, its potential for establishing industrial symbiosis in practice has not been developed by academia. The literature demonstrates the limited success of designed eco-industrial parks and the difficulties associated with establishing multilateral arrangements. I contend that the process of bilateral symbiosis avoids some of the problems that inhibit the development of conventional industrial symbiosis and that it is applicable to manufacturing in NSW and similar scenarios in other jurisdictions.

A theoretical basis for bilateral symbiosis is derived from deconstructing the eco-industrial system at Kalundborg, which shows that its evolution was an accumulation of bilateral arrangements (Chapter 7, Figure 7.2). These involved transfers of waste, water or energy from one party to another rather than exchanges between them and that some of the transfers did not involve waste but were normal commercial products or services. Most significantly, deconstruction demonstrates that the network of relationships typically portrayed in the academic literature represents the *result* of industrial symbiosis but does not represent the *process* by which it evolved. In view of the very significant influence that the iconic symbiosis at Kalundborg exerts on academic thinking, I suggest it is crucial to understand the process of its evolution. I contend that conceptually, bilateral symbiosis can be used as the basis for theoretical analysis of eco-industrial systems, in the context of using waste and, by extension, is a viable strategy in practice for future sustainable development.

As outlined in Section 1.5, the initial aim of this research was to demonstrate the viability of autogenous bilateral symbiosis in practice. Strategy for the fieldwork proposed that projects were to be instigated by the participating organisations themselves, using techniques designed to substitute for the characteristics of 'evolutionary Kalundborg' that are conventionally thought to be necessary for successful symbiosis but are absent in situations where manufacturing is dispersed, as in NSW. Manufacturers will likely need resources such as knowledge, training and procedures or manuals to undertake the process successfully, all of which would have been made available during the projects as required.

Results of the initial fieldwork reported and discussed in Chapter 3 indicated that the strategy should be abandoned in favour of a radically different methodology, described in Chapter 4, to assess the viability of bilateral symbiosis. This new approach involved academic issues and required a range of techniques that had not been necessary in the original research. It entailed consideration of the more fundamental factors influencing bilateral symbiosis, such as regulation, agency, corporate capacity and services available to facilitate arrangements. As a consequence, this thesis explores the potential for bilateral industrial symbiosis generally, under manufacturing conditions in NSW and discovers some of the challenges that might be encountered in deploying the strategy in practice.

Chapter 3
Phase 1: Autogenous bilateral symbiosis

Production lines for disposable cloth (waste is collected in baskets adjacent to the left-hand line)
Source: Mr David Robinson, retired General Manager of the factory at Seven Hills, NSW

Remnants of disposable dish cloths

In February 1998, I was introduced to George Norman Pty Ltd, a company owned by Kimberly Clark, which manufactured disposable cloths and wipes in the north-west outskirts of Sydney. Their products were made from imported rayon fibre (re-constituted cellulose) and 18-20% by weight of acrylic, used as a binder. The process generated two types of waste: trim waste (edges trimmed from the rolls of material before they were cut to product size and flat waste), sheets or even whole rolls of rejected material. The waste was characterised by a relatively low bulk density, approximately 200 kg/m^3, a high water absorbency of approximately 200% by weight and an oil absorbency of approximately 80% by weight. On the basis of some preliminary research into possible uses, I submitted a proposal for a working arrangement. By December 1998, the project had collapsed because the operations manager at George Norman, although the most senior manager on site, was not empowered to enter into an agreement and the management at Kimberly Clark were otherwise preoccupied. In February 2001 the operations manager, who remained the same person throughout the eight years of this story, resurrected the project because Kimberly Clark had sold the company to an owner/manager who in turn had sold it to an Australian company called Multix Ltd.

Research on uses resumed immediately and over the ensuing two years diverse possibilities were investigated such as cattle feed (since rayon is reconstituted cellulose), fill for padded post bags, spill control equipment, a growing medium for horticulture, needle punching to make absorbent mats, bedding for domestic pets and platting to make cord for various uses. By November 2002 nothing had worked! In some instances the difficulties were technical as in cattle feed. Rumen trials done in fistulous cattle at the University of Queensland indicated that only about 8% of the cellulose fibre was digestible. In case of padded post bags, although cellulose decomposes biologically, the acrylic does not so the manufacturer deemed the material unsuitable for its purpose. Aside from the difficulty in finding a use for the waste, it transpired that the freelance general manager hired by Multix to run the manufacturing operation had a mercurial approach to business which prevented settlement on the terms of an agreement between Multix and Qubator. Accordingly, the operations manager and I decided to abandon the project.

In 2004, Multix Ltd sold the business to Merino Pty Ltd and again the operations manager got in touch to resurrect the project. This time we proceeded on the basis that commercial arrangements would be sorted out if and when Qubator was successful. Third time lucky – almost! In late 2005, I caught a fleeting glimpse on television of live lobsters being packed for export, wrapped in sheets of wet material exactly like the product made in Sydney. I contacted the TV station and was eventually put in touch with the company in northern Tasmania that had been featured in the program. They were using imported product so there was no conflict of interest with Merino. Trials using the trim waste, needle punched to make 10-mm pads, proved to be effective and would have cost about a quarter the price of their current packaging. However, by the middle of 2006, when trials using mats produced in 2002 had been completed successfully, the needle punching business had been sold; the plant had been transferred to Melbourne and was no longer available to make the mats. No other economically viable needle punching equipment was available anywhere in the country. In 2008, Merino closed the plant in Sydney and moved production offshore; it was the last remaining manufacturer of such products in Australia.

3.1 Introduction

As stated in Subsection 1.5.1, the original aim of this research was to test three hypotheses: the first was that generators would find uses for their own waste, given the necessary knowledge and skills, in house, to do so. In other words, they would undertake autogenous bilateral symbiosis, as distinct from the alternative approach in which arrangements are facilitated by an independent organisation, unrelated to either the generator or the user of waste. The second was that bilateral symbiosis can be facilitated successfully by an intermediary[1] and the third was that government environmental regulation exerts a dominant influence on the feasibility of bilateral symbiosis. In Section 2.6, I argue from an historical interpretation of the relevant literature that bilateral symbiosis is the basic process by which eco-industrial systems evolve. To the extent that a systematic, sustainable approach to using waste can be construed as an eco-industrial system, it was thought that verifying the first two hypotheses would enhance that argument. This chapter records the methodologies used for this phase of the research and the results of attempting to undertake the relevant fieldwork, and identifies the basis for subsequent work from a discussion of the results.

3.2 Methodology

A set of procedures was developed that formalised stages in the process of bilateral symbiosis. The general approach to conducting fieldwork was to recruit suitable organisations that would undertake initial trials in which the procedures would be applied. In light of the results, they would be refined and tested again, as required. Conceptually, the procedures had to be robust, in the sense that they could be applied to a wide range of circumstances. Commensurate with being effective, they should also be uncomplicated, in the sense of being easy to follow because they were intended to be used by line managers[2] who would likely not have the time or inclination to perform complicated tasks. A theoretical basis for the procedures was established by combining methods for organising a project suggested by Cleland (1994) with techniques for risk analysis described by Chapman and Ward (1997). A central element of Cleland's approach is the 'work breakdown structure', described in this chapter as a project breakdown structure (PBS), in which the entire project is divided into a system of subprojects. The subprojects are organised in 'levels', illustrated by the adaptation shown in Figure A5.1 in Appendix 5. Within each level, projects are similarly subdivided until a level

1 An organisation involved in the 'transaction' (as a facilitator, rather than as a transporter) other than the principals i.e. the generator and the user.

2 Managers responsible for day-to-day operations rather than those managing corporate functions such as accounts, occupational health and safety or compliance with environmental regulations.

of simplicity is reached at which there is no managerial advantage to be gained by further subdivision. Each subproject is allocated a unique identifier, which relates it to associated subprojects in the PBS. All subprojects have ascribed to them appropriate details such as objectives, tasks, costs, resources and management responsibilities. Risk is a more complex phenomenon but techniques for assessing it were also related to the PBS, as mentioned in the next subsection.

3.2.1 Developing and testing the procedures

The PBS for bilateral symbiosis developed for this study comprised three elements: a series of objectives, described as the project breakdown objectives (PBO), an abridged version of which is illustrated in Figure A5.2 in Appendix 5, a scope of work associated with each objective, described as a task group (TG) and an array of conditions that represent risks which might entail futile effort (after Chapman & Ward 1997). These are referred to as kybosh conditions (KC), which would or could prevent a project from progressing. Examples are given in Figure A5.3 in Appendix 5. The procedures were written in the format of MS Excel spreadsheets. Had fieldwork progressed as originally planned, the format might have been changed for subsequent trials if, for example, results indicated that a manual would be more effective.

Trials were intended to be case studies in which participants nominated by their respective organisations would have been briefed on the procedures and how to apply them. Progress would have been monitored at regular meetings throughout the trials and problems discussed accordingly. It was recognised that my participation at various stages might influence results. However, participation would have been limited to an initial briefing, similar to the training an employee might need for any new task and to the role of an observer-cum-mentor throughout the trial. Such involvement would have been recorded and its influence on the results determined accordingly. The principal purpose of the trials was to assess how effectively the knowledge and skills needed to instigate bilateral symbiosis could be transferred by the procedures to manufacturers and used successfully by them to avoid dumping waste. The corollary was to discover what other skills or knowledge, if any, would be required to make bilateral symbiosis happen in practice.[3]

Establishing the trials was planned as an operation in three stages. First, an outline proposal was to be submitted to the target organisations and managers responsible for making the relevant decisions persuaded that the organisation would benefit from

3 It is noted that the procedures could be used equally well by intermediaries such as brokers or facilitators and by manufacturers who want to acquire waste in place of existing inputs.

participating in a trial. Second, the situation in relation to the disposal of was to have been assessed and details of the project established accordingly.[4] A formal proposal would then have been drafted, ratified by the parties and submitted to the Human Research Ethics Committee of the University of Sydney for approval. For reasons discussed in Section 3.4, fieldwork did not progress beyond the first stage.

The intention was to conduct at least two but no more than three case studies simultaneously. This strategy was intended to minimise research risk and maximise experimental rigour. If a single case study were undertaken and it failed for reasons unrelated to the research (e.g. a corporate takeover) the research might have been critically delayed or possibly terminated. Assessing the results from two or more case studies was thought to provide a more reliable indication of how well the procedures fulfilled their purpose than would have been obtained from the results of a single study. A maximum of three case studies was set on the basis of a trade-off between the quality of information and its quantity. It was decided that better results would be obtained from the scope of this research if fewer than four studies were recorded with greater depth of detail than would be feasible if more than three studies were undertaken.

3.2.2 Criteria for selecting participants and assessing results

The principal purpose of bilateral symbiosis, from both a theoretical and a practical perspective, is that it should result in waste being diverted from landfill and used appropriately. This was set as the overarching objective of a trial, which a participating organisation would have been required to support with at least the following resources and capabilities:

- a ‘project champion’ – someone keen to participate who has sufficient authority in the organisation to ‘make things happen’ and with sufficient time available to spend doing the work required
- the funds to pay for expenses such as analysing samples, third-party reports, providing samples to potential users for assessment and to cover incidental costs
- the capacity to enter into agreements, memoranda of understanding or the like, with other entities (e.g. regulators, potential users, consultants) that may become involved with the project.

---

4 These include the type and amounts of waste to be dealt with, the resources to be contributed by each party, objectives for the project and various contingency arrangements in regard to unintended results.

Organisations were selected with respect to project criteria, which related to what they could expect from the trials and also with respect to research criteria relating to requirements of the research itself.

Project criteria

There must be a reasonable prospect of achieving the outcomes suggested to the prospective participant when presenting the project for consideration. Achieving the overarching objective must be feasible and in particular:

- it must be within the capacity of the organisation to make available the resources that would be required for the project
- the cost of disposal before the project is undertaken must be high enough to justify the effort of finding use for the waste and hence be attractive compensation for participating in the trials
- the idea of having its waste used by another organisation must be compatible with the participant's corporate policy.

Research criteria

There must be good prospects of achieving significant results in the context of this research, if not a final outcome within about 18 months of starting the trial.[5] In particular, the participant should be:

- accessible from Sydney within a day's return journey so that the trial can be instigated and monitored satisfactorily
- large enough to have the resources available to undertake the project, particularly the 'project champion'
- willing to give a written undertaking to support the trial as agreed
- able to provide accurate records of current waste disposal as a basis for assessing alternatives developed during the trial.

Assessing results

A general methodology for assessing results of the trials was contemplated while planning the fieldwork. It was recognised that the details of each project would need

5 This limit was imposed to allow the thesis to be completed within the time allotted but there is no reason why trials should not continue beyond this time limit to achieve a 'commercial' result.

to be known before a suitably refined basis for assessment could be established. As might be expected from a participant's perspective, the principal research criterion would have to gauge the extent to which the objectives of the trial were achieved. Other criteria would relate to the degree of facility offered by the procedures, for example, in terms of how easily they were understood and applied, which in turn has a bearing on how bilateral symbiosis might become a systematic, sustainable business strategy in practice.

3.2.3 Approach to recruiting participants

Lists used to identify potential participants were available from Qubator's records and from the Good Reputation Index, a survey formerly published by the Fairfax Media Ltd which rated the performance of Australia's top 100 companies on a range of environmental, social and workplace issues in various economic sectors.[6] Selecting target organisations was influenced by my knowledge of industry in NSW and my experience in arranging bilateral symbiosis. Based on the criteria mentioned in Subsection 3.2.2, 12 organisations were selected, as explained below:

- Construction companies – selected because this sector was known at the time to discard to landfill approximately 45% of the material inputs as waste.[7] The waste comprised materials that are potentially reusable e.g. metal, timber, ceramics and concrete, plastic and paper but dumped principally because they are intermingled. The three companies selected were Lend Lease, Mirvac and Leighton Holdings, all among the largest in Australia.
- Manufacturers of building products – selected because each of the two companies approached, namely CSR and James Hardie, discarded to landfill at the time a minimum of 200 tonnes per week of scrap fibre cement product (Qubator's records). These are significant quantities in terms of cost to the company and volume of landfill used.
- General manufacturers – the companies in this category were selected from Qubator's records except Thales Australia which was suggested by an erstwhile business associate because of its dominant size in the defence industry and was thought to send significant amounts of waste to landfill. Companies approached were: Nestle Australia (food production), O-I Glass (glass production), Thales Australia (defence supplies and services), BlueScope Steel (steel production), Rio Tinto (aluminium smelting), Johnson & Johnson (pharmaceuticals).

6 For example, see: www.smh.com.au/articles/2002/10/28/1035683351089.html.

7 See also for example: www.derm.qld.gov.au/register/p00484aa.pdf.

- Local government – the selection of Fairfield City Council was to some extent opportunistic in that management was known from previous discussions to be particularly interested in finding ways to minimise the amount of municipal waste council sends to landfill. As aggregators of 'hard rubbish' (e.g. white goods, electronic waste, furniture and household artefacts), municipal councils have similar problems to manufacturers in dealing with the waste they acquire. There is no theoretical reason why the procedures should not also be used by public sector organisations, so the council was selected.

In accordance with the operation mentioned in Subsection 3.2.1 for establishing the trials, prospective participants were initially approached by telephone, principally to contact the 'right person' with whom to canvas interest in participating. A written proposal introducing the research and outlining the project was submitted to those who were willing to consider a trial. Discussions were then held with prospective participant, in light of their response to the proposal. Results of these activities are outlined in the next section.

3.3 Results

Responses from the 12 organisations approached between April and September 2007 are recorded in Appendix 6, together with that of a 13th company canvassed in March 2008 as a result of a referral. Of these, three expressed tentative interest in undertaking a project. Proposals were submitted and meetings were held accordingly with representatives of each organisation but none decided to proceed. The reasons given are summarised below.

BlueScope Steel Ltd

They did not proceed because their strategy is to rely on alliances with third parties to solve their problems for them. They have the expertise in house to negotiate such alliances and did not think there was any value to the company in acquiring their own expertise in bilateral symbiosis. They view their underlying problem as not having the contacts they need to find uses for their waste. However, they would not devote resources to developing those contacts as, for example, would have been the result of undertaking trials.[8]

---

8 Four years after this meeting I sat next to my erstwhile interlocutor at a conference dinner in September 2010. It transpired that they had made no progress at all in finding uses for the waste that had been proposed for their trial.

Fairfield City Council

The director of waste clearance services was very keen to proceed with the trials and recognised the potential benefit of acquiring the expertise. The council could certainly finance the trials but decided eventually not to proceed because the employee identified to be the project champion became too heavily committed to other projects. They tried to engage an ex-employee, part time, specifically for the project but were unsuccessful.[9]

James Hardie Ltd (JH)

The National Purchasing Manager at JH wanted to divert a particularly large stream of waste away from landfill. Their strategy until 2007 when we met to discuss the trials had been to wait until a solution dropped into their lap (his phrase), that is, they were relying on third parties to solve their problem. They had considered at least four opportunities to deal with this waste over the previous five years, none of which had been pursued, so there seemed to be good prospects for the trials to proceed. However, the manager could not see how JH would benefit from the trials and so declined to participate.[10]

Contacting the 'right person'

Contacting the 'right person' in an organisation with whom to canvas interest in the trials emerged as a critical issue. In some cases I was introduced by a mutual acquaintance. In others, I was referred to someone in corporate services such as a group environmental officer or technical services manager. It transpired that such service people do not have responsibility for disposing of waste. Line managers, i.e. those in operations, have that responsibility but getting 'past' the services people to contact them directly was difficult and in one instance was not possible.

3.4 Discussion

The hypothesis to have been tested in this phase of the research was based on the premise that autogenous bilateral symbiosis is the most economical way for manufacturers to deal with their waste and would likely also be viewed as entailing the least risk. The underlying assumptions were that generators of waste:

---

9 Having declined to participate in trials for this research, the director asked me to submit a proposal, from Qubator, to do much the same work as would have been done during the trials.

10 As with Fairfield City Council, I was subsequently asked to submit a proposal to find a use for this waste, as a fee-paying project for Qubator. They accepted an outline proposal for a complete project and had requested a detailed proposal for Stage 1 but on 15 January 2008, they declined to proceed.

- have a problem disposing of their waste
- have a strong vested interest in minimising the costs of disposal
- would prefer to find uses for their own waste, given the requisite expertise.

It became apparent that these assumptions might not be generally true. The construction companies did not express any concern at all about their waste. BlueScope Steel and James Hardie had been content to wait until a third party dealt with their problem for them even though there was concern about cost and the lack of external resources. Others seemed to be influenced by more fundamental issues such as management capacity and corporate policy.

Proposals submitted to prospective participants outlined how the benefits resulting from the trial might be achieved, particularly the potential for reducing costs of disposal. Nevertheless, some managers had difficulty with the indeterminate nature of the proposal. They needed to determine a 'return on investment' before approving the project but since the commercial objective, as distinct from the research objectives, was to develop those benefits; the situation was a classic 'catch 22'.

The 12 organisations selected for trials were the most promising 'targets' with respect to the selection criteria and all had declined to participate. In view of this situation, there was thought to be very little likelihood of recruiting three or even two other suitable organisations willing and able to complete trials within the period scheduled for fieldwork. More significantly, although only 12 organisations had been canvassed, sufficient information had been accumulated to suggest that some fundamental issues needed to be resolved before doing further research on the application of autogenic bilateral symbiosis. It was therefore decided in November 2007 to postpone indefinitely further work on testing the hypotheses and to concentrate instead on researching those issues, as outlined in Section 3.5 that follows.

3.5 Issues that emerged from Phase 1

Recapping the results up to the end of November 2007, contrary to original expectations and the goals of the NSW government's approach to pricing landfill, some managers did not appear to be concerned about the waste generated by their organisations, either in terms of what happens to it or the costs of disposal. Others who did express concern nevertheless wanted third parties to solve their problems for them. Still others who were concerned would apparently have been willing to deal with their own problems, if they had the resources to do so. Several managers did not recognise the benefits that could be achieved from bilateral symbiosis.

It is significant that in most conversations, the perspective of management was being discussed, if not an individual manager as the deciding authority, rather than a higher level stance such as set by corporate policy. The implication is that the views and capacities of individual managers are prominent factors in determining a manufacturer's approach to dealing with waste.

These observations raised the following questions about manufacturers generally in NSW, on which Phase 2 of this research was based:

- Do managers believe they have a problem disposing of waste, either currently or in the foreseeable future?
- Do managers think that finding uses for their waste would be a satisfactory way of dealing with their problems?
- Would managers be willing to undertake autogenic bilateral symbiosis and if so, what resources in house could they make available?
- What external resources would managers enlist to help deal with their waste, if they did not make their own arrangements, in house?
- What factors influence managers' decisions about dealing with waste?

Chapter 4

Phase 2: Research methods

Scrap plastic-coated paper from the manufacture of packaging for liquid food products
Source: Mr Greg Andriske, retired Scrap Procurement Manager, Australian Paper Mills

Scrap plastic

As part of the continuing research mentioned in the vignette for Chapter 2, I contacted Australian Paper Mills in May 2003 at their factory in Bomaderry, approximately 160 km south of Sydney, to canvass their interest in using the scrap from Multix. My interlocutor, who became their 'internal champion' for this project, mentioned that they also have scrap that they dump but they would like to find a use for it. The factory produced very high quality paper. Part of their raw material is made up of fibre recovered from discarded Tetra Pac and similar containers used for milk, fruit juices and various other types of liquid food. The packaging is made from the highest grade of cellulose fibre and is coated with a plastic film on both sides. The company separates the fibre from the plastic, which it dumped plastic at the rate of five dry tonnes a day.

The company used a coal fired furnace for process heat, which burned an average of 20 tonnes a day of (-25 mm +12 mm) graded washed coal bought from the Baal Bone mine near Lithgow in NSW, approximately 250 km away. The plastic was mostly low-density polyethylene (LDPE) but some high-density polyethylene (HDPE) was mixed with it. These types of plastic are generally suitable for granulating and re-use but much of this particular material was coated with an aluminium film, used in some types of packaging to protect the contents from the effects of sunlight. The aluminium prevented the scrap from being recycled through the established system of traders. However, the plastic fraction was pure hydrocarbon with a calorific value comparable to fuel oil or natural gas and burns cleanly without emitting noxious gas. It was eminently suitable for fuel but could not be introduced to the furnace satisfactorily because instead of going into the fire-box, the updraft wafted the particles of plastic straight up the chimney.

I suggested increasing the density of the plastic by briquetting it with coal. I found a source of scrap coal that was being dumped at Unanderra in NSW, about 60 km from the paper mill. The scrap was high quality for thermal purposes and only required minimal processing before mixing with the plastic. Briquettes were made by the CSIRO at North Ryde, in Sydney, using equipment that produced satisfactory samples of lump size comparable to that of the coal then being used in the furnace. Equipment required for commercial scale briquetting was available 'off the shelf'. It is rugged, basic and capable of automatic operation without requiring sophisticated process control. Such details are important considerations for manufacturers.

Although burning the plastic was the most useful solution to the problem of disposal, an alternative was trailed simultaneously, in case briquetting did not work. As mentioned above, the scrap plastic was not recycled conventionally because of its protective aluminium film. However, if the aluminium were removed, it could be recycled conventionally. I discovered that soaking the plastic in a caustic solution removed the aluminium coating completely and very rapidly. Exactly this process is used routinely in commercial anodising plants to clean aluminium before it is anodised.

Results of both approaches were presented to senior management of the mill in February 2004, on the basis of which, it was agreed to proceed with pilot trials of the fuel briquettes. The project was abandoned by the engineering manager six month later, ostensibly due to the onerous requirements of the NSW environmental protection agency in relation to performance of the furnace, for which he was ultimately responsible. The 'internal champion' subsequently told me the real reason for the decision. Notwithstanding top management would have saved even A$50 a week if they could, given the parlous state of the business, the engineering manager was reluctant to increase his workload by accepting briquetting plant on site for which he would necessarily become ultimately responsible.

4.1 Introduction

The results of Phase 1 raised questions which suggested that in relation to a systematic, sustainable strategy for using industrial waste, it was perhaps premature to introduce an operational model for bilateral symbiosis along the lines recorded in Chapter 3. They suggested it is crucial to understand first the views of people who manage manufacturing from day to day and the capacities of their organisation to deal with the waste they produce. If managers who make the relevant decisions do not believe they have a problem disposing of waste or they are indifferent about the issue, then they are most unlikely to participate in bilateral symbiosis, no matter how or by whom it is instigated.[1] If mangers do recognise they have a problem then information on what measures they would consider taking to deal with it and the resources they need would likely indicate the extent to which systematic bilateral symbiosis might be a viable business strategy. The information might in turn suggest other, more effective, ways of implementing bilateral symbiosis than was attempted at the outset of this research or indeed a completely different approach to using industrial waste.

Restating for emphasis, the conclusions of Phase 1, which formed the basis of Phase 2 are:

- Do managers believe they have a problem disposing of waste, either currently or in the foreseeable future?
- Do managers think that finding uses for their waste would be a satisfactory way of dealing with their problems?
- Would managers be willing to undertake autogenic bilateral symbiosis and if so, what resources in house could they make available?
- What external resources would managers enlist to help deal with their waste, if they did not make their own arrangements, in house?
- What factors influence managers' decisions about dealing with waste?

The conceptual context for this methodology is that information would likely come from diverse sources and be gathered in different ways. A general methodology was adopted, therefore, which integrated five distinct research techniques. The first was a survey to gather information relating specifically to the questions listed above. It comprised a questionnaire, described in Section 4.2, interviews based on responses to the questionnaire, as described in Section 4.3 and a telephoning campaign described in

1 This view is supported by my experience on occasions when Qubator has failed to establish bilateral symbiosis due to the indifference of management.

Section 4.4. The second technique was to deconstruct the archetypical eco-industrial system at Kalundborg (Section 4.5) in order to substantiate both the preliminary understanding of bilateral symbiosis formed at the beginning of this research and its relevance in practice to manufacturing in NSW. The third technique may be thought of as indicative case studies. As outlined in Section 4.6, a senior representative of two companies actively engaged as the project champion in autogenous bilateral symbiosis was interviewed to find out the extent to which their experiences co-related with results of the survey. The fourth technique comprised a review of the National Industrial Symbiosis Program (NISP) in the UK, outlined in Section 4.7 and an assessment of its potential application in Australia. NISP is a systematic, nationwide deployment of industrial symbiosis that has, to date (July 2011), been demonstrably successful (Subsection 7.4.1). The fifth technique is participation in the development of the Australasian Industrial Ecology Network (AIEN), for the research purpose of observing its evolution and hence assessing its potential to facilitate systematic bilateral symbiosis (Section 4.8). This continues to be work-in-progress (September 2011) but some significant insights have already emerged (Subsection 8.5.4).

As research progressed, concepts evolved, relative to the manufacture of an external and an internal infrastructure that would support bilateral symbiosis. They are distinct from the usual notion of infrastructure involving close proximity of organisations, shared reticulation systems and the like, epitomised by Kalundborg (Subsection 2.5.6). The external infrastructure pervades the whole of industry and refers to resources such as educational institutions, government bodies, consultants and various types of contractor, which a manufacturer might approach for assistance. Internal infrastructure refers to the resources and capabilities that exist within a manufacturing organisation itself, which could be used in autogenous bilateral symbiosis. In this context, question 3 of the questionnaire (Section 4.2) relates to elements of an internal infrastructure and question 4 relates to elements of the external infrastructure.

4.1.1 Scope of research

Research is focused on waste arising from manufacturing, which is understood to include:

- primary activities such as smelting and casting
- secondary activities such as fabrication and assembly
- processing such as anodising, galvanising and rendering
- secondary food production in its various forms.

The principal reason for concentrating on manufacturing is that in NSW, waste is predominantly heterogeneous, geographically dispersed and typically does not arise in sufficient quantities at any one location to support dedicated processing facilities on site.[2] These characteristics are particularly problematic in the context of bilateral symbiosis so findings from the results were expected to be valid also in less stringent circumstances. Aside from this consideration, the landfill levies in regions within the geographic boundary of this research are among the highest in the country so it was thought that manufacturers in those regions would have a particular incentive to consider the potential for bilateral symbiosis. This study does not extend to waste from primary food production such as agriculture, horticulture and fishing or arising from extractive industries such as mining and forestry. It is recognised, however, that these industries also generate waste and that some of it could be amenable to bilateral symbiosis in which case findings from the study of manufacturing would apply.

In this research, bilateral symbiosis is viewed from the perspective of the organisation that possesses waste (the generator). The underlying objective is to avoid dumping waste, which is a generator's perspective, rather than to source inputs, which would be a user's perspective. The distinction emphasises that although bilateral symbiosis may be instigated by or on behalf of a manufacturer, the user may not be a manufacturer, as a result other industries might come within the scope of this study.

The geographic boundary of this research is notionally the state of NSW, from which most of the target respondents to the questionnaire and interviewees were selected. As mentioned in Section 1.2, NSW has the largest manufacturing base of any state in Australia and offers a variety of manufacturers from which to obtain data. Most organisations of interest were accessible from the University of Sydney, given the resources available for fieldwork. It is noted that the economics of bilateral symbiosis are largely dependant on the negative value of waste created by government regulations and as demonstrated in Section 1.3, the NSW government imposes the highest levies on landfill of any state in Australia. The legal options available for disposing of waste, other than for use, are limited to storage on site, incineration, dumping in landfill or discharging to sewer. Each option incurs costs which cannot be avoided so even where landfill levies are less than in NSW, bilateral symbiosis may still be economically viable. It was reasoned, therefore, that the findings from a study in NSW would potentially be valid for other jurisdictions.

2 As distinct from dedicated facilities at aggregation sites such as exist for paper, glass and abundant metals, for example.

4.1.2 Units of study

Theoretical discourse on industrial symbiosis is predominantly about the various relationships among organisations and between them and the environment. However, experience during Phase 1 (Sections 3.3 and 3.4) indicated that it is generally an individual manager within a manufacturing organisation who makes the day-to-day decisions about disposing of waste, not the organisation itself, represented for example by the board of directors (see O'Neil 1999 and McDowell 2001; Subsection 8.6.4). Factors such as corporate policy or a group strategy for waste disposal may influence how waste is dealt with but the responsibility nevertheless rests with an individual who will make the relevant decisions accordingly. The research questions listed in the introduction above focus on the views of individual managers, since they are thought to be the agent (Subsection 8.7.4) most likely to influence the disposal of waste. Question 4, however, alludes to organisations that might in some way help to facilitate bilateral symbiosis. The survey outlined in Sections 4.2 and 4.3 therefore has two units of study: an individual manager in relation to the questionnaire and an organisation in relation to the interviews and the telephone campaign.

4.1.3 Insider interviews and researcher embeddedness

My business experience outlined in the preface would appear to place me, as a researcher, in the sort of predicament described by Rose (1997) in the context of creating feminist geography through reflexivity or by Adriansen and Madsen (2009) in their efforts as academics to study their fellow academics. The general problem relates predominantly to interviewing when the knowledge and experience of the interviewer, which perhaps in some cases enables a clear understanding of the issues being discussed, may cause information to be distorted or ignored and may influence the accuracy of analysis. The problem is likely exacerbated by embeddedness, as in my involvement with AIEN (Section 4.8) when the actions of the researcher may affect what is being observed. Adriansen and Madsen (2009, p145) comment that 'It is, however, important to note that we cannot determine the direct effect of insider relations on the results.'

These authors and others such as Crang (2003) write about making highly nuanced geographies in which an understanding of how methodology influences results seems crucial for accurate analysis. In that context my experience was undoubtedly an advantage in understanding the perspectives and views of my interlocutors but given the nature of the information required, it was not thought to significantly influence the findings. Participation in AIEN is more problematic as a research technique in terms of possibly influencing the results but it is suggested that in this case also, the findings are unlikely to have been significantly influenced by my involvement with the organisation.

4.2 Survey – questionnaire

4.2.1 Target respondents

The person responsible for deciding how to dispose of waste is thought to be generally a senior executive such as an operations manager, an environmental manager with line responsibility[3] or a plant manager. People at this level were, therefore, the target respondents for the questionnaire. Their contact details were obtained variously from public information available on the internet, from telephone directories, from Qubator's database and by referrals, a process known as snowballing, explained by Valentine (Flowerdew & Martin 1997, p116).

In my business experience people in such positions typically have very little time or inclination to undertake extraneous tasks, such as completing a questionnaire. In conjunction with the recommendations by Parfitt (in Flowerdew & Martin 1997) and McLafferty (in Clifford & Valentine 2003), the questionnaire was designed with the following criteria in mind:

- It must be self-explanatory so that it can be completed without the guidance of a researcher.
- The response to a question should be as brief as possible. Notwithstanding Parffitt's view of 'yes/no' answers (Flowerdew & Martin 1997) this type of response was used where appropriate.
- Questions should involve as little 'thinking time' as possible.
- Questions should be avoided which might require searching for information such as, for example: 'how much waste do you dump per month'.
- The total time to read the introduction and respond to the questions should not exceed 20 minutes.

The complete questionnaire, shown in Appendix 7, was arranged in four groups of sub-questions relating to each of the principal questions mentioned in Section 3.5. A fifth group dealt with the respondent's willingness to participate further in the research. The computer software used to compose and present the questionnaire was Microsoft Office Word (MS Word) from which responses were transposed manually to Microsoft Office Excel for analysis. A due date for completing the questionnaire was deliberately not set because it was anticipated that respondents would be pre-occupied with business

3 That is, responsible for day-to-day operations as distinct from corporate services which are typically not responsible for operations.

operations, given the working conditions and time constraints imposed on senior managers and may not have bothered with a questionnaire after its due date passed. It was thought better to have a delayed response than no response at all. The consequence of omitting a due date is recorded in Subsection 5.1.1. The option of only a 'yes' or a 'no' response was provided in the first three sections of the questionnaire with a guiding note at the beginning to the effect that if either of these responses were inadequate then the respondent could indicate 'yes' and 'no' simultaneously and comment accordingly. With the hindsight derived from analysing the results, a third option such as 'maybe' or 'don't know' for each question may have been a better alternative to a guiding note at the beginning of the questionnaire as it might have reduced the ambiguity of some responses. Criteria for selecting a sample for the questionnaire relate to geographic scale, that is, the location of an organisation, the nature of its business, its size and my business experience. It is acknowledged that the method of selection used was, to some extent, purposive and that the information obtained might have differed from that generated, for example, from simple random or systematic sampling (e.g. Rice 2003). Reasons for the sampling methods used and the ramifications are discussed in the next section.

4.2.2 Target organisations

For the purpose of describing this part of the methodology, the term 'organisation' refers to a commercial entity, specifically a manufacturing site and the term 'business' refers to the activity in which an organisation is engaged. To the extent practicable, target organisations were selected according to one or more of the following criteria:

- their business was thought to involve the disposal of waste which would therefore likely be a problem for them
- they participate in a business that is conducted in other states of Australia in much the same way as it is conducted in NSW
- there are channels available for the mass distribution of questionnaires
- the organisation is a large, if not a dominant, participant in its business.

The rationale for this last criterion is twofold. Large organisations generally produce significant amounts of waste in terms of its environmental impact and in terms of the storage, handling and disposal costs involved. They were therefore thought likely to have a stronger incentive to avoid dumping than their smaller competitors. They were also thought more likely to have the resources available to instigate bilateral symbiosis. Canvassing small organisations with inadequate resources risked indeterminate bias in the responses. For example, if the option to participate in bilateral symbiosis is not available owing to a lack of resources then favourable responses relating to the respondent's 'willingness' to participate may be wishful thinking rather than an indication of feasible action. It was also thought likely that organisations with inadequate resources or problems which seem insurmountable might not respond at all, as may have been the case (Subsection 5.1.1) with the frame and truss manufacturers mentioned below. The intention was to gather data from two categories of organisations:

- Those operating within NSW engaged in any type of relevant manufacturing business. The majority of targets were selected from this category.
- Those engaged in two types of business (aluminium smelting and frame and truss manufacturing) conducted in other states as well as in NSW. It was thought that information from these sources might yield insights to applying bilateral symbiosis more widely than NSW.

4.2.3 Sample size and distributing the questionnaire

Information required from the questionnaire was intended to indicate circumstances pertaining to manufacturing and to guide subsequent research. Data was not intended to be used for predictive purposes that required advanced statistical analyses. It was understood, however, that basic analysis would be necessary to produce reliable findings for which a minimum sample size of 30 is regarded as statistically significant[4] (Parfitt in Flowerdew & Martin 1997; Rice in Clifford & Valentine 2003). A preliminary survey of manufacturers was undertaken with regard to the various selection criteria. As a result, it was thought that a target sample size of 50 completed questionnaires would be achievable and adequate for the purpose.

Pilot questionnaire

A pilot questionnaire in the format intended to be submitted to the Human Research Ethics Committee (HREC) of the University of Sydney was sent to nine respondents selected from Qubator's database. The pilot sample comprised organisations in various types of manufacturing. Respondents were asked to complete the questionnaire as if it were not a trial and to comment as they saw fit. Results from the pilot were used to modify the questionnaire which was submitted to HREC for approval.

4 Proven mathematically, for example, to be required for a dependable determination of standard error.

Distribution

Two methods of distribution were planned: mass distribution and direct distribution (the corporate equivalent of home delivery). Mass distribution was organised by the Frame and Truss Manufacturers Association Australia (FTMA), which has more than 150 members located mainly in the eastern seaboard states of NSW, Victoria and Queensland.

Contact details for direct distribution were obtained from telephone directories, the internet or from Qubator's records. Notwithstanding the preliminary survey mentioned above, identifying target organisations and contacting prospective respondents in practice was significantly more difficult than anticipated. The first questionnaires were sent in June 2008; the final batch was sent in August 2009. Most responses were received within three months but several were returned more than nine months after they had been sent. A preliminary analysis of the 20 responses received between June and December 2008 yielded information that was not significantly changed by subsequent responses (Subsection 5.1.1). In view of this and the length of time taken to conduct this part of the survey, it was decided in November 2009 that the 48 questionnaires that had been distributed directly by then would suffice. Of these, 32 responses were eventually returned which combined with those received from mass distribution yielded a total sample size of 37. It is noted that no responses to the mass distribution had been received from frame and truss manufacturer in NSW so during the period 13–17 August 2009 questionnaires were sent directly to the six largest organisation in the state, identified as a result of 'snowballing' and only one responded.

4.2.4 Recording and analysing responses

Responses to the questionnaire were recorded in an Excel spread sheet (Appendix 8) using a binary system suitable for computer manipulation. Data were transcribed manually from questionnaires returned by fax and from paper copies of questionnaires returned by email, which were made as back-ups of the electronic version. A sample size of 50 can be managed without the aid of complicated computer techniques and in accordance with Dorling's advice (in Clifford & Valentine 2003) a simple statistical analysis was thought to be suitable for extracting information from the data. If the response to a particular question were ambiguous and the respondent had indicated in Section 5 of the questionnaire a willingness to discuss the survey, then any clarification required was sought accordingly. Similarly, the respondent was contacted if a comment were made in the questionnaire that warranted elucidation. If a respondent did not indicate a willingness to discuss the survey then the ambiguity was noted and taken into account when analysing the results. Comments made in the questionnaire were correlated manually because they were not numerous enough to necessitate statistical methods analysis.

4.3 Survey – interviews

The purpose of question 4.4 of the questionnaire was to find out what type of organisations senior managers in manufacturing are likely to approach for help in finding uses for their waste. That is, what 'services' would predominantly constitute the *external* infrastructure required to facilitate bilateral symbiosis. The corollary is to find out what infrastructure currently existed at the time of the fieldwork for this research (2010) and what might be planned for the future. Two broad categories of organisations were canvassed in relation to these issues, as outlined in Subsection 4.3.2.

Information required for this part of the research is essentially factual, about an organisation, rather than personal or emotional about the respondent. It might therefore have been gathered by means of a questionnaire, however, interviews were thought to be a more dependable method. It would be easier to understand the extent to which an interviewee might overstate their organisation's capacity to provide a nominated service, particularly in a highly competitive business such as waste management, where the profit motive is paramount. Interviewees would be asked to speculate about the future and for this reason also, it was thought that assessing the results of an interview would be more informative than analysing those from a questionnaire.

Organisations in the second category outlined in Subsection 4.3.2 operate in broadly populated 'markets' such as environmental consultants and public academic institutions. The original intention was to interview representatives from these organisations, even though there are many more of them than in the first category. However, in light of the difficulties experienced in contacting the right person for the initial interviews and in distributing the questionnaire before that, it was decided to use an alternative method of gathering information, as explained in Section 4.4

4.3.1 Interview structure

Two options for structuring the interviews were considered. One was to establish a formal list of questions, from which there would be no deviation and no exchange of ideas, that is, a highly structured interview. The other was a semi-structured interview for which would be prepared a list of topics to be canvassed that are introduced opportunistically during conversation and commented upon by the respondent during the natural 'flow' of the interview (Longhurst 2003 in Clifford & Valentine 2003). The option of an unstructured interview, tantamount to a conversation with no particular agenda, was not thought to be as useful as a structured approach, given the greater risk of neglecting some factual information that might have been required. It was recognised that, except for the regulator, organisations of a given type would likely be represented by interviewees with differing roles and levels of authority. Although interviews should be as consistent as possible, to maintain research rigour, they must also accommodate differences between organisations. A semi-structured approach was chosen as the more likely option to satisfy these requirements. The initial sets of questions (Appendix 9) were compiled on the understanding that they may change as the campaign progressed, in light of previous interviews. Each interview began with an explanation of what the research is about and an introduction to topic of discussion.

4.3.2 Selecting interviewees

Information on two categories of organisation was intended to be gathered by interview. One comprised organisations able to influence directly the development of bilateral symbiosis in NSW. The principal among these is the NSW Department of Environment, Climate Change and Water (DECCW). The Waste Management Section in DECCW is the regulator and is responsible for administering the law in relation to waste. The manager (G1) of that section was interviewed. This category also includes political parties, especially when they are in government. At the time of the interviews (2010), the Labor government had been in power continuously since 1995. Policies with respect to industrial waste were therefore well represented by DECCW. Labor was voted out of office in March 2011 but no significant changes in policy had been made by the time of writing (July 2011). Those of the then Opposition Liberal Party/ National Party Coalition were not represented by DECCW so the Shadow Minister for the Environment was asked for an interview. The request was declined on the grounds of not being an expert in the field and that the Coalition's policy on waste had not by then been finalised.

The other category comprised organisations that might provide project management or total project services to facilitate bilateral symbiosis.[5] Target interviewees in this

---

5 Project management services are performed under the direction and control of the generator of the waste who retains responsibility for conduct of the project. Total project services are undertaken without any involvement by the generator of the waste, other than to commission the project. The organisation providing the service takes full responsibility for the conduct and result of the project. These services involve active participation in carrying out a project whereas simply offering advice requires the generator of the waste, or a 'third party' but specifically not the organisation providing the advice, to undertake the work required to give affect to it.

category included the manager (G2) of the Sustainability Advantage program within DECCW. Industrial organisations employing more than 40 employees[6] are eligible to join a program through which assistance is provided by the government to improve the performance of their operations. Although this section does not have a specific mandate to deal with waste, it is able to do so if disposal is an issue for a participant in the program. Other sections of the department concentrate specifically on aspects of 'resource recovery' such as recycling plastics but a manager in this section declined an interview as their purview was too narrow in the context of this research and he thought an interview would not be useful. Organisations in this category that were thought to offer advice only, such as universities and environmental consultants, were canvassed by means of a telephone campaign, as described in Section 4.4.

Responses to question 4.4 of the questionnaire indicated that interviewees in this category should also represent waste management contractors. As a result of rationalisation since the early 1990s, four major waste management contractors now dominate the market in NSW. Their customers include the major generators of manufacturing waste, who rarely use small local contractors due in part to the rationalisation and the increasing trend of interstate or multinational organisations to contract for 'total site services' on a national or international basis. The core of the waste management business remains the traditional service of 'haul and dump', however there is diversification into processing municipal waste such as operating materials recovery facilities (MRF) and generating energy from waste (EfW), processing liquid waste and rejuvenating waste oil. Each of the major contractors was asked for an interview. There is a plethora of waste management contractors and skip bin operators whose business is predominantly 'haul and dump' and whose services are offered to local domestic, municipal and commercial customers. The likelihood of these locally orientated organisations being able to offer statewide services in bilateral symbiosis was thought to be so low that they were not canvassed, as a class, for this research. However, interviews were held with the managing director of two substantial local contractors, based in Sydney, who were known to be interested in 'niche' opportunities. Their views on developing a capacity to facilitate bilateral symbiosis gave insights to the future of the process.

Responses to question 4.4 also indicated that the infrastructure supporting bilateral symbiosis includes specialists in bilateral symbiosis, the operators of waste transfer stations or dump sites and environmental consultants. With regard to the first of

6 As of January 2010, a proposal was being considered by DECCW to extend the program to organisations with fewer than 40 employees who would be able to access a limited range of services relating only to waste. By August 2011, a decision to do so had not been made.

these, there are no organisations in Australia such as the National Industrial Symbiosis Programme (NISP) in the UK (Subsection 7.4.1). Similarly, no such services are available as were provided by the program run by Judy Kincaid in North Carolina, USA (Kincaid & Overcash 2001). Qubator has specialised in arranging bilateral symbiosis since 1989 but the scope and scale of its current operations could not serve the purpose envisaged in this research. Nevertheless, this option of a specialist in bilateral symbiosis was included in question 4.4 to gauge the potential 'demand' for such services. The significance of the response to this question is discussed in Subsection 8.4.1

WSN Environmental Solutions (WSN) is the dominant organisation managing waste disposal facilities in NSW; it controls 12 waste recycling, processing and disposal facilities in the greater Sydney region and beyond. At the time this fieldwork was undertaken, WSN was owned by the NSW government but the organisation was sold in December 2010 to one of the national waste management companies interviewed for this research. An interview with the general manager was requested in March 2010 but declined as he was preoccupied with preparing the organisation for sale. Major facilities not controlled by WSN are managed by the large waste management contractors mentioned above. The managers of single or minor waste disposal facilities such as a privately owned dump site were thought not to have the capacity to offer services relating directly to bilateral symbiosis either statewide or even within an industrial area like the Illawarra, south of Sydney and were therefore not included in this research.

4.3.3 Arranging interviews

Contact details were obtained from conference proceedings, telephone directories, the internet and Qubator's records. It is emphasised that there are few relevant organisations in each category. For example, there are two government departments which have a direct involvement with industrial waste and as mentioned above, only four major waste management companies.

Contacting the right person to interview was an unexpectedly difficult part of the fieldwork. Automated telephone answering menus invariably did not include an option: 'finding a use for industrial waste'. Human receptionists, often in a call centre, generally did not understand the purpose of my call or know who could deal with it. The enquiry would be referred through several people and days might pass before a response was received to a message. Each organisation was structured in a different way so there was no commonality of roles or responsibilities such as, for example, accounts payable or the environmental manager. Thus, in one organisation the national marketing manager was the 'right' person to meet while in another it was the general manager of operations or in another the business development manager. It transpired that only senior people, generally at the national level of management, were qualified by their knowledge and experience to contribute to the research. The larger the organisation and the more senior the 'right person', the more difficult it became to make initial contact and subsequently arrange an interview. This experience has a bearing on the issue of an external infrastructure supporting bilateral symbiosis, as explained in the next section and discussed in Section 8.4.

4.3.4 Recording and analysing interviews

Interviews were recorded by an Olympus DS-50 digital voice recorder and transcribed into MS Word documents by a professional transcription service. Since the research interest is essentially in facts and intentions rather than feelings or emotions, it was not thought necessary that every word be accurately transcribed or nuance of speech recorded, as might have been done for an ethnographic study. Where meanings in the transcript were unclear, the audio recording was replayed accordingly. Transcripts were annotated using a form of open coding (Crang in Flowerdew & Martin 1997) and results compiled accordingly.

The formal part of an interview would typically last between 60 and 90 minutes. In the first two interviews the recorder was turned off after the formal part had been concluded. However, the conversation continued, unrecorded, during which some useful information was mentioned by the interviewees. In all subsequent interviews, therefore, the recorder was not turned off until my interlocutor and I parted company.

4.4 Survey – telephoning campaign

It became clear from the experience in arranging interviews outlined above that attempting to canvass by interview the contributions that universities, TAFE colleges and various consultants make to the external infrastructure supporting bilateral symbiosis would be unrealistic in the time and with the resources available to carry out the work. An indication of their respective contributions was obtained instead from a telephoning campaign inspired by the technique of triangulation in which data obtained by different research methods are correlated to produce coherent results (Valentine in Flowerdew & Martin 1997). On the premise that senior managers in manufacturing operations are typically very busy people, it was surmised that their propensity to pursue bilateral symbiosis would be influenced by how accessible the right person is, with whom to discuss relevant services. The approach was to imagine what a manager would do in practice to find a use for waste, assuming he or she has no knowledge of bilateral symbiosis.[7] Given this scenario, the procedure was as follows:

- select a sample of between five and 10 organisations, either recognised names or otherwise, from the appropriate category in the *Yellow pages* business telephone directory or other sources of information available to the general public such as the internet
- use whichever telephone number seems 'the right one' and call the organisation
- start each telephone call by stating: 'I would like to talk to somebody about finding uses for industrial waste.' Explain further the purpose of the call, as necessary.

It was expected that the procedure might involve more than one telephone call and/or talking to several people before the right person is contacted. When that occurred, the purpose of the call would be explained in relation to this research and the issue discussed accordingly. The original intention was to record values for parameters that were thought relevant to a measure of accessibility. They comprised a time factor, a 'hassle' factor and a result. The approach is summarised in Table 4.1 below.

Table 4.1 – Accessibility of third parties for assistance with bilateral symbiosis

Factor	Parameter	Measure/Rating
Time	The time elapsed between when the call is first answered, either automatically or by a 'live' person and when a conversation begins with the 'right' person who can provide the help required	Average time and longest time (minutes)
	The time it takes someone to respond to messages	Longest time (hours or days as relevant)
Hassle	The number of people to whom the 'call' is referred before reaching the right person	Average number and the largest number
	The number of calls that had to be made before contacting the 'right' person	Average number and the largest number
Result	Spoke to the right person – appropriate assistance available for bilateral symbiosis	Successful
	Spoke to the 'right' person but the organisation does not provide appropriate assistance for bilateral symbiosis	Unsuccessful
	No response to messages or follow-up calls – contact subsequently abandoned	Unsatisfactory

7 Industrial ecology, industrial symbiosis and bilateral symbiosis are academic terms which, in

In order to establish a level of accessibility with which to compare the results, selected respondents to the questionnaire[8] were to have been asked what they consider to be acceptable values for the various parameters. In the event, this was not necessary (Subsection 6.3.2).

There are 15 post-secondary, publicly owned academic institutions in NSW, including collectively the colleges of technical and further education (TAFE), the Commonwealth Science and Industrial Research Organisation (CSIRO) and 13 universities. All of these organisations were contacted during the campaign. There are 276 environmental consultants listed in the *Yellow pages*.[9] Of these listings, 77 did not indicate by the name or in the listing itself what their specialisation is e.g. 'air pollution consultants' or 'environmental testing laboratory'. In view of the limited resources available, a sample of eight entries was selected, which represented 10% of what was thought to be an eligible population. The sample included two organisations known to be large national consultancies and three other consultants referred by interlocutors.

Responses to the questionnaire (Section 5.9) indicated that respondents would approach the manager of a waste transfer station or a landfill site for assistance with instigating bilateral symbiosis. It was mentioned in Subsection 4.3.2 that the NSW government owned Waste Services NSW (WSN) which controls most of the waste receiving facilities in the Sydney region. The rest are owned and/or operated by the four national waste management contractors, whose capacities to provide services for bilateral symbiosis were canvassed at interviews. As part of the preparation for Phase 1 of this research, a briefing meeting was held with the general manager of WSN, arranged by a mutual business associate. The meeting was not recorded formally as an interview, in accordance with the approval subsequently given by Sydney University's Human Research Ethics Committee. However, it was indicated generally that WSN is predominantly involved with municipal and commercial waste. At the time of the meeting (November 2007) the organisation had no interest in offering services related to industrial waste and had no capacity or plans to develop any capability in the foreseeable future. In view of this circumstance outlined in Subsections 4.3.2 and 6.3.1, it was decided not to contact the WSN facilities by telephone but to rely instead on the information provided in 2007.

---

my professional experience with Qubator are almost entirely unknown by operational managers of manufacturing organisations in Australia.

8 Only those who have indicated in question 5 a willingness to cooperate further with this research would have been approached.

9 Paper edition of the business telephone directory listings by category in the Sydney region for 2010.

4.5 Deconstructing Kalundborg

The town of Kalundborg in Denmark provided the original inspiration for academic study of industrial symbiosis and continues to be a focus of interest (Subsection 2.5.6). The situation is invariably described as a network of relationships with particular social characteristics, established between organisations having specific attributes and being in close geographic proximity one to another. It seems that this scenario is regarded, in a sense, as mandating a set of conditions and attributes necessary for symbiosis to take place. Based on these ideas, efforts are being made to develop methods for identifying spatial and functional conditions with a view to instigating IS where circumstances are propitious (e.g. Chertow 2007).

Manufacturing in NSW typically does not exhibit the characteristics or have the attributes of the industrial ecosystem at Kalundborg. Nevertheless, using waste is a principal objective in both scenarios, which prompted the idea that there may be some commonality between them that could inform an approach to developing systematic bilateral symbiosis in NSW. Accordingly, the arrangements at Kalundborg were deconstructed temporally, to assess the degree of mutual dependence, and spatially with regard to distance between participants and with reference to the purpose of the relationship. These dimensions were thought most likely to yield useful insights. Deconstruction was also motivated by my personal interest in understanding as much as possible about this extraordinarily influential phenomenon. It is clear from the literature (Section 2.4 generally and Subsection 2.5.6 specifically) that Kalundborg is still the exemplar of industrial symbiosis but reconciling different descriptions (e.g. Desrochers 2002 with Jacobsen 2006) by referring to other secondary sources was not satisfactory. Information for the deconstruction was gathered by a combination of site visits to Kalundborg, meetings,[10] personal communication and access to information available from the internet such as corporate histories and the origin and development of Orimulsion. Results of the deconstruction are given in Subsection 7.2.2 and discussed in Section 8.6.

4.6 Case studies

Interviews were held with a senior manager in two organisations who had undertaken autogenous bilateral symbiosis. They were conducted in the way outlined in Subsection

10 The meetings were generally attended by more than one retired manager from Kalundborg. They were treated as opportunities for discussion and sometimes involved a PowerPoint presentation. In these respects they differed from formal research interviews, even though the events were digitally recorded and when appropriate, participants signed documents to comply with HREC requirements.

4.3.1. Opportunities to discuss the experiences in practice of a project champion, working voluntarily on a difficult task from the perspective of a generator of waste, provided useful insights. The concept of an internal infrastructure for bilateral symbiosis (Subsection 8.3.6) evolved from the results of these interviews. They also illustrated emphatically the organisational and human characteristics which are thought to constitute the core of that infrastructure.

One of the organisations is a client of Qubator and it was while discussing with the general manager the use of waste from one of their manufacturing sites that he happened to mention their attempts to establish bilateral symbiosis at another site. The other organisation had been approached in 2007 to participate in trials for Phase 1 of this research. As noted (by inference) in Section 3.3, the manager responsible for waste services decided not to participate in the trials, however, we kept in touch because of our mutual interest in using waste. Having failed to obtain a satisfactory tender from any waste management contractor, in early 2008 the manager undertook to solve his own problems.

4.7 Research on NISP

Research relating to NISP in the UK was guided initially by a review of the relevant literature available before 2009 (Subsection 2.5.6). Notwithstanding its apparent success, NISP depends entirely on government funding from various sources, which makes it vulnerable to adverse changes in political fortune. Government funding in Australia was not thought likely in the foreseeable future but the extent to which the program could be adapted to Australian conditions, as they exist in NSW, remained an issue of interest.

I attended two presentations about NISP, given by the regional director responsible for operations in South East England. The first was from a European perspective and given at the 6th Research Symposium on Industrial Symbiosis in Kalundborg, 18–20 June 2009. The second related specifically to Australian conditions and was given at the 2nd Australasian Industrial Ecology Conference in Sydney on 2 September 2010. I attended a meeting with the Regional Director of NISP and senior managers at DECCW on 30 August 2010 at which strategic policy issues were canvassed and again with field staff and managers at DECCW on 1 September 2010 at which operational issues were discussed. An interview with the regional manager was held on 1 September 2010 to consolidate information about various topics that had arisen during informal discussions in Sydney, particularly funding for the program. A further meeting was held with the same regional manager in 29 May 2011, after he had conducted a series of NISP-style workshops in NSW and Victoria.

4.8 Observation of AIEN

The Sustainability Advantage (SA) program run by DECCW (Section 1.3) has some characteristics in common with NISP but it does not have the capacity to perform all the functions of a national program. As explained by interviewee G2 (Subsection 7.4.2) it is restricted geographically to NSW, only organisations that join the program can be assisted and these must employ at least 40 people to be eligible. Assistance is confined to financing consulting services provided by third parties. One way that the managers of SA thought the program might acquire more capability was to support an embryonic initiative to promote the use of industrial waste. It was being organised by a group of businesspeople under the auspices of the Waste Management Association of Australia (WMAA), which represents the waste industry nationally. The inaugural Australasian Industrial Ecology Conference was held in Sydney at the end of July 2009. It appeared to differ from other gatherings related to industrial ecology in that it was organised by businesspeople, partly sponsored by government and attended predominantly by delegates from industry and government. A few academics attended but nothing like the numbers that attend conferences organised, for example, by the International Society for Industrial Ecology[11] (Section 7.5).

The conference endorsed a proposal to establish the Australasian Industrial Ecology Network (AIEN) as an organisation dedicated to promoting, initially, the strategies of industrial symbiosis. I attended the conference and recognised the potential for AIEN to do the sort of work undertaken by Kincaid in the USA (Subsection 2.4.2) and perhaps eventually offer the range of services provided by NISP in the UK. In order to pursue the aims of this research and participate in developing the initiative, I joined the steering committee, formed in August 2009, which managed formal establishment of the organisation as a working group of WMAA. From an academic perspective, the intention was to discover the issues that might inhibit AIEN from developing the capabilities necessary, for example, to emulate NISP and also to gain insight to how those issues are dealt with (Subsection 8.4.5). I was elected as an academic member of the committee which was formally constituted on 7 October 2009 and as at September 2011, I continue to participate in that role and also to conduct research on topics, related to AIEN that are beyond the scope of this thesis.

---

11 There were approximately 250 delegates at the ISIE conference in 2009. The conference in 2011 was attended by over 500 delegates, the maximum possible for the venue at Berkeley, CA. Over 700 abstracts had been received by the organising committee and the attendance was ‘rationed’ as a result.

4.9 International conferences

By the beginning of 2009, three tasks ancillary to the main topics of interest were thought to warrant further research. The first was to canvas within the academic community the concept of bilateral industrial symbiosis that had been maturing since my visit to Kalundborg in 2008. Although bilateral arrangements had been mentioned in the literature (Section 2.4), there appeared to be scant, if any, acknowledgement of their potential to deal with waste. I was particularly interested, therefore, to know if there were any fundamental reasons why the strategy would not be viable in conditions such as existed in NSW. The second task was to discover, first hand, more about how NISP actually operates in the UK and particularly to understand its funding model, which I believed, was fundamentally flawed in terms of its longevity. The third task was to establish, if possible, exactly what constitutes industrial ecology. The literature appeared diffuse, conflicted and redolent with definitions (Appendix 10) but at that time the question nevertheless seemed relevant to my research. These issues are discussed in various sections of Chapter 8, based on information gathered while attending the following events:

- The 6th Industrial Symbiosis Research Symposium (ISRS) held in Kalundborg, Denmark, 18–19 June 2009
- The 5th Conference of the International Society for Industrial Ecology (ISIE) in Lisbon, Portugal, 21–24 June 2009
- The 8th ISRS in San Francisco, 5–6 June 2011
- The 6th Conference of the ISIE in Berkeley, 7–10 June 2011.

It was suggested at the beginning of this chapter that before an operational model for bilateral symbiosis is developed beyond the stage recorded in Chapter 3, the views of managers and the capacities of the organisation they manage should be canvassed in relation to various topics. The questionnaire was designed to accomplish this task. Other issues had also to be canvassed, which were thought to be more effectively addressed by interviews and the telephone campaign. Deconstructing the eco-industrial system at Kalundborg was undertaken to provide a chronological understanding of its evolution, which supports the proposition of bilateral symbiosis, whether autogenous or facilitated. The case studies of actual practice in Australia, the examination of NISP in the UK and my continuing involvement with AIEN were all intended to produce information that was thought to be crucial for understanding the potential of bilateral symbiosis in NSW. The next three chapters record the results of these studies, starting with the questionnaire in Chapter 5.

Chapter 5

Phase 2: Results of the survey – questionnaire

Briquettes for furnace fuel (made at CSIRO, North Ryde, NSW from CCI coal dust and shredded scrap plastic from Australian Paper Mills, Bomaderry, NSW. Dimensions: 25 x 20 x 20 mm)
Source: Qubator Pty Ltd

Scrap coal

In September 2003 I contacted CCI Pty Ltd at Unanderra in NSW with a view to obtaining coal to combine with scrap plastic generated by Australian Paper at Bomaderry, about 60 km away, so that the plastic could be used as a fuel. As mentioned in the vignette at the beginning of Chapter 3, by June 2004 it was clear that the project with Australian Paper had foundered so there was no immediate prospect of using the scrap coal. However, the general manager of CCI was keen to avoid dumping scrap, on principle, so I agreed to search for other possible uses, even though the amount was small by industrial standards; the wind-blown losses from the coal stock pile at the steel works about 5 km away is typically 40 tonnes a week. Fuel for coal-fired furnaces seemed to be a likely possibility but they are almost entirely extinct within an economically viable transport distance of the source. Most furnaces in the region had been converted during the previous 15 years to burn either oil or gas. The two remaining coal fired furnaces I was able to locate used graded coal of lump size –25 mm +12 mm; the material available at CCI ranged from 75 mm down to –1 mm and finer and was therefore unsuitable.

Several other possibilities were canvassed, including its use as a source of carbon in potting mixes. The most promising, however, was to cart the stuff as a backload some 300 km to Lithgow in central west NSW where it could be added to material that was already being turned into briquettes for the Mount Piper power station. This strategy was certainly viable commercially but required stock piling the scrap at Unanderra until 40 tonnes or more had been accumulated; sufficient to fill a B-double semi-trailer. By the middle of October 2004, CCI had accepted in principle the proposal that a simple bunker should be built in which to stockpile the scrap and plans were made accordingly. Then the problems started: the local council had to be consulted; the landlord's approval had to be obtained; the GM became frantically busy during the months before Christmas and the company went through a period of very tight liquidity. By February 2005, the project had become just too hard for CCI to cope with so it petered out. Meanwhile, the general manager at Unanderra put me in touch with his counterpart at their office in Mackay, Queensland where they also generate scrap coal that is dumped. Initially, there was enthusiasm for the prospect of reducing operating costs but dealing with management in Mackay was fraught with difficulty. After four months trying to obtain something as straightforward as a specification of the scrap and failing, this initiative also petered out on February 2005.

A year later, I re-established contact with CCI in Mackay because the general manager from Unanderra had taken over from the previous incumbent. We agreed to resurrect the project and by the end of June 2006, I had found a company that could use the total output of scrap from CCI as fuel for their furnace. However, the user was unwilling to pay for supplies and while CCI were willing to pay for transport, they would not pay Qubator any fees for making the arrangements. This was the first and only time in Qubator's experience the classic 'catch 22' of bilateral industrial symbiosis occurred. The generator will deliver waste at no extra cost because a 'demand' exists for the material while the user will accept the material but will not pay for supply, because they know it would cost money to dump. This case illustrates a commercial/ethical dilemma: does the facilitator prevent the coal from being used, merely because it will not be paid for its services, in which case scrap would continue to be dumped in landfill or should it complete the transaction for environmental reasons and 'walk away'? Qubator completed the transaction.

5.1 Introduction

The methodology described in Chapter 4 outlines five different research techniques which include a survey comprising a questionnaire, interviews and a telephone campaign. This chapter records the results of the questionnaire. Responses to question 4.4 determined the rest of the survey, as recorded in Chapter 6. Results of the four other techniques, loosely construed as 'case studies', are recorded in Chapter 7.

Recapping part of the introduction to Chapter 4: the survey related directly to issues arising from the results of Phase 1. The intention was to gather information about managers' views and practices with regard to manufacturing waste, regulations and the environment. The questionnaire asked for information on the following issues:

- Do managers believe they have a problem disposing of waste, either currently or in the foreseeable future?
- Do managers think that finding uses for their waste would be a satisfactory way of dealing with their problems?
- Would managers be willing to undertake autogenic bilateral symbiosis and if so, what resources in house could they make available?
- What external resources would managers enlist to help deal with their waste, if they did not make their own arrangements, in house?
- What factors influence managers' decisions about dealing with waste?
- Responses to the fourth question were used to identify targets for interview and the telephone campaign.

5.1.1 Statistics

Distribution of the questionnaires began in June 2008. As mentioned in Subsection 4.2.3, questionnaires were sent directly to 48 potential respondents, of which 32 were returned, representing a response rate 67%. Of the 150 questionnaires distributed by the Frame and Truss Manufacturers Association, five were returned with a response rate of 3%. By the middle of October 2008, 15 had been returned which provided the basis for a preliminary analysis of the results. By mid October 2009, 36 questionnaires had been returned; the 37th was returned on 20 January 2010. The significance of these results is discussed below. Unless otherwise indicated, results in this chapter are presented as percentages of the total number of 37 completed questionnaires and are rounded to the nearest whole number. This is considered to be sufficiently accurate for the depth of analysis required in this study but will likely introduce rounding error that may produce sums (of percentages) that do not equal 100. Respondents were able to provide more than one response to certain questions so for that reason also sums may be more or less than 100. It is noted that although the target number of 50 responses was not achieved, the total of 37 received were sufficient for statistical purposes (e.g. McLafferty in Clifford & Valentine 2003)

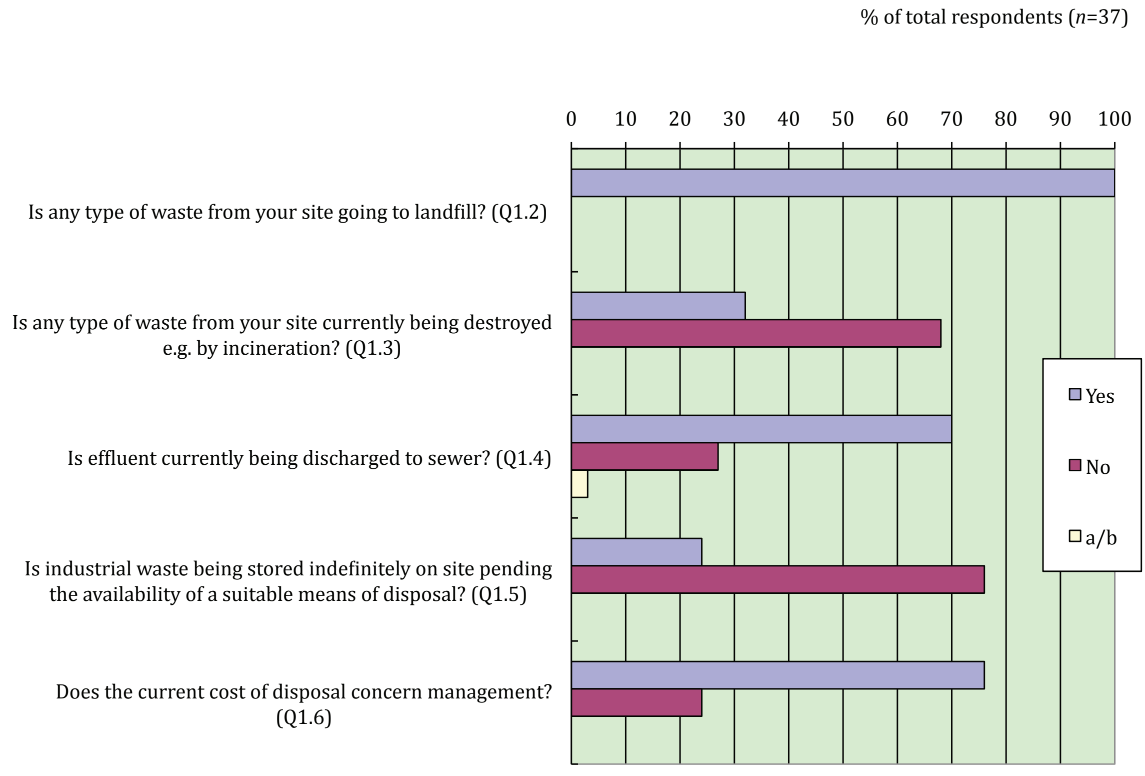
A response rate of 67% is relatively high compared, for example, with rates of about 36% found from studies of academic surveys in Baruch (1999) and in relation to research on corporations by Baruch and Brooks (2008). This indicates a high level of concern among manufacturers about waste generally, as outlined in this chapter. The response rate of 3.3% from the mass distribution of questionnaires among members of the Frame and Truss Manufacturers Association (FTMA) was significantly lower than a level of approximately 10% that had been expected, on the basis of previous personal experience in the insurance industry, for example. Aside from the comments in Subsection 4.2.2, the principal cause of this result was thought to be the unfortunate timing of distribution, occurring as it did during the month or so before Christmas, which is the busiest period of the year for the industry. However, studies of response rates to surveys by email, unaided by pre-postal or post-postal support, as in this case, show that results of approximately 3% seem to be the norm (Gi & Trumbo 2000; Kaplowitz et al. 2004). During a conversation in February 2009 with the general manager of the FTMA, he suggested that many of their smaller members might have been indifferent to the questionnaire because waste is such an intractable problem for them that they just dump it and accept the cost accordingly. This comment has particular significance in the discussions of internal and external infrastructure (Subsections 8.3.6 *et seq.*)

Questionnaires were returned over 19 months, from June 2008 until January 2010. The protracted duration of this survey is not thought to be detrimental to the results for two reasons. First, comparing results available in October 2008 with those available in October 2009 indicated no significant change from a statistical perspective (Appendix 8). This fact also supported the decision to terminate the survey in January 2010, with 37 responses, rather than delay progress of the research generally while attempting to achieve the target of 50. Second, the circumstances canvassed in the questionnaire which caused respondents' concern about the future were not thought to ameliorate within the time span of this research (August 2005–2011). A questionnaire completed 18 months after the survey began in June 2008 would therefore be expected to reflect essentially the same circumstances as any preceding it.

5.2 Confirmation that waste is a problem

A principal purpose of the questionnaire was to find out if generators of waste *think* they have a problem disposing of it. Responses to the survey indicate that managers believe they do have a problem. As a starting point, all respondents dispose of waste to landfill. As shown in Figure 5.1, 70% discharge effluent to sewer and 32% send waste for incineration or a similar method of destruction. Nearly a quarter of respondents (24%) store waste indefinitely pending permanent disposal, a circumstance that incurs indefinite amounts of costs over time. The current cost of disposal concerns 76% of respondents, which is fewer than might have been expected, given that all respondents dump waste.

Figure 5.1 – Confirmation that waste is a problem



Comments cited below associated with a negative response to question 1.6 indicate the view of individual respondents but do not explain fully the apparent anomaly. It remains a matter of speculation as to why 24% of respondents are not concerned about cost.

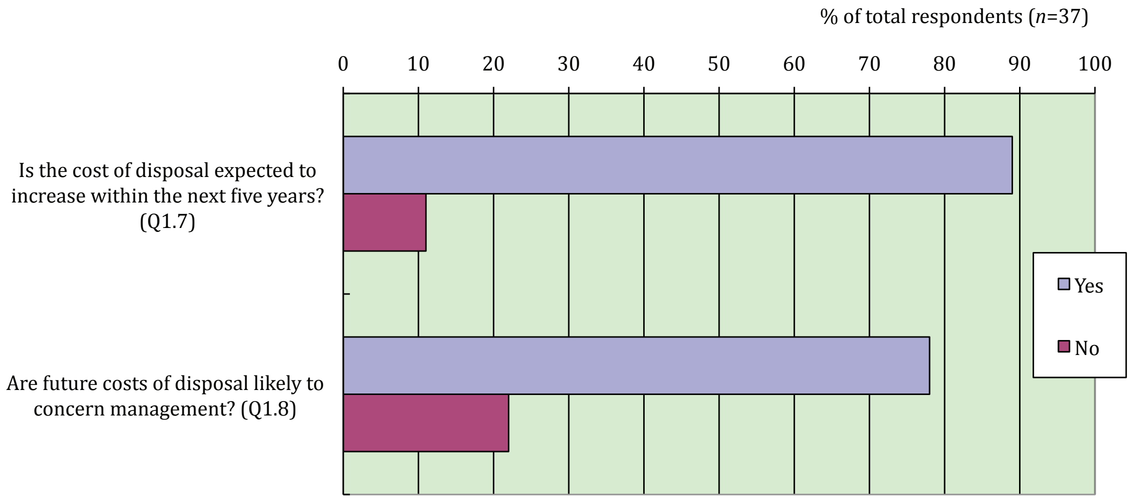
> (Respondent 38) – We currently get money for our waste. This was a big concern two years ago when it went to landfill.

(Respondent 20) – Minimal cost.

(Respondent 16) – Has been reduced by recycling > 80% of site waste.

With regard to expectations of future conditions, the responses are similarly indicative. As shown in Figure 5.2, 89% of respondents expect costs to rise and slightly more respondents (78%) are concerned about the expectation of future cost than are concerned about current cost. These responses accord with the strategies of the regulator, recorded in Section 6.2.

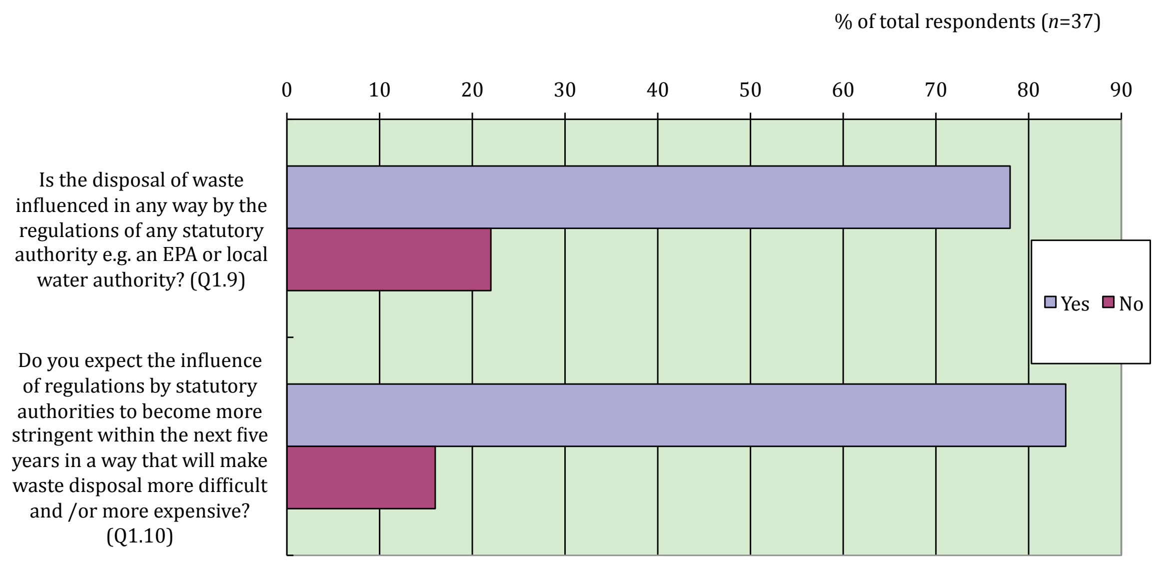
Figure 5.2 – Expectations of future trends



5.3 The influence of regulations

The role of regulations and the impact manufacturing has on the environment are closely related issues since the prime purpose of the former is to control the latter. In the context of this relationship, Figure 5.3 shows 78% of respondents indicated that current operations are influenced by regulations. It is noted that 84% of respondents expect the influence of regulations will become more stringent in the future which suggests some operations that are not regulated now will be regulated in the future.

Figure 5.3 – The influence of regulations



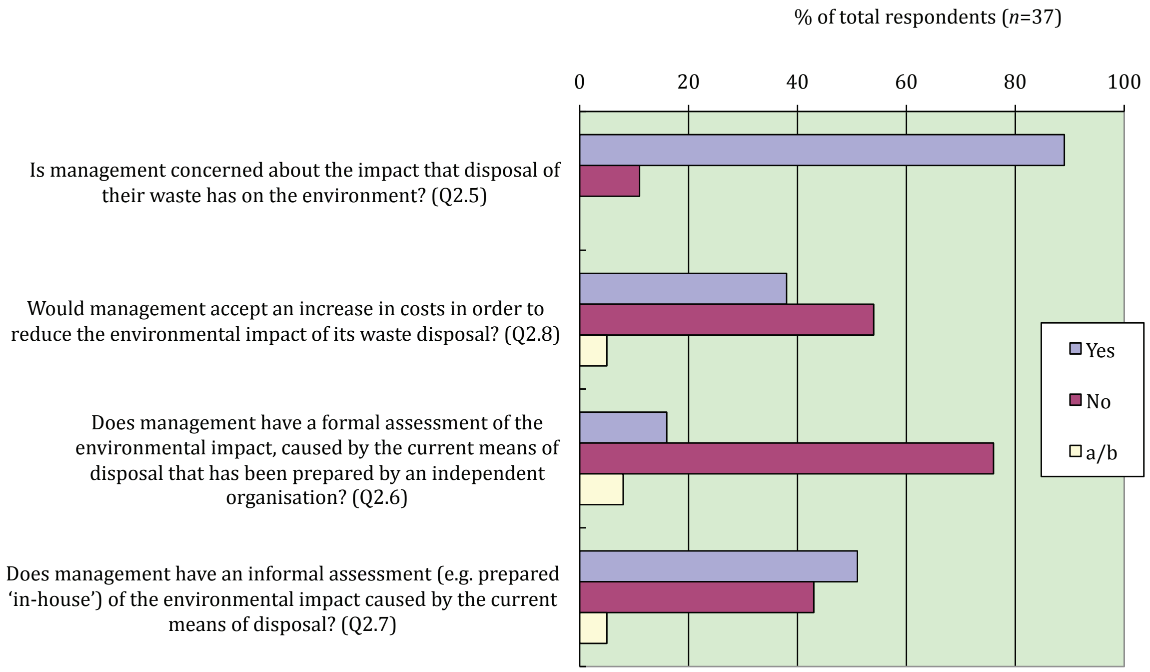
5.4 Views on the environment

Respondents' views in relation to the environment suggest a collective ambivalence, to judge from the results summarised in Figure 5.4. Although 89% of respondents indicated a concern for the environment, less than a quarter of them have a formal assessment[1] of how they impact the environment and only 51% of respondents have an informal assessment.[2] The relatively low level of (documented) environmental impact assessment leaves moot the question of what basis respondents have for being concerned. It is significant in the context of implementing bilateral symbiosis that notwithstanding this high level of concern, there is a relatively low propensity (38% of respondents) to pay more for the disposal of waste in order to protect the environment. It is noted that of the 13 respondents who indicated a willingness to accept an increase in costs, eight represented multinational organisations and two represented large national organisations, each of whom may be expected to have the corporate ethos, policies and capacity to take this approach. The three remaining respondents represent organisations in the frame and truss industry that is known to have a particular difficulty in disposing of timber waste.

1 A formal environmental assessment is done by a third party, typically an environmental consultant or engineer and generally for a formal purpose such as a requirement of the regulator or as part of an environmental impact statement in relation to a development application.

2 An informal assessment is done by the organisation itself, in house, generally for operational purposes or for reporting internally.

Figure 5.4 – Views about the environment



5.5 Willingness to deal with the problem

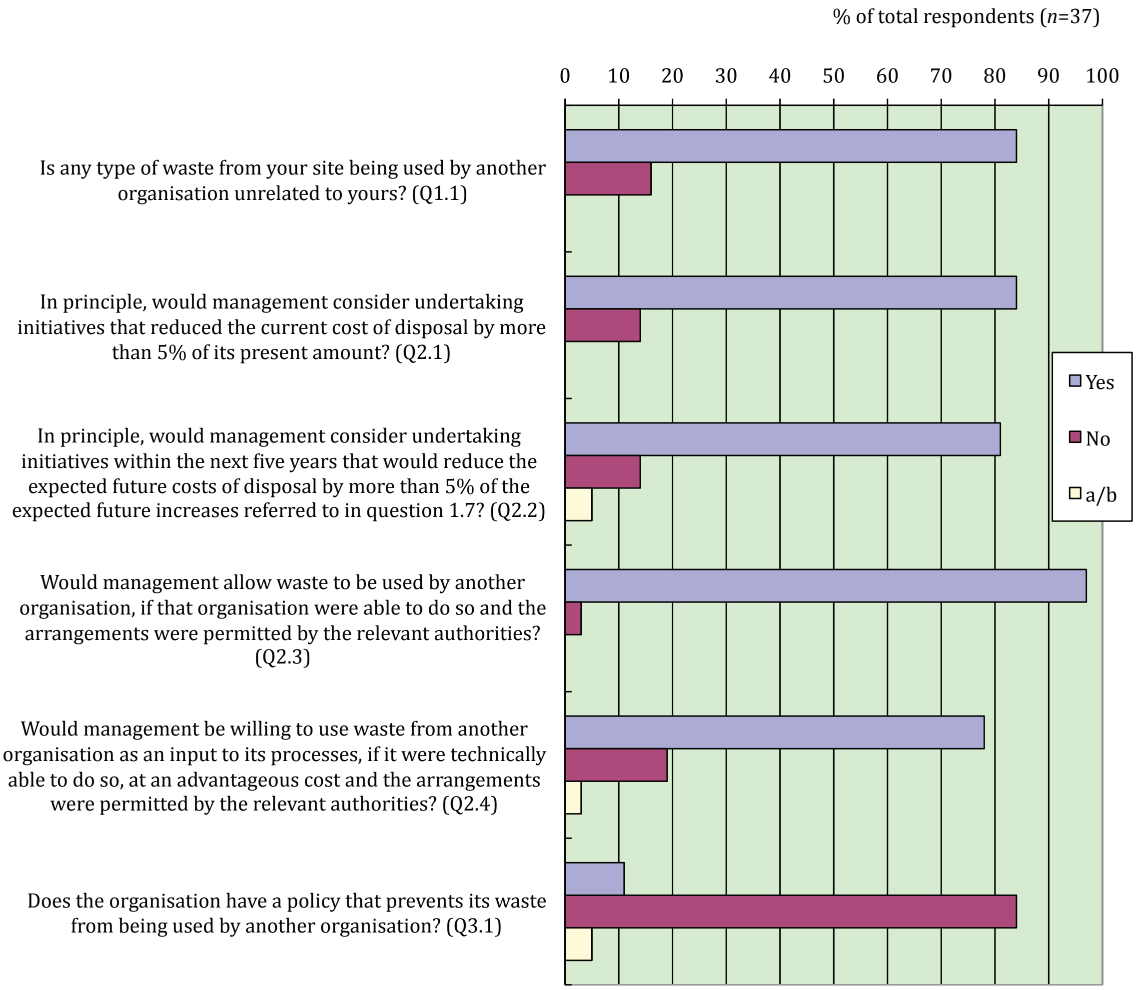
Having identified that there are problems with the disposal of waste, the next issue to consider is whether or not generators are willing to do something about dealing with them, both now and in the future. As shown in Figure 5.5, responses to the relevant questions emphasise positive views. A majority of respondents (84%) sent at least some waste for use by other organisations so there is a precedent for the concept of bilateral symbiosis. The same proportion of respondents (84%) are willing to consider initiatives that would reduce their current costs of disposal. Only one respondent would *not* consider mitigating future expected costs for the reason he gave that:

> (Respondent 35) – Where [sic] not expecting future cost increases for our main bi-product [sic] to be that high.

It is particularly significant in the context of bilateral symbiosis that almost all respondents (97%) are willing to allow their waste to be used by another organisation. Even so, there may be impediments for the generator as indicated by the following comment:

> (Respondent 14) – Other than regulation, managing the transfer of risk and/or liability can be a potential barrier.

Figure 5.5 – Willingness to find uses for waste



There is an anomaly between the responses to question 2.3 and to question 3.1 in that it would be logical to expect the negative responses to question 2.3 to equal or exceed the positive responses to question 3.1. The results appear to controvert this expectation and are explained in Subsection 8.3.3.

With regard to using waste, the proportion of respondents who indicated a willingness to do so (78%) is high enough to suggest that bilateral symbiosis could be viable. There are issues, however, that might cause organisations to be circumspect about using waste, as indicated by the following comments responding to question 2.4:

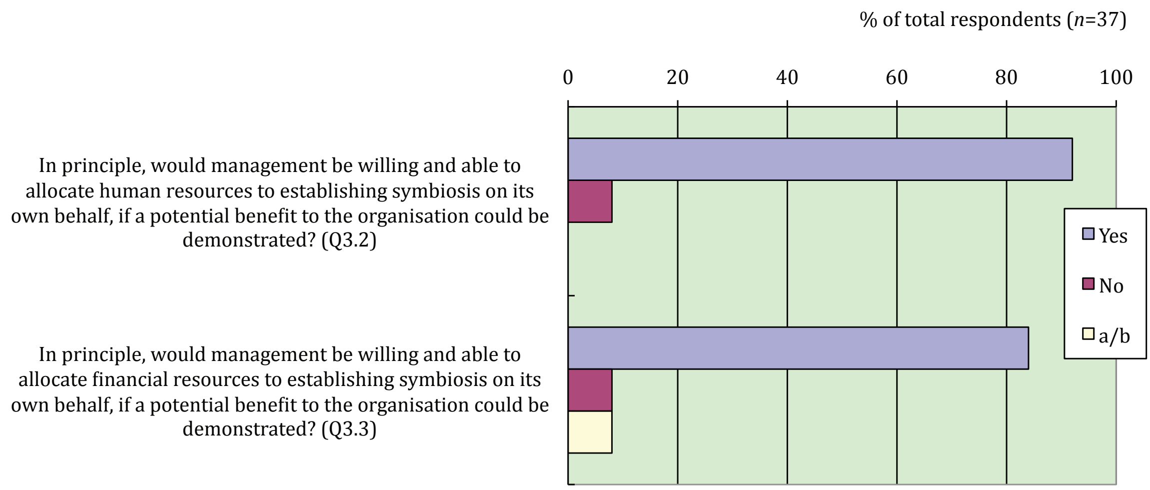
> (Respondent 30) – Probably unlikely unless cost saving and risk of product contamination and process upsets would not occur were met.

> (Respondent 26) – Highly unlikely but possible if all conditions/risks are addressed.

> (Respondent 25) – Unsure; virgin raw material is always difficult to replicate in the process.
>
> (Respondent 6) – TGA [Therapeutic Goods Administration] requirements would inhibit use of third-party waste.
>
> (Respondent 14) – As a food manufacturer, satisfying the food quality and food safety requirements is paramount. Nevertheless, some our [sic] existing raw materials undoubtedly were once someone's waste.

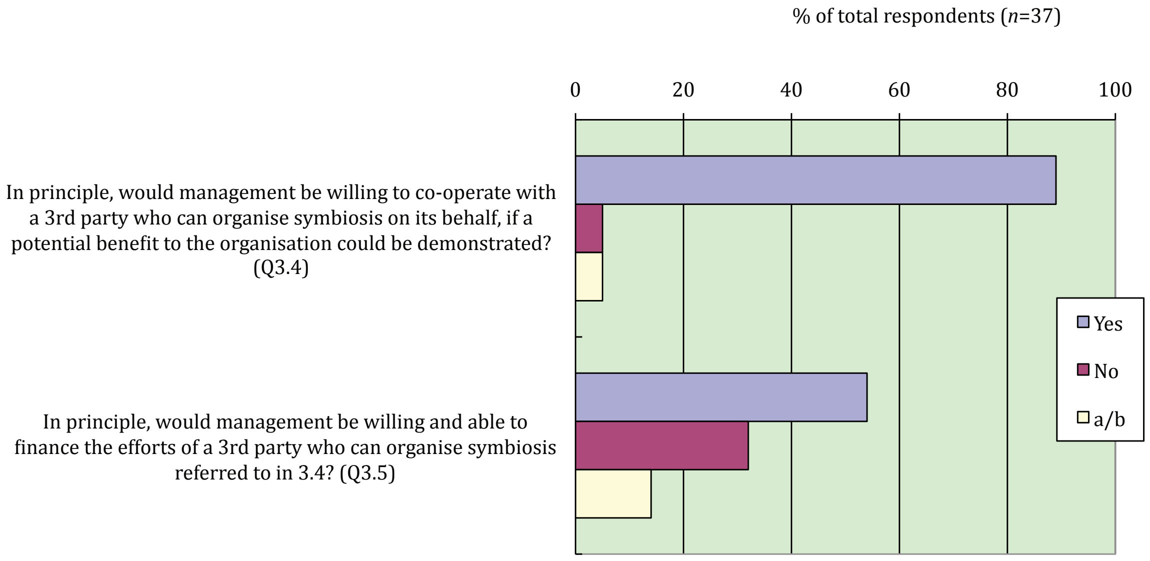
Questions about a respondent's capacity to establish (autogenous) bilateral symbiosis provided further information about their willingness generally to use waste. As listed in Figure 5.6, a high percentage of responses indicated a willingness to finance relevant activities as well as commit the necessary human resources.

Figure 5.6 – Capacity to undertake bilateral symbiosis



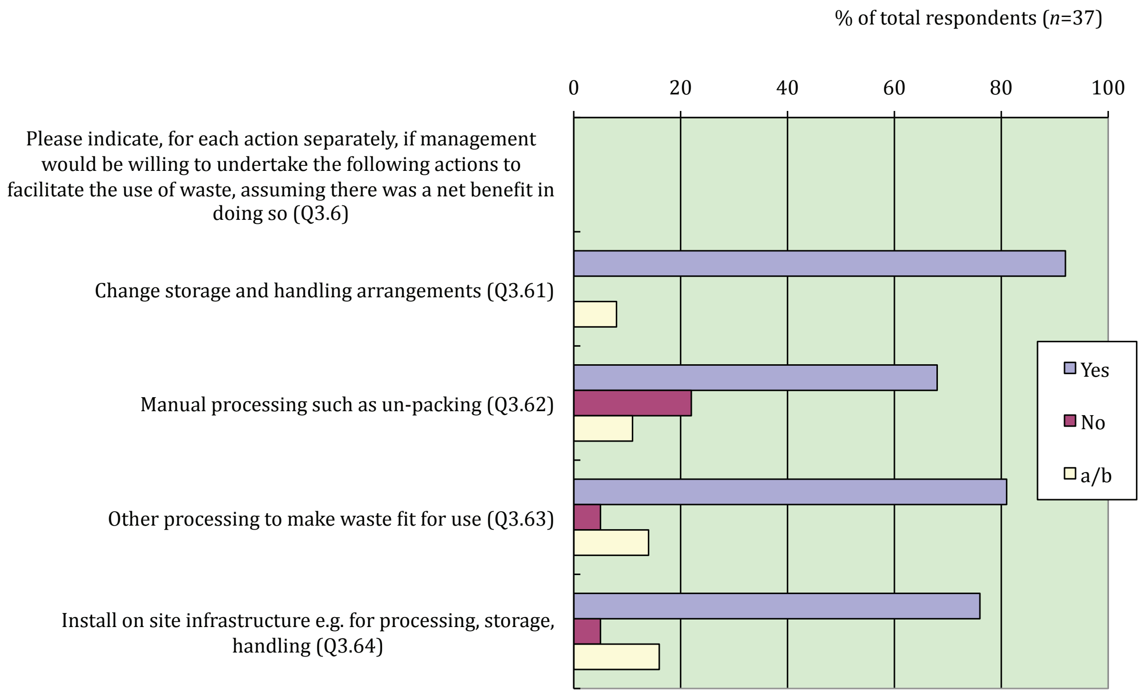
The issue of finance seems to create interesting anomalies, one of which has been mentioned already in relation to respondents' concern for the environment (Section 5.4). Respondents' willingness for a 'third party' to arrange bilateral symbiosis on their behalf indicated another anomaly. As shown in Figure 5.7, while 89% of respondents are willing to cooperate with a third party, only 54% would be willing to finance their efforts whereas 84% or respondents are willing to finance their own efforts to establish bilateral symbiosis. These and other anomalies mentioned elsewhere in this chapter are discussed in Subsection 8.3.3.

Figure 5.7 – The issue of finance



The capacity of an organisation to participate in bilateral symbiosis will likely depend as much on its physical infrastructure and operating procedures as it does on the willingness of its managers to make available human and financial resources. Responses to questions about adapting internal operations are shown in Figure 5.8.

Figure 5.8 – The issue of internal infrastructure

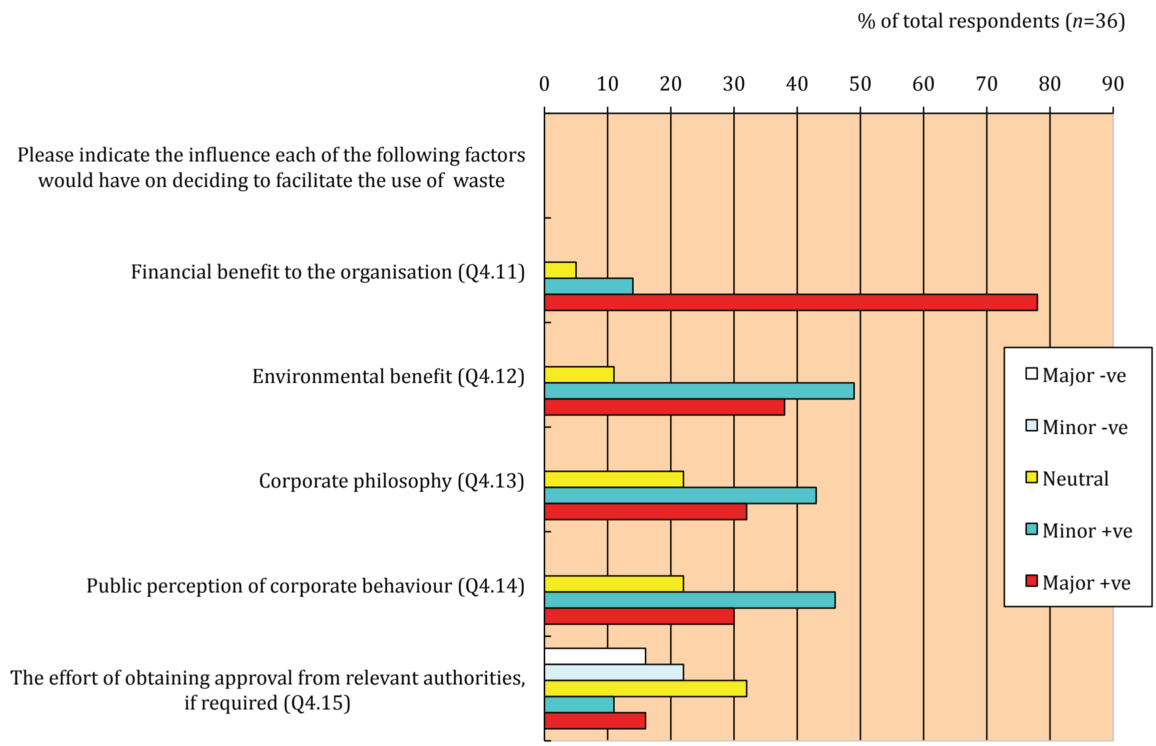


Responses are again strongly indicative of 'willingness' to participate in bilateral symbiosis, irrespective of how it is instigated. However, responses become less strongly correlated when issues of influence to act, strategy and cooperation with third parties are canvassed, as reported in the following sections.

5.6 Factors that influence a decision to act

The factors thought most likely to influence an organisation in deciding whether or not to facilitate the use of their waste were canvassed by the questions listed in Figure 5.9 below. The responses show the strong influence of financial benefit with 78% indicating it is a major positive influence and 14% indicating a minor positive influence. In contrast, 38% of respondents rated environmental benefit as a major positive influence with 49% rating it as a minor positive influence and 11% indifferent about the issue.

Figure 5.9 – Factors that influence a decision to act

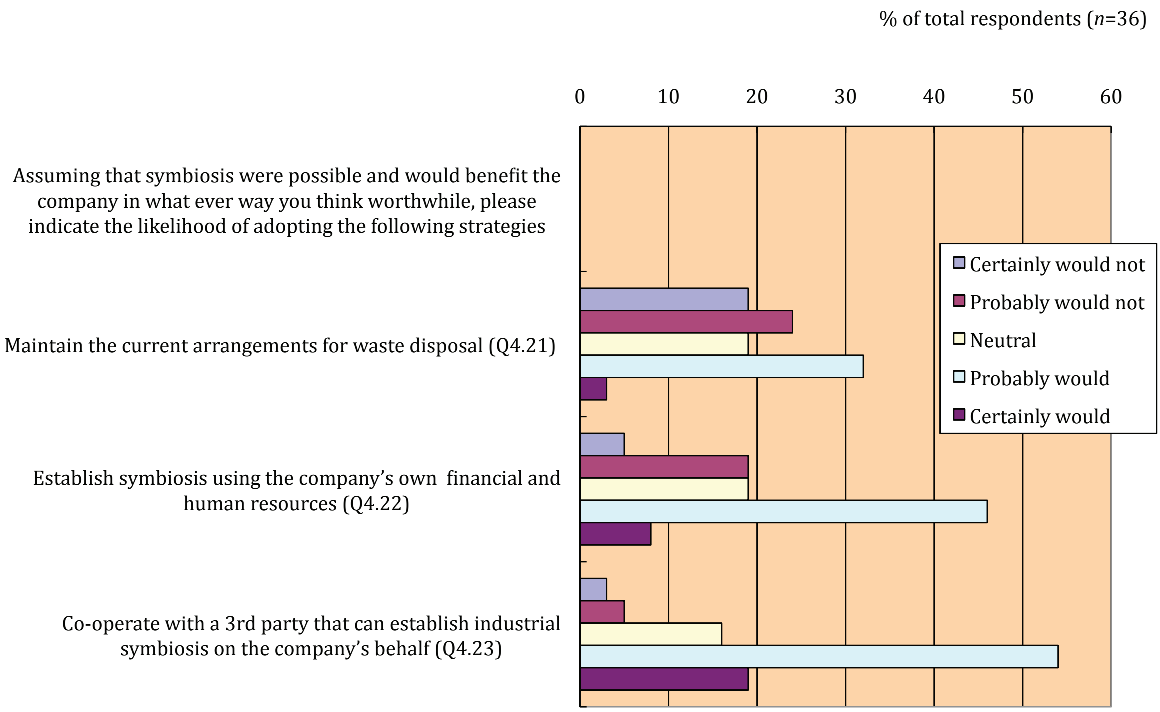


Responses to questions about the influence of corporate policy and public perception of corporate behaviour indicate similar views of these influences as were indicated for environmental benefit but none were comparable to the strong influence indicated for financial benefit. This result, discussed in Subsection 8.3.4, correlates closely with responses given by interviewees C1, C2 and C3 (Section 7.3). The only negative influence identified related to the issue of obtaining approval from relevant authorities to use waste. Although not as strongly influential as the financial 'imperative', dealing with the authorities is more of a deterrent than an encouragement, a factor emphasised by informants during interviews.

5.7 Strategies for action

In light of what influences corporate decisions about dealing with waste, the issue arises of what strategies respondents would be inclined to pursue for its disposal. Three questions canvassed this issue, as shown in Figure 5.10. Interpretation of the responses is less decisive than for previous questions because they are more evenly spread between the degrees of likelihood.

Figure 5.10 – Strategies for action

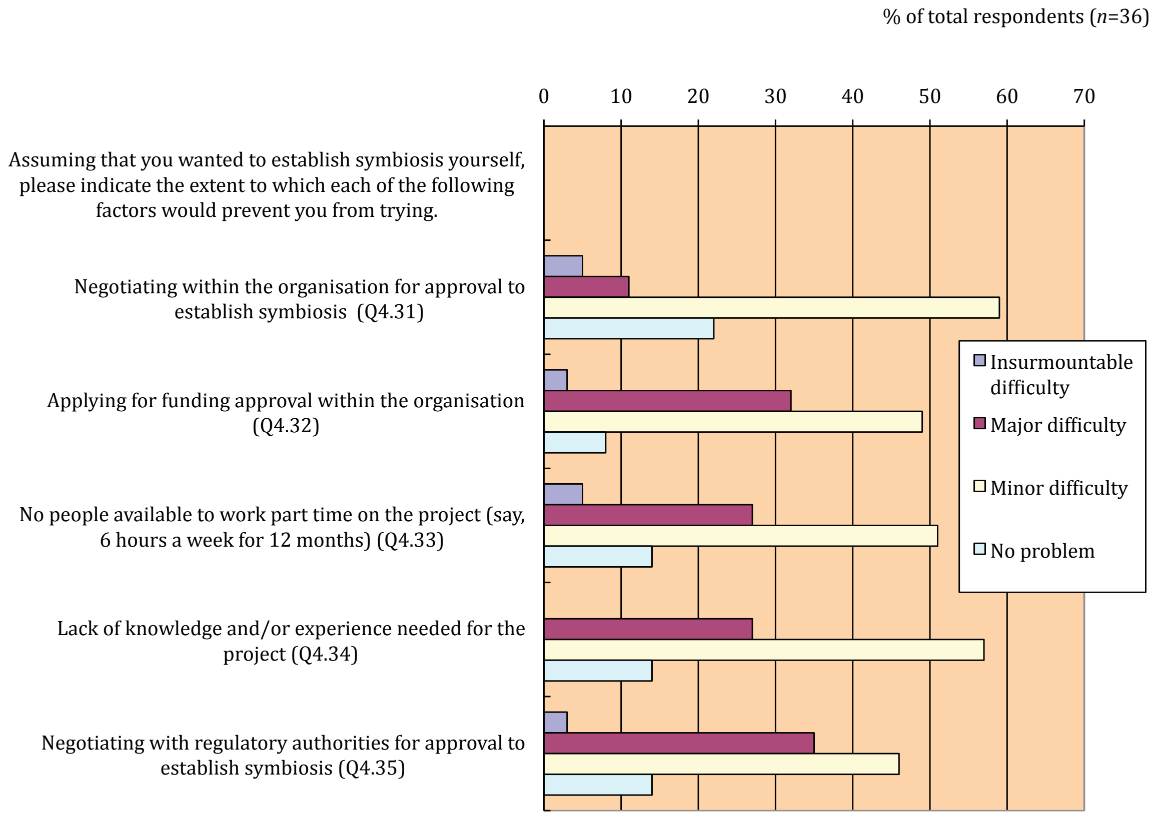


The propensity of respondents to maintain current arrangements is canvassed in question 4.21, to which 32% indicated that they probably would and 3% definitely would. These proportions are higher than might have been expected, given respondents' concerns about waste indicated in preceding parts of the questionnaire. This result is explained in Subsection 8.3.5. Ambivalence (the 'neutral' response) about maintaining current arrangements represents the views of 19% of respondents and is consistent with ambivalence towards instigating bilateral symbiosis. The indication is that respondents have some inclination toward instigating bilateral symbiosis, along the lines of the approaches suggested. The option which relies on the company's own resources would be pursued by 46% of respondents but that it is less attractive than the option of establishing bilateral symbiosis in cooperation with a third party; an approach that would be taken by 54% of respondents.

5.8 Factors inhibiting action

The extent to which factors 'in house' might prevent an organisation from adopting bilateral symbiosis was canvassed in question 4.3 with the responses shown in Figure 5.11.

Figure 5.11 – Factors inhibiting action



In relation to the factors suggested, the results indicate that a majority of respondents would experience difficulty establishing bilateral symbiosis. A relatively small number of respondents (3–5%) indicated the difficulties are insurmountable which implies that for the majority, bilateral symbiosis could be a viable strategy notwithstanding that it would be difficult to instigate. Negotiating with regulatory authorities is the only factor over which an organisation does not have direct control. It is a significant issue and 81% of respondents indicated that it would involve some degree of difficulty. Questions 4.31 and 4.32, broadly stated, relate to 'in-house' persuasion. At least 70% of respondents indicated that persuading the organisation to establish a project would be difficult and even more (81%) indicated difficulty financing it. Questions 4.33 and 4.44 relate to the human resources that would be required and here again, the difficulties are significant. Allocating people to work on a project is seen as a difficulty by 78% of respondents; a result that is corroborated by interviewees (Subsection 6.3.1) and discussed in Subsection 8.4.3. A lack of knowledge and/or experience also rates highly among respondents, 84% of whom indicated it as a difficulty. The issue was canvassed further by question 4.4 as reported below.

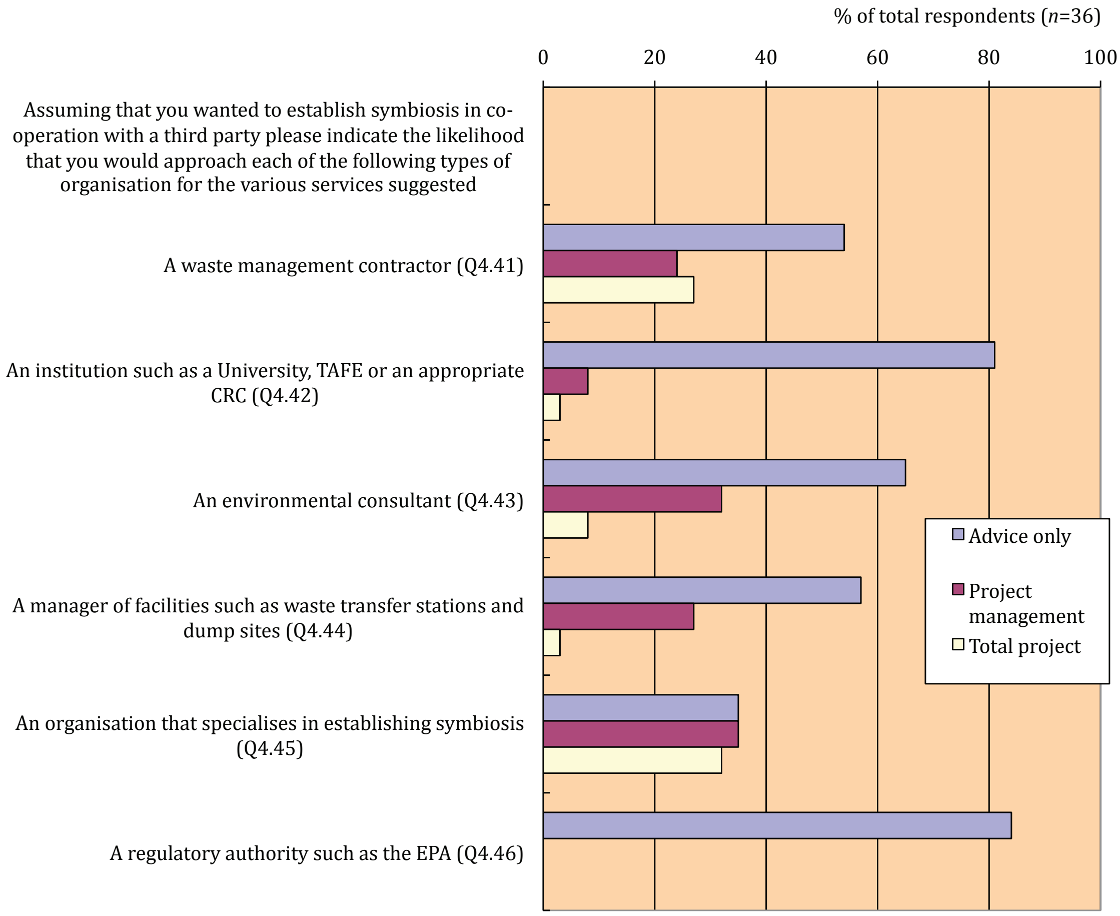
5.9 Assistance from third parties

In the event that a generator of waste did not have the human resources to establish bilateral symbiosis or wanted to do so in conjunction with a third party, a question arises about the *type* of organisation that might be expected to help, as shown in Figure 5.12. It is noted that 'advice' in the legend of Figure 5.12, means simply providing information. The generator takes action accordingly and is responsible for the entire project. 'Project management' means work undertaken by a third party who establishes and manages the project. The generator does not participate actively in day-to-day operations but retains total control over the project and is responsible for the results. An arrangement in which a third party takes total control of the project and responsibility for the results is designated as a 'total project'. Although there may be legal constraints on the generator in terms of its responsibility for the waste, in effect the waste problem is totally 'out-sourced' by the generator. Project management and total project are referred to below collectively as 'project services'.

Responses to question 4.4 were intended to indicate the direction and form of further fieldwork so the results shown below are interpreted accordingly. All six types of institutions rated significantly in terms of providing (unspecified) advice. The relatively high proportion of respondents (84%) that would seek the advice of a regulatory authority can be attributed to the influence such authorities in NSW have over the disposal of waste, as discussed in relation to infrastructure (Subsection 8.4.2).

The academic institutions mentioned in question 4.42 also rate relatively highly (81%) as a source of advice, which is likely to be technical rather than legal, given the nature of the institutions. They are not rated significantly (8% and 3% respectively) as a source of project services for bilateral symbiosis which contrasts, for example, with the academic work on network symbiosis at Curtin University in Western Australia and at universities overseas such as Yale in the USA (Section 2.4). This point is discussed in Subsection 8.4.1 *et seq*.

Figure 5.12 – Assistance from external organisations



Question 4.45 is hypothetical since no organisation of an appropriate size is known to exist in Australia which specialise in establishing bilateral symbiosis. The reason for including the question was to assess the likely demand for those services, were such an organisation to exist. The results indicated that it would be more strongly favoured for project services (35%) than any other type of organisation, though not for advice (35%); a result that is, perhaps, counterintuitive but there is no apparent explanation for it.

The manager of waste disposal facilities rated similarly to waste management contractors (57% and 54% respectively) for advice, most likely because one or the other is typically the first 'point of contact' for disposing of waste in an operational sense. They are also regarded similarly in terms of project management (27% and 24% respectively) but for a total outsourcing of the waste disposal problem a waste management contractor (27%) is strongly favoured in preference to the manager of a waste disposal facility (3%). This can be explained by the 'proactive' approach of waste disposal contractors to winning business. It was discovered during interviews

(Subsection 6.3.1) that waste management contractors might offer to arrange what is tantamount to bilateral symbiosis as part of their inducement to customers but as discussed in Subsection 8.4.3 their capacity to do so is deficient.

In regard to providing advice, environmental consultants rated third highest (65%) behind the regulator and academic institutions. They also rated relatively highly (32%) for project management, comparable to specialists in arranging bilateral symbiosis. However, they did not rate as highly (8% vs 32%) for taking on a total project. These results correlate well with those in relation to consultants obtained from the telephone campaign (Subsection 6.3.2). All are consistent with the typical role of a consultant who would be unlikely to take on a total project which may require capital infrastructure and an operational capacity that they would not have in the normal course of their business.

Question 4.4 suggested six types of organisation a generator might approach for assistance in establishing bilateral symbiosis. The responses indicated that some types were particularly favoured for certain forms of assistance, which raises the issue of what capacity organisations within those types have to provide the assistance required. Interviews and the telephone campaign reported in the next chapter were undertaken to gather information about this issue.

5.10 Summary

Respondents to the questionnaire gave a very clear indication that they did see a problem generally with disposing of manufacturing waste and that their situation will deteriorate in the future. They all sent some form of waste to landfill and the cost of doing so concerned almost 80% of them (Figure 5.1). With regard to the future, costs were expected to increase (Figure 5.2), which is exactly what the relevant legislation is intended to achieve (Subsection 8.3.2). Almost 80% of respondents stated that regulations currently influence some aspect of their waste disposal activities and even more expected regulations to become increasingly stringent in the future (Figure 5.3). In short, from a manager's perspective, disposing of waste will become more costly and more demanding.

Questions about how respondents view the environment produced some particularly interesting results. The most conflicted is that 90% indicated their concern for the environment but less that half would be willing to accept an increase in waste disposal costs in order to reduce the impact of their activities. Less than 20% of respondents recorded that there was a formal assessment of the environmental impact caused by their organisation and only 50% recorded that an informal assessment existed. These results raise the question of what the basis might be for such a high level of concern for the environment (Subsection 8.3.1).

In regard to dealing with the general problem, respondents indicated a very strong willingness to find uses for waste. Well over 70% would undertake relevant projects; would use waste from other organisations and would allow their waste to be used by others (Figure 5.5). There appears to be an even stronger willingness to provide the capacity to undertake projects with over 90% indicating they had the human resources available (Figure 5.6) and comparable proportions willing to make various changes to their operations accordingly (Figure 5.8). Over 80% of respondents indicated they would fund their own efforts to instigate bilateral symbiosis (Figure 5.6) but only slightly more than 50% would be willing to finance the efforts of a third party, doing on their behalf much the same things as they would have done for themselves (Figure 5.7). However, aside from the issue of funding, 90% of respondents indicated a willingness to cooperate with a third party who can organise bilateral symbiosis on their behalf (Figure 5.7).

Several questions canvassed the issue of action that might be taken to deal with waste. In relation to the influence of various factors on a decision to act, financial benefit to the organisation was by far the most significant; almost 80% of respondents rated it as having a major positive influence on deciding what action to take. The influence of environmental benefit, corporate philosophy and public perception of corporate behaviour were comparable, all being rated as a positive influence by 30%–50% of respondents (Figure 5.9). With regard to what type of action might be taken, maintaining current arrangements for waste disposal was the least preferred option, which might be expected in light of the concern about rising costs and the powerful influence of financial factors on decisions to act. Notwithstanding the strong willingness to commit resources in house for establishing bilateral symbiosis and a relative unwillingness to fund the efforts of a third party, respondents indicated a distinct preference for cooperation with a third party to do so (Figure 5.10). However, all the factors suggested in question 4.3 to some extent inhibit action. Negotiating with the authorities and arranging (internal) funding were each seen to be equally the most inhibiting (Figure 5.11). The lack of human resources, knowledge and experience were all similarly inhibiting and comparable in significance to funding etc. These responses in relation to resources etc. might seem inconsistent with those in regard to willingness but they can be reconciled by making a distinction between aspirations and capability.

The last question reported in this chapter related to the issue of third-party cooperation, canvassed in question 4.23 (Figure 5.10). The regulator and public sector academic institutions rated highly as sources of advice, being nominated by over 80% of respondents in each case (Figure 5.12). However, they did not rate significantly for providing project services. For these, the most favoured type was a specialist in organising bilateral symbiosis, being rated by over 30% of respondents for all three services. This is a particularly significant finding in relation to an external infrastructure, discussed in Subsection 8.4.1. Waste management contractors, environmental consultants and managers of facilities such as waste transfer stations were all rated comparably for advice (by 55%–65% of respondents) and for project management services (by approximately 25%–35%) but only waste management contractors rated significantly for total project services and in these, they are only slightly less likely to be approached than a specialist.

The general situation described by these results is that manufacturers have a problem, they are willing to do something about it but they probably do not have the capacity to act alone. They will most likely need assistance from various types of organisation which collectively form the external infrastructure. Canvassing the capacity of that infrastructure, by interviews and the telephone campaign, is recorded in the next chapter.

Chapter 6

Phase 2: Results of the survey – interviews

Scrap perlite (LHS) ready for disposal to landfill
Source: Qubator Pty Ltd

Scrap perlite

In September 2005, a product manager with Orica Chemnet Pty Ltd, a company that was supplying Qubator with perlite filter aid at the time, mentioned that the factory which manufactures their product generates baghouse dust (AP-10), which they send to landfill at the rate of approximately 25 tonnes a week. As the operation was economically marginal, they were keen to reduce their costs of disposal. Perlite is a naturally occurring, non-crystalline, aluminosilicate, volcanic mineral containing molecular water. When heated to 900°C, the mineral phase softens and the molecular water volatilises, producing an ultra lightweight aggregate. AP-10 arises when the expanded aggregate is milled and classified to produce various products. Its particle size ranges between +10 –300 microns, with 90% <54 microns and an average of 27 microns. It typically has a bulk density of 230 kg/m^3; water absorption of 143% w/w and oil absorption of 69% w/w.

On the basis of this specification and some general ideas about potential applications suggested by the product manager, the task of finding a use for AP-10 seemed relatively straightforward. Negotiations began on an agreement between Orica and Qubator, which took more than nine months to finalise. The project progressed in the meantime on the basis of a 'gentleman's agreement' but without any satisfactory result. By the end of 2006, the following opportunities had been canvassed: a filler in plastic, particularly nylon for which talc is not suitable; a filler in paint, protective and decorative coatings; an aggregate for lightweight concrete; an aggregate for technical ceramics; slag coagulant and/or insulation in steel production; a raw material in glass production; a raw material in glass wool and rock wool insulation; a precursor for geopolymer (in collaboration with the Australian Nuclear Science and Technology Organisation); a component of horticultural growing medial, particularly for mushrooms; or an ingredient in abrasive soap.

Nothing worked! There was always some detail which prevented AP-10 from being used. Some required a narrower distribution and/or a finer particle size, such as for paint or a plastic filler so I investigated options for contract toll classification. There are no such facilities in Australia. The only feasible possibility was a company in Sydney that manufactured novel, highly sophisticated classification equipment but it went bankrupt while we were negotiating arrangement. Some wanted a larger particle size, such as for slag suppressants so I investigated opportunities for agglomeration, either prilling or briquetting. There are similarly no facilities in Australia for that sort of toll processing.

At the end of 2006, Orica sold the perlite business to a private company in New Zealand. The new owners were also keen to find a use for AP-10 and were willing to continue the arrangements with Qubator, notwithstanding they had plans of their own to use the material. At the time of writing (August 2011) the output has increased by approximately 50% and the quest for a use continues but the opportunities become rarer. In October 2010, I canvassed the interest of a plate glass manufacturer but the material contains more iron that their process can tolerate, without discolouring the product. About the same time, I contacted another organisation that has developed new technology to produce plate glass from cullet, scrap glass prepared for re-use. They are interested in AP-10, however, they do not expect to be in production for at least two years. In June 2011, I met someone at a conference who wants an inorganic filler for manufacturing carpet tiles. Two months later, we had our first telephone discussion about the opportunity. Maybe this is one will work.

6.1 Introduction

Respondents to the questionnaire indicated the type of organisation they would approach for various forms of assistance in establishing bilateral symbiosis (Section 5.9). Interviews were intended to gather information about the capacity of organisation in each type to provide the relevant services. The regulator rated the highest for advice only. In NSW, one organisation acts as the regulator, which at the time of the interview, was the NSW Government Department of Environment, Climate Change and Water (DECCW).[1] Considering all three services together, a specialist organisation was rated the highest even though none is known to exist in Australia.[2] Waste management contractors were also rated significantly in terms of providing all three services. There are four major waste management contractors that offer general services to manufacturers nationally and one other national organisation whose services are somewhat different to the norm. In light of the relative importance of the regulator and the waste management contractors it was decided to approach these types of organisation first. As there are relatively few (significant) organisations in each type, it was thought that a small number of interviews in a short period of time would provide a good indication of the overall capacity to facilitate bilateral symbiosis.

The objective of the interviews was to find out about the policies and practices of an organisation rather than subjective information on topics such as behaviour, mores, corporate ethos and the like. It was thought that one interviewee representing each organisation would be sufficient for this purpose. However, that person had to be in a senior management position in order to have the purview required to provide relevant information. The issue of seniority created a problem of access: some interviews took months to arrange because the interviewee was so busy. One person declined to be interviewed because they didn't have the time. For much the same reason, another person would only comment by exchange of emails, instead of an interview. Eventually, interviews were held with four of the five major waste management contractors. Other types of organisation canvassed in question 4.4, which rated significantly for a particular service, such as public sector academic institutions and environmental consultants, are represented by a wider range of participants in their respective type. In view of the difficulties mentioned above and the time constraints on fieldwork, a telephone campaign was used to gather information rather than attempting to organise and conduct interviews (Section 4.4).

1 As noted elsewhere also, after the state election in March 2011, DECCW became the Office of Environment and Heritage (OEH) in the Department of Premier and Cabinet.

2 Apart from Qubator Pty Ltd which is currently (2011) not large enough to satisfy the requirements of a national or even a statewide system.

6.1.1 External infrastructure

This chapter is arranged with the notion of an external infrastructure in mind (Section 8.4), which refers to all the resources required to instigate bilateral symbiosis, other than those a generator might have available within its own organisation (Section 7.3). Two types of resources constitute the main components of an external infrastructure: one comprises organisations which are approached to provide predominantly 'professional' services such as advice or project management. The other component comprises organisations which are approached predominantly to provide 'physical' resources such as testing or research laboratories, facilities for conducting trials or equipment for hire. A third component may be thought of as a hybrid of these two, outlined in Section 7.4. The focus of this chapter is on the component comprising professional resources (Section 6.4). Researching the provision of physical services is beyond the scope of this study; however, the topic is discussed briefly in the context of future development (Section 9.5). Similarly, funding institutions and the like were not canvassed, although the Sustainability Advantage program was included (Subsection 7.4.2) because it was thought to be potentially a model for instigating systematic bilateral symbiosis in NSW.

Two central questions relating to the external infrastructure were canvassed at interviews:

- What services and resources does the interviewee's company currently (2010) offer for instigating bilateral symbiosis on behalf of a customer?
- What services and resources are likely to be offered within the next five years?

Responses to the questionnaire indicated that the regulator strongly influences the ways in which manufacturers dispose of waste. Rather than being part of the external infrastructure, as outlined above, the regulator's role and legislation more generally are seen as shaping it to a significant extent. This view is corroborated, in a negative sense, by those interviewees who indicated their organisation would fund infrastructure for specific purposes if legislation and the regulations were conducive to long-term investment. In light of its influence, the interview with a representative of the regulator is recorded first and sets a context for most of the other interviews.

6.2 The role of the regulator

Protecting the environment from damage that might be caused by industry is a principal responsibility of the Regulation Section of DECCW. The interviewee, G1, explained that what they are trying to do is:

> [to] make sure that bad things don't happen with waste at any stage of the process, so that in its storage initially, in its transport, in its treatment, in its processing, in its disposal, in recycling processes, bad environmental things don't happen. (G1)

The approach to this task is to provide a regulatory framework that establishes, among other things, a definition of waste, rules for dealing with it, a licensing system to control its generation and all stages of its disposal. The regulatory approach is essentially 'command and control' (Subsection 8.4.2 and 8.5.3) into which the regulator has introduced a system of exemptions that allows some types of waste to be used in particular ways. There are two broad categories of exemption. One is a generic exemption for waste which conforms to a given specification and may therefore be disposed of as stipulated by the exemption, without requiring a licence. The other is a resource recovery exemption, which is required for any waste that is intended to be used on, or will ultimately be applied to, the land or burnt. From the regulator's point of view, exemptions are intended to facilitate the use of waste. The process of obtaining an exemption is intended:

> to provide that gateway [for using waste] but also in a precautionary way … there are some [applications] that are taking longer than we would like … to approve … in most cases, we are not as timely as we should be. It's where we are having to go back to industry to get more information … (G1)

This quote alludes to particular difficulties the regulator has in carrying out its functions. The interviewee commented after the interview that the section does not have enough officers to deal adequately with applications for resource recovery exemptions. He mentioned that by reason of the regulator's position as an impartial entity, its officers cannot give advice or guidance to an organisation applying for a resource recovery exemption. All they can do is state requirements of the law, which may be complicated and exacting. It seems that an officer can indicate where an application is deficient but will not suggest what more information is required or otherwise how to rectify the deficiency. The applicants have to work that out for themselves so the process is iterative and protracted: 'You gradually get information and then you realise that it wasn't adequate. You go back for more' (G1).

The corollary to providing a regulatory framework is the role of enforcement and in this capacity the regulator is also constrained by what might be regarded as the 'rules of engagement'. It has the authority to require an organization to clean up any mess it makes and to enforce: 'undertakings that can require someone to do certain things to make sure that only good things happen [to the environment]' (G1).

However, the principal instrument of enforcement is the court, which for the regulator is generally the Land and Environment Court. There are guidelines for prosecution that the regulator must follow in proceeding to court but in dealing with the matter the court has a broad range of remedies that may be used to redress a situation. Ways in which the regulator might influence the choice of remedies were not discussed at interview.

Besides providing a regulatory framework for dealing with waste, the regulator's role is as much to 'encourage' the diversion of waste away from landfill. The principal mechanism for achieving this is the imposition of a levy on dumping in landfill: 'we, as a regulator, do a pretty hefty amount of encouraging through the use of the waste and environmental levy' (G1).

As noted in Section 1.3, the current landfill levy[3] (2011) is approximately A$82/ tonne and is legislated to be approximately A$118/tonne by 2016. The levy goes directly into consolidated revenue for general purposes. The objective of the levy is to create an incentive for industry to avoid dumping waste:

> There is the levy … that makes disposal more expensive and thus makes all of those other things [potential methods of use] more viable. If you have to spend an extra $60 or $120 on disposal, you can think about quite expensive things to recover resources … it gets people into the mental attitude of thinking of … what resources you are using … can you get waste to use as your resource … can you use less material and thus generate less waste? … Can you find someone else who will use [your waste]? (G1)

At the beginning of the interview with G1, I mentioned that a very high proportion of respondents to the questionnaire had indicated they would approach DECCW for advice about using waste and asked G1 to comment on the reasons for this result:

> Well, there are probably two explanations for it. One is if they're going to have to do something that is otherwise unlawful, they're going to have to come to us … [The other is] our sustainability programs division that facilitates and promotes … recycling, resource recovery and just as much, waste avoidance in the first place, cleaner production ... (G1)

Although the landfill levy goes to NSW state consolidated revenue and is not used directly to fund infrastructure or services which facilitate the use of waste, notionally, some of the levy partially funds the Sustainability Advantage program set up within the

3 In the greater Sydney region, for example.

Sustainability Programs Division of DECCW to help companies become generally more sustainable. As reported in the next section, an interview with a senior manager, G2, in the program provided insights to its operation, which were of particular interest in regard to the possibility that the program might be a model for developing systematic bilateral symbiosis in NSW, given that no organisation, which performs that role, currently exists in Australia (July 2011).

6.3 Professional component of an external infrastructure

Respondents (Section 5.9) were asked to select from six types of organisation which they would approach for advice or project management services. These are provided by the professional component of an external infrastructure, of which waste management contractors and various types of consultant are the main constituents. The question suggested several types of public sector academic institution, which would generally be categorised as belonging to the hybrid component, given their capacity to provide both professional and physical resources. However, since the context of the question implied professional resources rather than physical, academic institutions are recorded in this study as belonging to the professional component. Results of interviews and the telephone campaign are recorded in this rest of this section.

6.3.1 Waste management contractors

Four waste management contractors operate nationwide and as such, dominate the waste disposal industry. Each was approached for an interview. Senior managers (N1 and N2) representing two national operators agreed to be interviewed. A representative (N3) of another to whom I was referred did not have time to be interviewed and was unwilling to nominate a substitute but did agree to exchange emails in lieu, which provided useful information. A representative (provisional) N4 of the fourth national operator refused to be interviewed because the corporation was being restructured at the time and he did not want to respond to issues mentioned in the written request for interview. Having been refused an interview at the first attempt, it was considered unethical to approach other executives in those two organisations, even though it would have been possible to do so. However, 12 months after (provisional) N4 refused an interview, top management had been 'restructured' and I was invited to re-submit a request for interview. As a result (confirmed) N4 contributed useful insights to this study. The managing directors (S1 and S2) of two companies operating mainly in the Sydney region were interviewed because they are known to have an 'imaginative' approach to developing business. An executive (N5) of a national company based in Queensland was interviewed because it has an unusual, perhaps unique, business model which appears to be more oriented towards facilitating bilateral symbiosis than its competitors, albeit currently (July 2011) for a relatively small number of large international and national customers.

Responses to the central questions about services were usually scant. Issues raised by the interviewees seemed to be more significant than the questions themselves, in the context of what the respective companies were doing at the time of interview in relation to bilateral symbiosis or may do in the future. Results of these interviews are therefore recorded principally by reference to those issues, preceded by a brief, general description of the conventional waste management business. The significance of these results is discussed in Subsection 8.4.3.

Conventional waste management services

Conventional waste management companies, irrespective of size, depend principally on the (short-haul)[4] transportation of waste to landfill and hiring out the equipment (skips, bins, compactors and the like) to facilitate transport. These services are usually referred to as 'haul and dump'. Each of the four national operators owns some form of waste processing infrastructure such as a liquid waste treatment plant or a materials recovery facility (MRF). This infrastructure is principally intended to process municipal and commercial waste. Apart from segregating and processing construction waste for use, there is no infrastructure dedicated to processing industrial waste, although liquid waste facilities generally accept industrial effluent and chemicals, by prior arrangement. Each of the national operators also manages, if not owns, one or more landfill sites from which they generate income for themselves, in addition to collecting levies on behalf of the government. Until December 2010, the NSW state government owned an enterprise called Waste Services NSW (WSN), which in turn owned and operated, among other assets, 12 waste transfer stations throughout the greater Sydney region. These stations accumulate waste from any source, compact it and transport it to landfill. The government sold WSN in December 2010 to one of the four national waste management contractors for A$235 million.

Current services

All respondents said their company will attempt to find uses for waste, but how that is construed and the way each does it, varies. One contractor devotes resources specifically to instigating bilateral symbiosis but only on an ad hoc basis, if requested

4 Maximum short-haul turn around time in the major metropolitan areas of NSW is about 2.5 hours. The corresponding time between waste collection and discharge to landfill or a transfer station is about an hour.

by a customer to do so. None of the other companies represented by interviewees have resources allocated specifically to bilateral symbiosis. The company represented by N4, who is the national manger for strategic development, has manAgers in each state whose role is to create new business. In that capacity they may explore opportunities to divert waste from landfill, if not actually to instigate bilateral symbiosis. They took this sort of initiative for a major customer in putting nine of their own employees on two of the customer's sites to act as resource managers responsible for finding uses for the various waste streams. However, there is no formal strategy to facilitate bilateral symbiosis, notwithstanding they could apply significant resources to such activities, as N4 noted. He mentioned that the company employs over 130 chemists and similar technical staff, nationwide, but they are scattered throughout the various businesses so cannot easily be identified or marshalled for action.

In the organisation represented by N3, it is up to the business manager (the person responsible for a particular customer's account) to decide what to do. If individual managers think they can find a use for their customer's waste, they will try. Otherwise, they will not bother and the waste will go to landfill. In relation to dry waste specifically, N2 stated that the big waste management companies, one of which he represents, are prone to dumping rather than finding uses for waste. They are:

> interested in doing everything the law tells them to do, but they're not very proactive as far as extending what is available to them. It's cheaper for them to get it into the ground, than it is for them to – they'll make more money if they try to on sell it, but they're not interested in doing that. The sort of people they employ are not focused in that area. They probably don't have the capacity to do that. They have to employ people specifically to do that. (N2)

This view was corroborated by S1 who mentioned that 'they (the larger companies) just want to be a haul-and-dump service' and by N1, though from a somewhat different perspective. In the context of owning landfill sites, i.e. void space, N1 stated the company's position that such assets are:

> future income to us. So the longer we can extend the life of that landfill, the better the financial return. So we've got some competing interests, even in our own business. We're trying to recover resources in my department, but also, even within my department, there's landfills who are competing to attract waste to be put into their— (N1)

N2 mentioned that contractors dealing with liquid waste are more proactive than those who deal with dry waste because the costs and difficulties of disposal are generally higher than for dry waste. Even so, the likely end result is to dump the waste, owing to competition in the market. Quoting N2:

> For me to get a product, even into a treatment plant now, the cost is so prohibitive that I now go looking … [for alternatives] but that's time consuming, costs a lot of money and loses a lot of work because … while I'm trying to help somebody, there's not a lot I can do myself … a bigger company might come along with a cheaper tipping price and they're driving it. So they keep their prices low. So it's just easier to tip it, rather than actually re-use it. (N2)

In response to the question about current services, N1 raised the issue of contaminated or co-mingled waste which has to be processed before it can be used. If a customer can make available a discrete stream of (uncontaminated) material then they might be able to do something with that material. However, the normal situation is that:

> We have waste co-mingled, thrown in together … the problem for a processor and a receiver like us is we have to then re-extract that material before it can go onto a further use. That is the rate-limiting step of a lot of what we are trying to do in waste management because we cannot get people to source separate. (N1)

The same question about arranging bilateral symbiosis for customers was put to each representative of the smaller, regional waste management contractors. The responses indicated a more proactive approach to business; as S2 made clear:

> Well, the way we see it is not so much wanting to. I see it that we have to [innovate] because we don't have a landfill and theoretically, if you're a waste contractor, you should be able to provide the basic service. That's a given. So we need … to find a point of difference and this is one of those very things. (S2)

The company represented by S1 owns and operates a MRF which is the core of its business. Responding to the suggestion about providing services in bilateral symbiosis, S1 stated emphatically that they do that now but it transpired later in the interview that his concept of finding uses for waste was limited to recovering materials such as paper, plastic, glass and metal from his MRF and selling them in established markets. At the time of interview,[5] his company concentrated on municipal and commercial waste. It did not attempt to deal with industrial waste other than to receive uncontaminated materials that it could 'pass through' to established markets.

---

5 The interview took place in January 2010. The company went into liquidation in October 2010.

This view aligned with those of the other interviewees, except N5, in that recycling is limited to supplying their own processing facilities with waste from which they recover materials for sale in established markets. Their businesses focus on servicing municipal, commercial, construction and demolition customers, being the principal sources of such materials. Notwithstanding *ad hoc* attempts to find a use for a specific waste stream, in practice only haul-and-dump services are generally available to industrial customers.

Future services

Interviewees indicated that in the foreseeable future their services are unlikely to include arranging bilateral symbiosis. Neither N1 nor N2 thought a convincing 'business case' could be presented to top management for such services. S2 saw the potential as a point of differentiation from his competitors but did not have the resources to establish such a service: 'I have difficulty doing what I'm doing, let alone taking it to the next level'. For S1 bilateral symbiosis is 'not on the radar'. Even though industrial waste is beyond the company's current range of operations, S1 might consider pursuing such opportunities but ad hoc and only if he were presented with a challenge.

Factors inhibiting services

All interviewees alluded to the difficulties they saw in facilitating bilateral symbiosis, the two dominant being a dearth of funding and of expertise. Funding was succinctly summarised by N1 who stated that they are 'very, very tight on capital'. Explaining the corporate position more fully:

> the fact is, getting the buy-in and the support and the resourcing that you need around roles like that is very difficult … the culture in this business and I'm sure many other waste management businesses, is you are firstly fighting for the money to get a bin because you can't pick up waste without a bin or some type of container … in branch land, you're running on the smell of an oily rag. And that's the reality of what we face every day. It's very, very tough. (N1)

This quote also emphasises the priority given to conventional haul-and-dump services, illustrated by the need for bins and the intense competition for that type of business. None of the interviewees seemed to recognise the potential for generating profits from organising bilateral symbiosis i.e. to be self-funding. This may be due to the scarcity of human resources, particularly expertise in finding opportunities for bilateral symbiosis and the ability to organise its instigation. Developing a successful 'business case' without those attributes is unfeasible. N1 make this point unequivocally, which again emphasises a preoccupation with conventional services:

> we are very, very stretched on the front lines with staff … we expect our territory managers to sell across (a broad offering of) different services. So we're asking a lot of them already. To pull away from their front-line duties and focus on one task or one market for a period of time is just not going to happen. (N1)

The lack of expertise is exacerbated by the general tendency of managers to 'circulate' among the four national waste contractors when they change jobs, or move to the larger regional companies. This 'churning' of talent, predominantly in haul-and-dump logistics, tends to inhibit the development of new services. The problem is just as acute for the regional companies. While discussing industrial waste, as distinct from municipal and commercial waste, S1 commented that:

> we've no experience in that area … we're not professional in … dealing with that style of product … my qualifications here is [sic] all … commercial wastes, office buildings, hotels et cetera. (S1)

This quote relates also to the point about 'churning'. S1 mentioned that over the previous six months he had built up a 'lovely crew of people' who had been working for the larger companies.

Aside from funding and expertise, sharing ideas between business territories or divisions seems to be difficult in the large national companies. N2 talked about the mentality needed to operate the liquid side of the business as being different from that managing dry waste. While discussing this issue, N1 mentioned an example in which an employee in one state developed a very simple solution to a ubiquitous problem but from the corporate perspective 'we had to dig deep to find it, because they (the state management) don't like to share those ideas'. His company is organised in 'silos' along state lines. Strategic capital expenditure requires national board approval; otherwise state managers make all operating decisions and are responsible for profits. As such, they seem loathed to share knowledge that might diminish a profit advantage over counterparts in other states, even though it would be better for the company as a whole if they did.

Two interviewees commented on the attitude of customers towards finding uses for their waste. Asked if his company would spend days or even weeks searching for a use for waste, S2 responded:

> Without a doubt but the problem … is finding like-minded people at the industrial end … finding somebody that's actually serious at the generator's end that's not going to f*** you around and as you know, that happens. (S2)

In responding to essentially the same question, N2 commented that he would search the internet for a use but thought that the generator should be finding uses for their own waste instead of relying on others to do it for them. All interviewees commented on the generators' dominant preoccupation with cost in selecting waste management services. Several saw this as a short-sighted approach to disposal. The lowest-priced quote would typically not include genuine[6] attempts to organise bilateral symbiosis, but would generally win the contract.

The way waste management contractors respond to enquiries was specifically raised by one interviewee and indirectly by two others. It seems from comments by N2 that telephone receptionists and clerical staff generally are not well trained in dealing with anything other than routine enquiries and that people to whom calls are referred typically do not respond promptly. This certainly reflects my experience in trying to arrange these interviews and in carrying out the telephone campaign (Subsection 6.3.2). People in the regional waste management contracting organisations who answered my initial telephone call put me in touch directly with the managing director. In all the national organisations and particularly the academic institutions, people had difficulty deciding with whom I should be put in touch.

An alternative model to haul-and-dump

The organisation represented by N5 has developed a business model that is fundamentally different from the haul-and-dump model used by conventional waste management contractors, outlined above. The company is 'retained' by a customer to manage their waste in the best way they can. Revenue is derived entirely from management fees rather than from providing conventional services. In fact, the company has to subcontract such services on behalf of their clients, if required. The company's customer base fluctuates between 12 and 16 national and international corporations operating in Australia and New Zealand. So far (2010) it has resisted invitations to operate in other countries for reasons mentioned below. The company focuses on minimising the customer's cost of waste disposal, which may entail extensive work on developing ways to avoid dumping. It has financed the development of new technology to enable a customer's waste to be used and is willing, in principal, to do whatever it takes to achieve the most beneficial results for the customer. Notwithstanding N5's assertion that they have always saved their customers more than the value of their fees, their service is a 'very hard sell'. He mentioned, as did the other interviewees, the difficulties with customers' attitude to waste generally: their short-term preoccupation with cost; the view that waste is not

6 That is, where revenue from the contract is paid on *success* in finding uses for waste rather than including in the contract merely an intention to do so.

'core business' so resources expended on dealing with it should be minimal and the lack of interest and expertise within a customer's organisation.

In N5's view, the issue of expertise is also a critical determinant of his company's own capacity to provide the services they offer. Their workforce is stable and each employee has an intimate local knowledge of his or her customer's operations, which is developed by long association with their business. In addition to the specific skills required to find uses for waste, the ability to provide continuous, day-to-day operational support for the customer is paramount, particularly when things go wrong. Such a workforce takes time and corporate diligence to acquire and maintain. The company has so far been unable to marshal a suitable workforce anywhere but in Australia and New Zealand; without it, they will not expand their business overseas.

6.3.2 Academic institutions and consultants

It was mentioned in Section 6.1 that owing to the length of time required and the difficulty in organising interviews, a telephone campaign was undertaken to gather information about other constituents of the professional component than were canvassed in Subsection 6.3.1. The campaign took place between 29 June and 24 August 2010. Details of the campaign and the data collected are recorded in Appendix 11 and show that none of the organisations contacted offered services to facilitate bilateral symbiosis. Of the 13 academic organisations, nine approaches were unsatisfactory. That is, the call was referred to an appropriate contact who was unavailable at the time and who did not subsequently respond to a message. Of the nine consultants contacted, two were unsatisfactory for the same reason. The average amount of time spent contacting an organisation was seven minutes, and 11 of the 22 contacts made took seven minutes or less. The measure of accessibility that was initially intended to be developed according to the approach described in Section 4.4 became irrelevant, given the relatively short duration of each contact and the general result that none were satisfactory. It is noted that one university (Newcastle) offered limited fee-based services relating to characterisation of materials, which would be categorised as part of the hybrid component but in any case, those services alone are not adequate to facilitate bilateral symbiosis. These results are discussed in Subsection 8.4.6.

6.4 Summary

The results recorded in Chapter 5 address the issue of using waste, as seen from the generator's perspective. A general finding from those results is that generators would prefer to 'outsource' bilateral symbiosis and for various reasons will need assistance from the external infrastructure. The results recorded in this chapter indicate that organisations comprising the professional component do not provide relevant services in NSW.[7] A specialist organisation such as NISP in the UK (Subsection 7.4.1) does not exist in Australia. None of the waste management contractors are willing to provide assistance, other than taking an *ad hoc*, rudimentary approach to finding a use for waste, if they are specifically asked to do so by a customer. In fact, it appears that facilitating bilateral symbiosis would be against the financial interests of any organisation which operates a landfill site, as all the major contractors do, because their current business models are all based on fees from haul-and-dump services. There is no capacity to engage systematically or even opportunistically, in bilateral symbiosis and there are apparently no plans to do so in the foreseeable future.

Results of the telephone campaign indicate that the academic institutions and environmental consultants are less able to provide relevant services than the waste management contractors. None has comparable 'market' presence or physical assets, which might potentially be mobilised to achieve bilateral symbiosis. The results are also significant from a practical, business perspective in that so many attempts to discover whether or not an organisation could provide assistance were unsatisfactory. These and the other results recorded in this chapter are discussed in Chapter 8.

The overarching issue of this research is establishing systematic bilateral symbiosis, given the general conditions prevailing in NSW. Results recorded in this chapter suggest that prospects are bleak of achieving that objective by, say, 2015 when landfill levies will be double what they were in 2010. Nevertheless, generators will need assistance, as indicated by the responses to the questionnaire, so other lines of enquiry were followed in an attempt to gain insights to resolving this issue. They include a deconstruction of the industrial symbiosis at Kalundborg, interviews with successful 'project champions' in Australia and several forms of 'researcher participation', as recorded in the next chapter.

7 There is strong anecdotal evidence to suggest that such services are not available anywhere in Australia.

Chapter 7

Phase 2: Results of other research

Ultimate users of many types of digestible waste
Source: Mr Tom Smith, owner, Kia-Ora Piggery, Yarrawalla West, Victoria

Bakery waste

In October 1998, I began a search for food waste that could be used in rations for pigs. The owner of Kia-Ora Piggery in Victoria, about 250 km north-west of Melbourne, had asked me to find suitable material that would help reduce his production costs, in the face of competition with unrestricted imports from subsidised farmers in Denmark. As a result of a recent project involving a company called Simplot in Sydney, I contacted their plant in Melbourne that manufactured baked products including meat pies and cakes. By February 1999, the operations manager had recovered sufficiently from the Christmas hiatus to take an interest in the proposition that instead of sending their scrap to landfill, it could be used for stock food. At a meeting on site in March 1999 with the piggery owner and me, the operations manager confirmed that they dumped up to 2000 kg per day of raw pastry and a similar amount of finished product. These estimates did not include the raw meat and other ingredients that were discarded each day. During the meeting, an agreement, in principle, was reached between Simplot and Kia-Ora, and work began on detailed arrangements for handling and storage on site, transport and drafting a formal agreement.

The next stage of the project was to conduct trials of the material at a commercial scale and the system for managing it. Part of Qubator's work during this stage was to negotiate approval of the proposal by the Chief Veterinary Officer of Victoria (CVOV). No raw meat or anything that may have come into contact with raw meat, such as pastry, can be fed to pigs unless it has first been sterilised. Obtaining this approval was critical as without it, the project would fail, which it did anyway but for other reasons. Simplot were unable to provide a trial load of scrap until August 1999. By October that year, a semi-retired consultant had been appointed to assess the general situation with regard to waste across the whole site and so he assumed responsibility for this project. He had not been briefed on it and had started negotiations with another organisation to do much the same thing as Kia-Ora had agreed to do. During the next five months the project progressed very slowly and without any involvement at all by line management, particularly the operations manager with whom the arrangements had originally been agreed upon. Documents were drafted and re-drafted; the consultant raised extraneous issues about which he wanted information that needed to be researched and although he gave assurances that things were being dealt with by top management, nothing in the way of a decision ever materialised.

In March 2000 the consultant let me know that his assignment with Simplot had been completed and that he would be leaving the company imminently. He suggested I contact the plant manager to discuss progress. The plant manager had no idea at all that the project existed. He had never been briefed on it by either the operations manager or by the consultant. Moreover, he was surprised it had ever begun as he claimed the plant only produces about 100 kg of scrap a day from both production lines. The project collapsed.

7.1 Introduction

This chapter records the results of other 'lines of enquiry' that were undertaken in conjunction with the fieldwork recorded in the previous two chapters. Continuing the format used in Chapter 6, this chapter is arranged according to types of infrastructure, relative to a manufacturer: an internal infrastructure, outlined in the next section and the hybrid component of an external infrastructure (Subsection 6.1.1). Interviews in relation to three attempts at finding uses for waste in practice yielded insights relevant to an internal infrastructure (Subsection 8.3.6). Fieldwork relating to an external infrastructure included interviews and other personal communications with representatives of the National Industrial Symbiosis Programme in the UK (Subsection 7.4.1), a senior manager of the Sustainability Advantage program (Subsection 7.4.2) and my association with the Australasian Industrial Ecology Network. Supplementary fieldwork included attending conferences and research symposia organised by the International Society for Industrial Ecology (ISIE).

In a different, fundamental, line of enquiry, the eco-industrial system at Kalundborg was deconstructed principally to assess how relevant the conventional view of industrial symbiosis is to conditions prevailing in NSW. In doing so, the attributes of bilateral symbiosis were verified and issues addressed such as the nature of the various transactions and those associated with geographic proximity. Results of this work are recorded first, as they do not have a direct bearing on the topics of infrastructure.

7.2 Kalundborg deconstruction

It was mentioned in Section 4.5 that deconstructing the arrangements at Kalundborg was intended to discover if their evolution could yield insights about developing systematic bilateral symbiosis in NSW. The two scenarios appear to be entirely different. Nevertheless, since Kalundborg is the archetypical example of industrial symbiosis, it was thought that its characteristics might form part of a suitable model. Conversely, and of particular relevance to manufacturing in NSW, deconstruction might also reveal reasons why bilateral symbiosis would not be viable in Australia or why, to date, it had not been developed.

I first visited Kalundborg at the end of July 2008. Arrangements included meetings with two retired senior managers (K1 and K2) who were intimately involved with developing the relationships during the 1980s and 1990s that now constitute the network. I was given a private tour of Asnaes power station, which is at the centre of the network and a tour of Kalundborg town to see other participants in the symbiosis and some of the infrastructure which supports it. I visited Kalundborg again in June 2009 during which progress on the deconstruction was discussed with K1 and some details confirmed accordingly. I also met several times with K1 in Sydney, NSW at the end of August 2010 and in San Francisco, California in June 2011, where we collaborated on presenting ideas about industrial symbiosis at the 8th ISRS (Section 4.9).

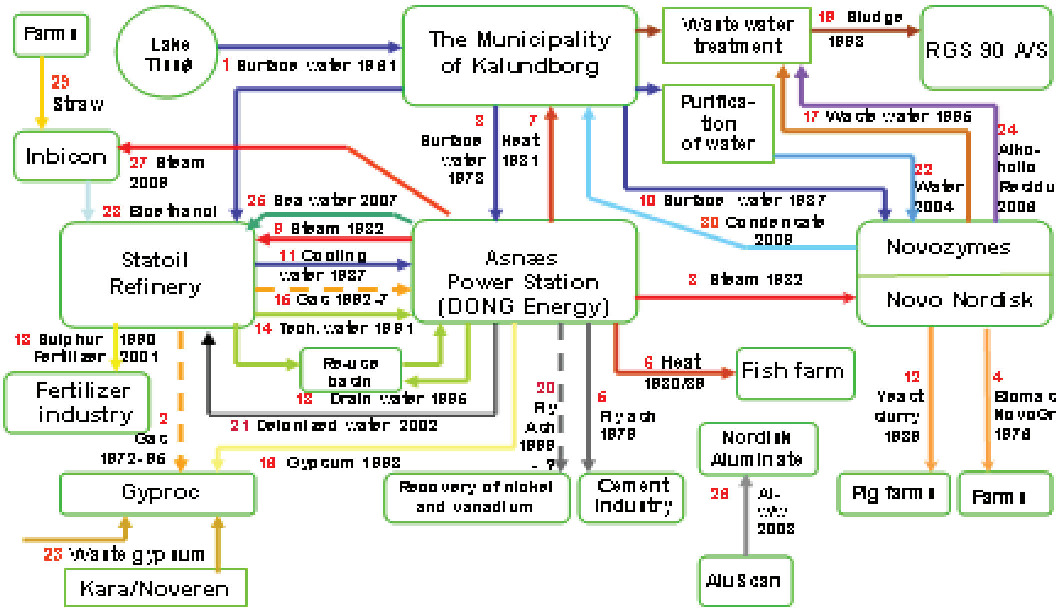
7.2.1 Characteristics of the network at Kalundborg

Characteristics of the symbiosis at Kalundborg have been widely recorded in the literature (Section 2.4 and Subsection 2.5.6) and presented in many parts of the world by Christensen.[1] They are summarised in four key points, as follows:

- Relationships are set up to use waste in some form or share resources such as water or energy.
- Parties to an arrangement must be in close geographic proximity. Although this phrase is not defined in the literature as having an exact, specific meaning, Christensen points out that all the major participants at Kalundborg are within three km of Asnaes power station, the 'notional' hub of the network.
- There must be a close mental distance between the managers of organisations participating in the network. Again, this characteristic is not described definitively but it is taken here to mean that they must know each other well enough to understand their respective businesses, rely on each others capacity to collaborate and trust each other's business integrity (K1 and K2).
- The system is invariably presented as a network of exchanges (e.g. Figure 7.1). The implication of a network is that each element is dependant on the existence of others (Subsection 2.5.6). Furthermore, a network is typically described as comprising 'exchanges' of material or energy, which gives a sense of two-way flows or swapping between participants in an arrangement.

1 Jørgen Christensen has presented on IS at conferences in Denmark, England, Norway, USA, Canada, Brazil, Germany, Austria, Netherlands, Belgium, France, Spain, Italy, Switzerland, India, China – personal communication, 8 July 2010.

Figure 7.1 – Typical illustration of symbiosis at Kalundborg, Denmark
Source: Jørgen Christensen – 2011



7.2.2 *Results of* deconstruction

By June 2009, 30 'projects' had been established since 1961, when the first was instigated. The projects are listed in Appendix 12 which also identifies the parties involved, the purpose of the project and comments. Projects were categorised in relation to what was understood to be the commercial status of the material involved[2] and the primary motivation for the project.[3] The types of projects are: supply of raw materials, supply of a service, sale of products, sale of byproducts[4] and the disposal of waste. Deconstruction is summarised in Table 7.1, in which 'project number' identifies the project detailed in Appendix 12

2 The commercial status of the material has been assessed according to the following rubric: waste is not wanted by the generator and would be dumped if not used by a third party; a byproduct is produced incidentally from a process; it is not wanted by the generator but has intrinsic commercial value for which there is a ready market; a product is deliberately produced by the 'generator' for sale to a third party.

3 All projects had to be justified economically and most were influenced in some way by government protection of the environment. However, some projects were established primarily as normal commercial transactions.

4 It is argued in this thesis (Section 1.7) that a byproduct is definitely not the same thing as waste and so the term is not used as a euphemism for waste.

Table 7.1 – Summary of the deconstructed arrangements at Kalundborg

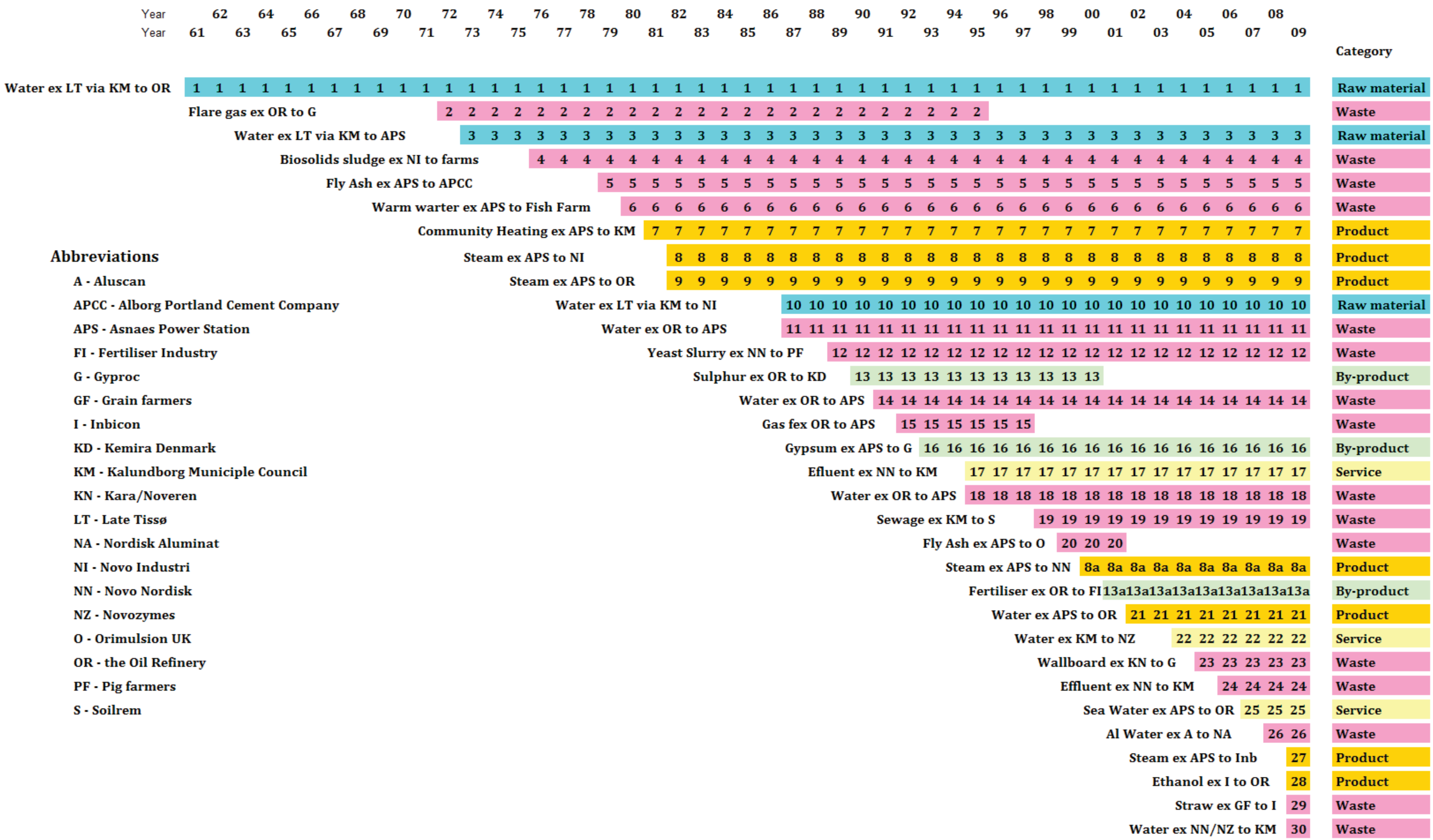
Project type	Project number	Tally	Distance > 50 km	Tally
Raw material	1,3,10	3	1,3	2
Service	17,22	2		
Product	7,8,9,21,27,28	6		
Byproduct	13,16	2	13	1
Waste	2,4,5,6,11,12,14,15,18,19,20,23,24,26,30	14	4(?),5, 12(?),20	At least 2
(TBD)	25,29	3		
Total		30		At least 5

At least 14 projects involved the use of waste and as such, comply with the precepts generally understood to comprise industrial symbiosis. Of the 16 remaining projects, 11 involved the supply of raw material (water from Lake Tisso), the provision of a service or the sale of a product. Whether or not those involving the supply of water from Lake Tisso (projects 1, 3 and 10) could be construed as sharing a resource (the pipeline infrastructure laid in 1961) and therefore be regarded as genuine industrial symbiosis is moot but projects involving the provision of a service or the sale of a product are normal commercial transactions which would not seem to come within the purview of industrial symbiosis. Two projects involved the supply of byproducts in circumstances which make them comparable to products rather than to the use of waste and would therefore also not constitute typical industrial symbiosis. These results are discussed in Section 8.6.

Not all transactions involved delivery over short distances. Fly-ash was transported at least 170 km,[5] liquid sulphur was transported 86 km and Orimulsion ash was sent to the UK for processing. Close mental distance between participants does not appear to have been necessary for some projects to succeed. For example, Mogens Olesen, the director of Asnaes power station at the time, 'sold' the idea of using fly-ash to the Aalborg Portland Cement Company after inspecting cement plants in the UK. Aalborg is on a different island to Kalundborg. Similarly, projects involving liquid sulphur, the disposal of effluent to farms and yeast to piggeries, are not thought to have involved the close mental distance associated with projects involving industrial steam, water treatment or district heating.

5 If by sea but further by land.

Figure 7.2 – Temporal development of the symbiosis at Kalunndborg, Denmark



7.2.3 Bilateral symbiosis

Part of the reason for deconstructing the arrangements at Kalundborg was to assess the temporal relationship between the various projects and the degree of mutual dependence (Section 4.5). These factors are seen as the principal characteristics of bilateral symbiosis. If projects are separate in time and hence co-exist independently of one another, then they are each amenable to analysis as a bilateral arrangement, which has particular significance both in theory and in practice (Section 8.8). In stark contrast to Figure 7.1, the Gantt chart shown in Figure 7.2 presents the same information but in a way which illustrates that the symbiosis at Kalundborg evolved as a series of independent projects, all of which were arranged bilaterally.

7.3 Internal infrastructure

Recapping Section 4.1, notions of an external infrastructure and an internal infrastructure are relative to the manufacturer. Hence, internal infrastructure refers to the capabilities that exist within the manufacturing organisation itself and might be required to instigate and maintain systematic bilateral symbiosis (Subsection 8.3.6). An adequate internal infrastructure would certainly be required for autogenous bilateral symbiosis but some may also be required if a project were facilitated by third parties. The internal infrastructure includes intangible factors such as corporate structure, ethos, policies and motivation. It also includes human resources, the capacity to fund projects and the physical assets to support them.

Interviews were held in October 2009 with two senior managers (C1 and C2) who had instigated bilateral symbiosis for their respective organisations in NSW. The project undertaken by C1 was operational at the time of interview; that undertaken by C2 was well advanced but still being developed. The environmental manager (C3) for a multinational metal processor, operating in NSW, was also interviewed. He responded to the questionnaire, as did three others who collectively represent all such plants in Australia, each of which have similar problems with waste. C3 is part of a management group, which successfully established bilateral symbiosis to deal with one type of waste. The comments of these interviewees relate to the notion of an internal infrastructure; they are recorded below and discussed in Subsection 8.3.6.

7.3.1 Corporate motivation

All three interviewees (C1, C2 and C3) were unequivocal in their respective views that financial benefit is the 'driver' for bilateral symbiosis. If a project does not at least reduce costs, it will not happen. These views align closely with those of K1 and K2 in regard to the projects at Kalundborg (Subsection 8.3.2). None of the interviewees rated environmental or social benefits as principal reasons for instigating a project, although such considerations may influence a decision. The only deviation from this position is when action is required by law (Subsection 7.3.4).

7.3.2 Corporate characteristics

Structure and ethos are the determinants of successful bilateral symbiosis. A corporate structure must enable unfettered interdepartmental cooperation within an organisation. The 'silo' structure which constrains people to carry out only the formally allotted responsibilities of their respective departments and inhibits inter-departmental cooperation is not conducive to developing bilateral symbiosis.

Closely related to the issue of structure is the style of top management. It must be sufficiently flexible to allow 'non-core', informal activities to be undertaken. A corporate ethos which tolerates failure and encourages perseverance is more conducive to success than one that does neither. Comments by C2 about the champion (Subsection 7.3.3) make these points in an operational context:

> provided you've constructed your organisation so that it is understood by whoever that champion is that, not only are they allowed to step outside the box and think crazy ideas and phone people up but indeed they are encouraged to do that and they know that if it all goes pear shaped they are not going to get beaten over the back of the head for wasting all that time doing something that was a crazy idea. So there has to be a lack of fear in the organisation and there has to be the motivation … (C2)

In the organisations represented by C1 and C2, there is no formal, systematic or even informal process for transferring to other employees the knowledge and expertise they had gained by their experiences. The results of their individual efforts were recognised at higher levels of management but that was the extent of corporate knowledge. It is noted that C2 was interviewed in October 2009 and resigned from the company in January 2010. He was not replaced by another general manager. Instead, his non-manufacturing responsibilities, including his bilateral symbiosis projects, were allocated to the group accountant. Subsequent conversations with this person between February and May 2010 indicated that scant information had been passed on about the development or current status of those projects.

7.3.3 Project champion

There must be a project champion, an individual who is committed to achieving a successful result. The champion must have the authority to do whatever is necessary to achieve the result, particularly marshalling resources in various parts of the organisation. Both C1 and C2 were very senior managers; C1 reported directly to the general manager and C2 *was* the general manager. Each gave the impression that the champion should be patient and above all, persistent; everything takes longer than expected. The champion should have the ability to recognise opportunities and the enthusiasm to exploit them. The champion must also be an effective communicator who can explain clearly what needs to be done and persuade people to respond appropriately.

All three interviewees commented that projects had originated by happenstance. That is, someone just happened to ask a question or think of an idea which sparked a train of thought which led to some investigation and so the project developed 'legs'. C2 described how his operations manager just happened to call a company nearby which he thought might be able to use effluent (about 95% water) in their production process. It turned out that they would not unless it was de-coloured but merely asking the question brought other opportunities to mind which have been more successful. Similarly, C1 cast around for an opportunity to reduce operating costs and, being responsible for procuring waste disposal services, thought about finding uses for their scrap finished product, instead of dumping it. C3 described a situation at his site where a plant manager developed, unofficially and entirely on his own initiative, a process for reusing waste within his own plant. Although not an example of bilateral symbiosis, it is an instance that occurred purely by happenstance, resulting from the personal attributes of the manager involved.

7.3.4 Consideration of external factors

Developing an internal infrastructure will likely be influenced to some extent by management's consideration of external factors. As recorded in Section 6.2, perhaps the most influential is the regulator. According to C1, the regulator (DECCW)[6] must be 'kept happy and on side'. Nothing will be achieved in practice if the regulator is against it. This feature was acknowledged indirectly by C2 when discussing the motivation for bilateral symbiosis. He mentioned that everything they do is within the limits set for them by the regulator so they do not have a problem in that respect. Had that not been

6 After the NSW Government elections in March 2011, DECCW became the Office of environment and Heritage (OEH) in the Department of Premier and Cabinet.

the case, then complying with the regulations would be the dominant motivation for action, irrespective of financial considerations. C3 commented extensively on the role of the regulator in ‘stimulating’ change in the practice of dumping chemically hazardous waste on site, in the open. Having recognised threats to the environment posed by this practice, the regulator informed the company that in its view their customary methods of disposal are not sustainable. Irrespective of any financial considerations, the company had to change its practices, even though there is still (2011) no practical use for the material. As a result, the company built covered storage facilities for the waste and set about developing bilateral symbiosis. The regulation also acts in various ways that inhibit bilateral symbiosis. For example, C1 commented that: ‘regulators are extremely conservative and risk adverse. So even if it’s the right thing to do, they’re reasonably conservative in terms of giving anyone a green light (C1)’

In another part of the interview C1 described his approach to dealing with the regulator:

> we had quite a few setbacks with them [the regulator] and each time you take it on the chin and, look, what else can we do? That was the approach. Whether we thought we were right or wrong was irrelevant. At the end of the day, they’re the regulator and we need their ticks and we will do whatever they want us to do to get it [the project] over the line.

Aside from his dealings with the regulator, C1 commented on his experience with waste management contractors, which correlates with the results of interviews reported in Subsection 6.3.1 and is discussed in Subsection 8.4.3. His initial approach to finding a use for their waste was to issue a request for tender to all the major waste management companies, including the four national operators. The tender documents clearly stated that a use was to be found for the waste. He went on to say that:

> every single one of those companies came back with landfill, basically. And there’s a number … Collex, SITA, TPI, JJ Richards … those sorts of companies … So you’re talking about big multinational companies … (C1)

In another part of the interview, C1 described circumstances with regard to jurisdictional differences in Australia, which profoundly affect the viability of bilateral symbiosis, as discussed in Subsection 8.5.1. His company devoted significant management time and resources to finding a use for its waste arising in NSW, where the landfill levy at the time they started the project was A$30/tonne; it is currently (July 2011) A$82.20/tonne (Section 1.3). However, in Queensland where there was no levy at the time, identical waste was dumped because that was the cheapest option.

A more subtle set of factors, in terms of their influence on an internal infrastructure, is illustrated by the approach to bilateral symbiosis explained by C3, which is different in some respects from those taken by C1 and C2. In the first instance, bilateral symbiosis is a formal, corporate initiative, undertaken collectively by a group of managers, rather than by a single, inspired individual acting unilaterally. The approach relies entirely on an external company to find a use for the various waste materials, most of which are chemically hazardous and therefore subject to stringent control by several regulating authorities. The external company is expected to identify a use, establish a demand and develop whatever technology may be necessary to facilitate the use, all at its own cost. In explaining the company's policy, C3 was unequivocal that dealing with waste is a *non-core business* and therefore an activity on which they will expend the minimum resources possible. They are willing to pay a fee-for-service and contribute capital resources such as making their own land available for a pilot plant but the bulk of the responsibility for success rests with the external organisation. C3 mentioned that they are currently (2009) disposing of one particular type of waste under such an arrangement but in relation to establishing similar arrangements for what is by far their largest output of waste, which also happens to be classified as hazardous, he commented that:

> the … process has been going on for 12 years now and I am quite certain that it is not a money making exercise for anyone in the process. It is still in its early infancy because of the nature of the raw material – in getting … international acceptance as the right solution. [The external organisation] … have had to invest significantly in capital in terms of keeping it going to the extent it is. (C3)

A particular feature of an approach which relies to a large extent on the performance of a third party may be described as its vulnerability to the vagaries of commercial reality. Aside from these weaknesses in their approach to bilateral symbiosis, C3 pointed out that in the case cited above, the external organisation owns the rights to any intellectual property associated with processing the waste and also controls access to the markets that use it. Discussion with C3 emphasised how intangible factors such as doubt about the continuing commercial existence of a collaborating organisation, its power to negotiate fees and its capacity to cope with unintended eventualities, compound the operational difficulties associated with this type of approach.

7.4 The hybrid component of an external infrastructure

The three components of an external infrastructure (Subsection 6.1.1) included the notion of a hybrid comprising organisations that provide both professional and physical resources. Examples include various sources of funds and research institutions which undertake technological development, such as ANSTO[7] and the CSIRO.[8] The component also includes various initiatives undertaken or sponsored by government. The Triangle J project in North Carolina, USA (Kincaid & Overcash 2001) showed that such initiatives can be successful. In light of results relating to the other two components of the external infrastructure (Section 6.4), it seemed particularly apposite to assess the potential for similar initiatives to be developed in NSW. Three variations of the general approach were considered: the National Industrial Symbiosis Programme in the UK (NISP), the Sustainability Advantage program (SA) in NSW and the Australasian Industrial Ecology Network, initially established also in NSW but with the intention of expanding nationally. The subsections of this section record the results of these studies.

7.4.1 The National Industrial Symbiosis Programme (NISP)

In the context of using NISP as a model in Australia, it was stated in Section 4.9 that the two issues of interest are the way it operates in the UK and particularly how it is funded. Information recorded in this section was obtained by personal communication with the following people, either face-to-face at various events (Section 4.9) or correspondence:

- Peter Laybourn, Chief Executive Officer, International Synergies Limited[9] (ISL) and Programme Director, NISP UK – at the ISIE conference 2009
- Dr Rachel Lombardi, University of Birmingham, UK – at the 8th ISRS, and the 6th ISIE conference, June 2011
- Gary Foster, Senior Consultant URS-Scott Wilson UK and Director, NISP for South East England – at the 6th ISRS in Kalundborg 2009, at the 2nd AIEN conference in Sydney, September 2010 and again in Sydney, May 2011.

With regard to operations, the general arrangement is that the United Kingdom is divided into nine regions, each of which is managed separately but crucially, all access a central database for information and to record projects. ISL originated the program and is responsible to the various government-funding bodies for the entire system. It manages operations in several of the regions while other regions are managed under subcontract by organisations such as URS – Scott Wilson, which is responsible for South East England. Originally, workshops seem to have been the principal mechanism by which opportunities were identified. Participants were invited to attend, their respective situations with regard to waste were researched and introductions made

7 Australian Nuclear Science and Technology Organisation

8 Commonwealth Scientific and Industrial Research Organisation

9 http://www.international-synergies.com.

at the workshop accordingly. Typically, participants were left to pursue opportunities among themselves, however, particularly large or promising 'leads' would be followed up by NISP managers, who would assist as required. As knowledge of the program spread, increasingly organisations approached NISP directly, rather than through a workshop. The general quality of information gathered at workshops was reported by one commentator to be significantly inferior to that obtained by other means. The core of the system appears to be the database in which is stored all the technical and commercial information gained from each project. This resource has been standardised across regions and now internationally as the concept is 'rolled out' in other parts of the world. It enables links to be made systematically between sources of waste and potential uses rather than by happenstance. The commercial arrangements are that organisations must be a registered member of the program, however, there is no joining fee and all the pecuniary benefits of symbiosis accrue to the participants. NISP receives no remuneration from the arrangements it facilitates, apparently because a funding with the government prevents it from doing so.

The program is entirely funded by several government entities, including the regional governments of Scotland and Wales. Three pilot projects were established in 2003 to demonstrate the concept. In 2005, ISL was allocated £27 million for three years to establish the program nationally. The current contract, which expires in 2011, provides approximately half the original level of funding and as in June 2011, there is no indication of whether or not the contract will be renewed or at what level of support. In November 2010, the Scottish regional government withdrew funding completely,[10] with the immediate result that operations in Scotland were terminated and the workforce disbanded. At about the same time, the national government re-organised its funding entities under one umbrella organisation, which increases the number of applications for the funds available and thereby further threatens support for NISP. There is evidence (e.g. International Synergies Limited 2009) that NISP could fund itself from operations but would need some time to transform the business model. A critically debilitating feature of the current funding arrangement is the perception by top management of ISL that if NISP were to generate revenue from its operations, all government support would immediately be withdrawn. The issue of government funding in relation to the external infrastructure is discussed in various sections of Chapter 8. It not only has a very significant bearing on the future of NISP but also on programs in Australia such as Sustainability Advantage and the Australasian Industrial Ecology Network, outlined in the following two sections.

10 The explanation I was given informally by a representative of NISP in June 2011 is that withdrawal of support was part of the government's initiative to reduce expenditure and hence the amount of public debt. I understand that for contractual reasons, this information can not be verified formally.

7.4.2 The Sustainability Advantage program (SA)

As mentioned in Subsection 6.1.1, the Sustainability Advantage program has been included in this study because of its perceived potential to systematically facilitate industrial symbiosis, statewide. The program resembles a 'business association' in that membership is restricted to companies with 40 employees or more; a joining fee of A$2000 has to be paid and services provided by the program are only available to 'partners' in the program. In outline, G2 described the program as follows:

> Well, it's a business partnership program. It recognises whatever the sustainability issue is, whether it's waste, energy, water, whether it is supply chain, it's got to be done in partnership. And partnerships typically include the government involvement, as well as community, as well as business, if you're looking at it from a holistic point of view. (G2)

As implied by the quote above, the program deals with a range of issues. Waste is a minor part and incidental to the principal objective of general sustainability of a business. If waste is raised by a partner as a particular issue, it is addressed during the program but otherwise it is not specifically identified as an integral part of the program.

There is no 'sunset' for participation in the program but partners must commit for a minimum of 18 months because that is about the time it takes to assess the company's sustainability status. The program comprises eight 'modules' each of which focuses on a particular aspect of sustainability, such as energy, cleaner production or resource recovery. They enable an organization to understand their current position and plan improvements. The program engages consultants to work with partners on these modules, for example:

> waste fits in the resource recovery module and we would typically send in a consultant for about six months to help them work through those waste and other resource issues. (G2)

DECCW pays third-party costs of the program, i.e. consultants, which typically range between A$6000 and A$30,000, depending on the level of support the business needs. However, the costs can exceed this range:

> So for $2,000 joining fee, they have potential to get access to $30,000, or even more. For example, in some of the larger organisations, where we're doing energy audits, just on energy alone, we're subsidising up to $80,000 on energy audits. (G2)

Membership of the association is not just about money; it gives members the kudos of an association with the government and keeps them in touch with developments generally:

> So industry has warmed to it [Sustainability Advantage]. It's not just the savings. It's the recognition and the fact that they are partnering government and looking at some of the sustainability issues like the trading scheme for energy, carbon trading schemes and all these things. They're getting a heads up on where things are going. (G2)

There is a flaw in the Sustainability Advantage program in that a partner is not obliged to make the changes identified by the modules that will improve its sustainability. There is no funding to help bring about changes that might have been recommended, such as for infrastructure, plant or equipment. The logic of the program is that an organisation will inevitably introduce change that is worthwhile, but the program does not address the *capacity* of an organisation to do so:

> I'd love to see more money in sustainability advantage in terms of going beyond just facilitated support through consultancy … particularly for companies that have done the 18 months. If they've got a major project that requires some infrastructure, which is the last thing New South Wales government puts money into, but, hey, if there's a good reason for it, for the benefit of the economy and keeping business in New South Wales and all those other good reasons, it would be great to access some of that levy to put into that. But that ain't [sic] there yet. (G2)

A systemic weakness of the program is its own sustainability. It has support legislated by the state government until the end of 2012; enough time, as from the beginning of 2010, for two 'generations' of new partnerships. By January 2010 about 300 companies had joined the program and its staff had increased from four at the beginning of 2008 to 24. There are plans to introduce restricted participation aimed at small businesses for a joining fee of A$500 which allows access to the energy module only. A budget of A$20 million over three years has been allocated to promoting that module. These funds were contributed by the Environmental Trust[11] which is not controlled by the

---

11 The Environmental Trust is an independent statutory body established by the NSW government to support environmental projects that do not receive funds from other sources. It was established by the *Environmental Trust Act 1998*. It is administered by DECCW, chaired by the minister and its members are the Director-General of DECCW plus representatives from the local government and ahires associations, the Nature Conservation Council and NSW Treasury. After the change of government in March 2011, DECCW became the Office of Environment and Heritage (OEH) in the Department of Premier and Cabinet. As at July 2011, there has apparently been no public indication that control of the trust or the legislation supporting it have changed. However, it is noted that the

state government. The future of Sustainability Advantage beyond 2012 is unknown even though the omens are propitious:

> the program itself is the only program that I can see, in the last 12 months that could receive significant increase, boosted funding, while other programs are being cut back from the government. It's very much – I hate using the word but it's probably the flagship of the DECCW at the moment … Look, it's been outstandingly successful and I think it's going to be more so in the next 12 months and two years. (G2)

The purview of Sustainability Advantage is limited to partners in the program, who must be located in NSW. Employees of DECCW cannot deal (formally) with any issue outside these parameters, no matter how meritorious an opportunity may be. Senior managers of the program recognised that sustainability is not bounded so arbitrarily and were therefore willing to support an initiative undertaken by a group of business people in NSW to establish what has become known as the Australasian Industrial Ecology Network (AIEN). It is hoped that the network (Subsection 7.4.3) will take a broader approach than Sustainability Advantage and is seen to have the potential to be a national organisation. The situation was explained by G2 in the following way:

> At the moment, I'd say we have 30 of the 300 businesses who are Sustainability Advantage, also supporting or hooked up to the AEIN, okay. What that allows me to do, and bear in mind SA is only about New South Wales. It's not about other states, which industrial ecology is about – it's Australia wide. So the support I provide to AIEN is support for conferences, seminars, workshops, breakfast information sessions, provided that it is supporting those 30 businesses that are our members. The fact that others come along, that's fine. But don't ask me to do or put money into a project to recover and use fly-ash if the supply chain involved in that isn't some way connected to Sustainability Advantage. Not interested. Go and find your funding somewhere else … (G2)

Other sections of the Sustainability Programs Division of DECCW deal with waste in the context of recovering resources but their approach is focused on specific issues such as the National Packaging Covenant[12] or the particular classes of material covered by the Waste Avoidance and Resource Recovery Strategy.[13]

---

balance of power in the Upper House has changed in favour of anti-environmental parties which advocate very substantial reductions in the size and activities of OEH.

12 The National Packaging Covenant was launched in 1999 as an agreement between governments and industry based on the principles of product stewardship with the objectives of minimising environmental impacts of used packaging, conserving resources and facilitating the re-use of packaging.

13 The Waste Avoidance and Resource Recovery Strategy (2007) provides targets for minimising

7.4.3 The Australasian Industrial Ecology Network (AIEN)

The AIEN was established in August 2009, under the auspices of the Waste Management Association of Australia (WMAA) as an organisation dedicated to pursuing the ideals of industrial ecology. At the time, its 'mission' seemed to be compatible with the concept of facilitating bilateral industrial symbiosis, along the lines of the Triangle J project (Section 7.4). From a research perspective, the two aims in joining the founding committee of AIEN and continuing to serve on it are to:

- observe its development, first hand, with particularly interest in issues that might inhibit its evolution as a nationwide, systematic facilitator of bilateral symbiosis
- gain insight to how inhibiting issues are dealt with.

Three issues have emerged to date (July 2011) which adversely influence the capacity of AIEN to facilitate bilateral symbiosis at all, let alone evolve into a systematic, sustainable national program. They are politics, funding and organisation, as outlined in the remainder of this section.

The issue of politics has a commercial dimension and what might be thought of as a bureaucratic dimension. During the committee's initial deliberations on the role of AIEN, I submitted a proposal that it acts as a facilitator, in the way that the Triangle J project had done (Kincaid & Overcash 2001) and NISP still does, but earn fees for doing so. The proposal was rejected by the committee because an organisation member of WMAA had objected to it on the commercial grounds that such a role would encroach on what the member perceived to be its own business interests. From a political standpoint, the objection had to be respected by the committee because the objecting organisation is a major financial member of WMAA. The bureaucratic dimension of the political issue relates to the involvement of DECCW with AIEN, through the Sustainability Advantage (SA) program. Being a state government department, its interests extend geographically only as far as the border with other states. For as long as the relationship between SA and AIEN exists, any political constraints imposed on SA, such as being restricted to NSW, will necessarily influence the development of AIEN.

Results recorded in Chapters 6 and 7 show that economic issues are at the core of this research; funding AIEN is no different. Top management of DECCW agreed to contribute, through WMAA, what are in effect the only funds supporting AIEN, on the basis that its activities would (somehow) introduce 'business' to SA and thereby

---

environmental harm from waste disposal. It proposes topics and actions to guide the work in NSW of conserving and using efficiently the state's resources.

enhance the performance of the program, reported from a political perspective. As at July 2011, the results have been unsatisfactory in this regard and AIEN has been given notice that if the situation does not improve substantially, from the standpoint of SA, its funding will cease. WMAA has organised three conferences on behalf of AIEN and sponsored workshops throughout the state in conjunction with SA, also in the name of AIEN. These activities have generated marginal revenue, which is not adequate to support AIEN and there is no apparent alternative source of funds.

From an organisational perspective, AIEN exists as a 'working group' of WMAA so its activities must be compatible with the objects stated in its constitution.[14] For example, facilitating bilateral symbiosis in the manner mentioned above was seen to be essentially a commercial enterprise. Notwithstanding such activities might have been permissible under the constitution, commercial operations are not thought to be an appropriate undertaking for WMAA and in practice, may compromise the performance of its principal functions. Other difficulties were foreseen such as assembling resources beyond those available from WMAA, particularly the skills and experience required to facilitate bilateral symbiosis, which are thought to be scarce in Australia. In these circumstances, it is not at all clear what role AIEN will perform in future.

7.4.4 A thematic view of the hybrid component

Up to this point, the influence of government has been recorded in the context of its role as the regulator administering environmental legislation (e.g. section 6.2). The data suggests that the dominant approach of 'command and control' taken by the regulator with respect to legislation is by manufacturers as inimical to bilateral symbiosis and un-cooperative, if not obstructive. There is, however, a different facet of government influence that emerges when the various initiatives mentioned in this section are seen in juxtaposition. All of them have been funded entirely by governments, which in one respect indicates a willingness to cooperate with industry rather than to obstruct it. However, the benefits are seemingly transitory in so much as government support may be withdrawn. The apparent absence of information on what happened to the Triangle J project after the government funding program ended suggests that it may have collapsed. NISP in the UK is vulnerable, given the successive cuts to its allocation of funds since 2009, as a result of the government's austerity policies. Responding to a question during an interview in 2010 about the prognosis for funding NISP, Gary Foster commented that: 'the bottom line is we don't know … we are never quite sure'. By September 2011 it was expected that funding in 2012 and beyond would be less than a third of its original level in 2005, in which case the operation would cease to

14 Available at www.wmaa.asn.au/director/about/constitution.cfm.

be viable. In NSW, Sustainability Advantage continues to be supported by the state government and is increasing its 'outreach' to industry. Whereas its mission was originally to help organisations improve their sustainability within a given site, interest recently has included the development of inter-site opportunities, which may include an element of bilateral symbiosis. A substantial amount of sponsorship for AIEN is provided by Sustainability Advantage, on the basis that its activities would in some way be complimentary to those of SA. However, since no progress had been made in this direction since its inception, other than organising an annual conference, G2 announced at a committee meeting in March 2011 that SA support will be withdrawn within 12 months if plans to be pro-active are not developed and implemented. The dilemma for AIEN is that it is invariably prevented from undertaking proactive initiatives by WMAA's constitution as an industry association.

A potentially more enduring and effective facet of government influence is the cooperation between the bureaucracy and manufacturing that could be developed on the basis of mutual trust and a sense of common purpose, that is, to protect the environment and remain economically viable. In Kalundborg, for example, the level of cooperation is such that K2 wrote about it:

> An extra motivation for the Symbiosis is, that the authorities know we are keen of [sic] the environment, so they thrust [sic] us and make it easier for us to get permission for new ideas, and forgiveness if we make mistakes. And then it is good publicity.[15]

Data recorded in Chapters 5 and 6 suggest that cooperation between government authorities and industry like that at Kalundborg has not yet become the general rule in NSW, particularly in relation to the regulator. However, initiatives like NISP, SA and even AIEN to a limited extent are seen to be well placed, as 'honest brokers', to make a significant contribution to the development of similar cooperative relationships between government and industry.

7.5 International symposia and conferences

It was mentioned in Section 4.9 that by the beginning of 2009, three topics were thought at the time to warrant further study. One was the concept of bilateral symbiosis itself, another was the operation of NISP in the UK and the third was a clearer understanding of what actually constitutes industrial ecology. Subsection 7.4.1 records the results relating to NISP. The issue of what actually constitutes the study of industrial ecology

15 Personal communication by email 16 May 2009.

has been abandoned in this thesis for reasons of space as other issues emerged which proved to be more significant in the context of systematic, sustainable bilateral symbiosis.

With regard to this last topic, Chertow (2007) had proposed a 3-2 heuristic as the minimum requirement for industrial symbiosis, conceptualised as a network. The issue was raised by Chertow who conducted a colloquium during the final session of the 6th Industrial Symbiosis Research Symposium (ISRS) in Kalundborg in June 2009. I proposed that bilateral symbiosis should, instead, be the fundamental component of industrial symbiosis, represented by a 2-1 heuristic rather than the 3-2 model. The point was noted but the debate was unresolved. The issue arose again at the 8th ISRS in San Francisco in June 2011 but in a more substantial way than previously. A group of European researchers, including Jørgen Christensen from Kalundborg and myself, proposed bilateral symbiosis as one of several models to be considered as a formal definition. Again the issue was not resolved but definitions proposed by other groups and related discussions may portend a significant change in thinking about industrial symbiosis. Aside from bilateral symbiosis, the notion of *internal* symbiosis was canvassed in the forum whereby arrangements are made to use waste entirely within the same organisation, whether or not on one particular site. This scenario has traditionally been excluded from the purview of industrial symbiosis, whether bilateral or otherwise (Section 2.4). I also discussed with a representative of NISP and other participants at the symposium the idea of distinguishing between physical (bilateral) and social (network) symbiosis. It is recognised that these public and personal discussions have not been recorded formally, as were the interviews reported in Chapter 6, however, the results are thought to be significant in the evolution of industrial symbiosis, as discussed in Section 8.8.

7.6 Summary

Fieldwork recorded in this chapter addressed three pivotal topics in this thesis. Deconstructing the situation at Kalundborg substantiated the theoretical conceptualisation of bilateral symbiosis and demonstrated that it can be seen as the basic mechanism by which arrangements for using waste may be established in practice. It also provided a reference point for distinguishing in theory between transactions involving waste and those involving other types of transfer, such as (genuine) byproducts, services or raw materials.

Parts of the questionnaire (Section 5.9) canvassed some general aspects of an internal infrastructure. This chapter records other aspects identified from the insights of senior managers who have actually instigated projects to use waste. Their discussions at interview reflected on intangible factors, such as the attributes of a project champion, corporate ethos and structure, which crucially affect the capacity of an organisation to engage successfully in bilateral symbiosis, whether autogenous or facilitated.

The Triangle J project in North Carolina and NISP in the UK were used as examples of what constitutes the hybrid component of an external infrastructure (Subsection 6.1.1). They indicate that projects funded by government can be an effective approach to dealing with the problems of industrial waste. However, they are vulnerable to the vagaries of political whim so their longevity is unreliable. Perhaps the nearest approximations in NSW are the Sustainability Advantage program and to a lesser extent, AIEN. Each belongs to the hybrid component but their effectiveness in dealing systematically with manufacturing waste is currently (July 2011) potential rather than actual.

This chapter and the two preceding it, record the results of fieldwork and related 'desk-top' studies. Taken together, they form a comprehensive basis for assessing the viability of bilateral symbiosis as a strategy for dealing with manufacturing waste in practice. In the next chapter, these results are discussed in relation to this objective and the contribution this thesis makes to theory.

Chapter 8
Discussion of results

Scrap gelatine web from the production of capsules
Source: Catelent Pty Ltd, Melbourne, Victoria

Scrap gelatine

Scrap gelatine arises as a continuous, perforated web from which capsules have been formed during the manufacture of pharmaceutical and healthcare products. The web is typically 43% bovine gelatine, 23% glycol, 34% de-ionised water with colouring. Scrap material also contains production lubricants such as soy or coconut oil. There are two main manufacturers in Australia: Sphere Health Care in Sydney, NSW, which produces approximately 15 tonnes a week of scrap and Cardinal Health (now Catelent) in Melbourne, Victoria, which produces approximately 10 tonnes a week. Having been told by a business associate that the scrap goes to landfill, I contacted the production manager at Sphere Healthcare in April 2007 to canvass his interest in finding a use for the material. Being either proteins or carbohydrates, the nutritional ingredients appeared to be suitable as feed for pigs. I contacted the owner of Kia-Ora Piggery in Victoria (featured in the vignette for Chapter 6) who was willing to trial the scrap, even though bovine gelatine is deficient in lysine, a particularly important amino acid for building muscle mass, which is the principal reason for growing almost all livestock.

At a meeting on site in June 2007, I was introduced to the production manager, the operations manger, responsible for creating the waste and the warehouse manager, responsible for its disposal, both of whom reported independently to the production manager. It was agreed at the meeting to begin collecting scrap for trials, however, by the beginning of October, only two bulk bags had been filled, amounting to approximately 1000 kg. Meanwhile, the piggery had bought special equipment to process the scrap and within two weeks of receiving the trial load, had confirmed that they could take the total output of both Sphere in Sydney and Cardinal in Melbourne (see below). One more full bulk bag was collected that year. The production manager left the company at the end of January 2008 and although the warehouse manager continued to be interested in the project, supplies to the piggery stopped entirely. The warehouse manager had no influence over the operations manager, whose workers were responsible for physically handling the scrap and who was indifferent to its disposal because it was not his responsibility. I was advised by the warehouse manager to contact the owner of the business but my attempts to do so over the ensuing 10 months were always intercepted by a seemingly protective personal assistant who was occasionally willing to relay information though unwilling to let us talk directly. In October 2008 a new production manager was appointed and desultory supplies resumed but ceased again two months later. Twenty workers had been 'let go' at Christmas so there was nobody available to load scrap into the bulk bags. The new production manager left suddenly in March 2009 and was not replaced. The warehouse manager left in November 2009, by which time nobody except the operations manger knew about the project and he maintained his indifference to what happened to the waste.

Encouraged be the initial interest at Sphere, in April 2007, I contacted the production manager at Cardinal Health in Melbourne. He too was enthusiastic about the prospect of reducing operating costs so we agreed on the terms on an arrangement. Incredibly, though, much the same difficulties arose in Melbourne as had in Sydney. An ex-employee of Cardinal had a maintenance contracting business and had been hired to look after all the services on site, including disposal of waste. I was asked to liaise with this contractor who was willing to consider any proposal, provided it did not involve more man-hours under his contract. By the end of March 2008, nothing had been achieved, not even a trial load and it seemed highly likely from a conversation with the production manager that nothing would be achieved in the foreseeable future. The project was abandoned; at least for the time being.

8.1 Introduction

This chapter tracks research recorded in Chapters 5, 6, and 7 from the point where specific attempts to create procedures for autogenic bilateral symbiosis discussed in Chapter 3 were subsumed by a broader study of the prospects for bilateral symbiosis in NSW. Factors which affect those prospects are discussed from the generators' perspective, since generators create the waste and are responsible for its disposal. However, the first section deals with the role of the regulator, which exerts significant influence in protecting the environment from harm but in some respects its actions can and do inhibit environmental protection and hence may cause unintended consequences. Section 8.5 also deals with the role of government but from the perspective of policy. In Section 8.3, I discuss key issues with waste disposal from the generators' perspective and their willingness to address them. It includes discussion of the generators' capacity, in house, to solve their problems; notionally, their internal infrastructure. In contrast, Section 8.4 deals with the external infrastructure, which appears to be a critical determinant of systematic bilateral symbiosis. The deconstruction of Kalundborg is then discussed in Section 8.6; a segue to the contribution this research makes to theory, as discussed in Section 8.7. In the final section, I comment on some general issues relating to trends in the development of industrial ecology and industrial symbiosis.

8.2 The regulator's position

The regulator performs three functions which particularly influence the viability of bilateral symbiosis in NSW. Ostensibly, its primary function is to protect the natural environment from harm that might be caused by industry at large (G1). Its responsibilities are carried out by a form of modified command and control policy (e.g. Sinclair 1997) in which it defines as waste every conceivable substance emanating from a manufacturing site[1] and prescribes ways in which to dispose of various classes of waste. The policy inhibits a generator from disposing of waste indiscriminately, at will. The policy is modified in that general exceptions are allowed by the regulator for substances that are not regarded as injurious to the environment. Specific exemptions, known as resource recovery exemptions (RRE), may be granted to individual applicants for the disposal of defined waste streams under specified conditions (G1). The process of applying for an RRE exemption is unsatisfactory for the regulator and for the applicant (e.g. G1, C1 and E2). It tends to operate counter-intentionally in that waste which might have been diverted from landfill is nevertheless dumped because the process is too onerous (S2). There are indications[2] that the regulator would consider adopting more

1 Except finished product.

2 Mentioned by the interviewee at interview and given informally by others at meetings such as the

cooperative approaches such as coregulation (e.g. Senden 2005), as has been enacted in June 2011, for the first time in any Australian jurisdiction, by the federal government with respect to electronic waste (Australian Government 2011). However, the current policy is apparently not conducive to systematic bilateral symbiosis.

The second function emphasised by interviewee G1 is that as a government entity, the regulator is responsible for the impartial administration of its affairs. This precludes giving advice on matters other than the law, policy and process (Section 6.2), which might help facilitate bilateral symbiosis. Such impartiality also prevents the regulator from taking measures other than court proceedings to deal with serious breaches of the law. The principal jurisdiction in NSW for such matters is the Land and Environment Court. It has powers to impose various remedies, which might include provision for bilateral symbiosis. However, according to G1, court proceedings are seen (by all parties in a dispute) to be protracted, labour intensive and expensive. It is thought that settling disputes by negotiation (e.g. US EPA 325-R-01-001 January 2001) would be more flexible and produce more satisfactory results generally.

The third function of the regulator is to advise the state government, indirectly, on the level of landfill levies to be set by legislation, which generate income for consolidated revenue. As explained by S2, the potential to increase revenue is a strong motivation for DECCW to open up more landfill sites, which conflicts with the regulator's primary responsibility to reduce dumping. At the beginning of 2010, government receipts from landfill levies were expected to be A$350 million, all of which would go into consolidated revenue for general purpose expenditure (G2). As levies are legislated to increase by a compound rate of approximately 10% per annum until 2015 (Section 1.2), the government has a powerful incentive to increase landfill rather than reduce it (S2). Private owners of landfill sites, such as represented by N1, are similarly motivated. A significant source of their income is derived from landfill fees so, in practice, there is no corporate incentive to divert waste away from landfill for use by third parties (N1).

8.3 The waste generator's position

The issue of what managers think about waste disposal is critical in assessing the practicality of bilateral symbiosis. If managers do not think they have a problem then even if it is widely understood by others that they do have one, they will do nothing about it. A stark example of this syndrome was given by C1 whose company manufactures identical products in NSW and in Queensland. At the time of the interview in 2009, there was a landfill levy in NSW of A$58/tonne but in Queensland there was none. C1

AIEN workshop on 14 July 2010.

spent three years developing a use for their waste arising in NSW but dumped what arose in Queensland because the managers did not think they had a problem there. From July 2011 their views may likely change as levies are introduced in Queensland. All the means of disposal canvassed in the questionnaire (Figure 5.1) incur costs and all respondents indicated they dispose of waste. Hence it is inferred that all the organisations represented by the respondents pay to dispose of waste and therefore recognise a general problem dealing with disposal. Literature about Kalundborg (e.g. Ehrenfeld & Gertler 1997) identifies concerns for the environment and the cost of waste disposal as the principal drivers for industrial symbiosis, seen as a beneficial solution to the general problem of waste disposal. The extent to which these drivers influence generators in NSW was therefore canvassed in the survey and at interviews. Results are discussed in the next two sections.

8.3.1 Concern for the environment

Results of the survey, shown in Figures 5.4 and 5.5 raise the question of how concerned are corporations about the environment. A high level of concern was indicated by 89% of respondents but this is apparently intuitive to some extent since only 51% have an informal (in-house) assessment of environmental impact caused by waste disposal. Even less (16%) have a formal assessment. This seemed to be anomalous since a higher level of factual information might have been thought to underlie such a high level of concern. However, the result may not be unusual; Marshall and Brown (2003) noted (albeit qualified) that they obtained environmental reports from only 50% of the companies surveyed for their research on metrics. The point about (credible) environmental reporting is significant to the extent that without factual, particularly quantitative information, environmental issues are unlikely to influence management decisions and hence corporate action. The discrepancies noted above are thought to arise partly as a result of there being a general and growing, ambient awareness of environmental issues in Australia among the population as a whole. Managers would likely have responded to the question about concern for the environment as individuals, whereas the questions about environmental assessments related to the corporate position, which may represent a significantly different perspective from that of an employee's personal view. This issue is discussed further in the context of factors that influence a decision to act (Subsection 8.3.4). As environmentally aware individuals, there may also have been a tendency for managers to give what they thought would be the 'right' answer. This would also account to some extent for the discrepancies.

8.3.2 The cost of waste

It is evident from the literature that costs are a dominant factor influencing management decisions. Posch (2010) found that reducing costs of waste is a principal driver of the symbiosis he studied at Styria. Early academic accounts of the symbiosis at Kalundborg note that relationships were motivated by the prospect of reducing costs associated with waste (Engberg 1993; Gertler 1995), a view corroborated by interviewees K1 and K2 in Kalundborg, and by interviewees C1, C2 and C3, with respect to their projects in Sydney (Subsection 7.3.1). As a consequence of this emphasis, it had been reasoned that all respondents would be concerned about their current circumstances but the results in Figure 5.1 indicate that 24% of respondents are not concerned. Of these, 8% stated reasons (Section 5.2) that related to their particular situations and these could not therefore be construed as generally relevant. Since the proportion of respondents unconcerned about waste disposal is relatively small, they are not thought to represent a significant factor influencing the viability of bilateral symbiosis in NSW. This view is supported by the finding that a majority of respondents, variously 78%–89% (Figures 5.2 and 5.3), expect costs to rise and the conditions of waste disposal to become more stringent. It is noted that their expectations are well founded, given the trend of legislation in NSW (Section 1.3), which will be emulated in Victoria and Queensland for similar reasons.

Notwithstanding concern for the environment mentioned in the previous section, less than 40% of respondents indicated their organisation would accept an increase in the cost of waste disposal in order to reduce their environmental impact. The relationship between cost and the environment recurred frequently during interviews. All interviewees from the private sector, both in Australia and in Denmark, emphasised that financial benefit is the paramount consideration, commensurate with acting legally. It is significant that whereas managers in Kalundborg assessed financial benefit accruing over periods of 10 years or more, respondents in Australia indicated that assessments are made in relation to short term operating budgets of one to three years and as S2 emphasised, are narrowly based on current market values. That is to say, the lowest quote invariably wins the contract, irrespective of what environmental or other (long-term) benefits competing quotes may offer. This can be understood in the context of short-termism, which is usually associated with corporate strategy in the face of (perceived) pressure from capital investors, exerted for example by stock market prices. Long-term financial benefits are foregone in preference for immediate gains but as Laverty (1996) shows, individual managers and the corporate culture within which they operate contribute significantly to the type of scenario outlined, for example, by S2. Laverty's findings are supported by Marginson and McAulay (2008) who also found that individual managers exercise short-termism, which likely may not be the best option for environmental protection in the long term.

Part of the NSW regulator's rationale for increasing levies is to provide generators with financial justification for taking appropriate, technically feasible action to avoid dumping. There is evidence that the strategy has been effective. At a workshop in July 2010 organised by the AIEN (Subsection 7.4.3) a presentation was given by an erstwhile interviewee for this research, during which he recounted his company's situation with regard to waste (Subsection 7.4.3). If dumping in NSW were free or relatively inexpensive, he would not have bothered to organise a use for their waste. He made the point that in Queensland where there was at the time no landfill levy, the company dumps exactly the same types of waste, even though they know how to make use of it, because the monetary cost of using it exceeds the cost of dumping. This same interviewee indicated that while the company is concerned about the environmental impact of its waste, it would not be willing to accept an (avoidable) increase in the cost of disposal. Results from the questionnaire (Figure 5.4) show this view is prevalent among respondents. The corollary to these findings is that if they represent the position of generators generally, then government action is critically important for protecting the environment, particularly the strategy of increasing the (negative) value of waste by raising landfill levies. Such strategies are likely to increase motivation but a generator's willingness to avoid dumping waste is a separate issue, discussed in the next section.

8.3.3 Capacity to deal with the problem

A generator's capacity to develop an alternative to dumping waste in landfill was canvassed in relation to corporate ethos, primarily willingness to avoid dumping, the corporation's capacity in terms of human and financial resources to undertake a project and the physical infrastructure available to support bilateral symbiosis. With regard to ethos, responses indicated a general willingness to consider alternative methods of disposal. Almost all respondents (97%) would allow their waste to be used by another organisation. Most respondents (84%) currently supply waste for use but it is thought that this is limited to conventional recycling of paper, glass, metal and plastics for which market infrastructure has been established. The reasoning is that all respondents send waste to landfill, which implies that no viable alternative exists. None of the waste management companies whose representatives were interviewed offers recycling services other than for conventional materials so waste that is recycled is deduced to be in this category. There is, however, an anomaly in the responses to question 2.3, which asked if management would allow their waste to be used by another organisation and question 3.1, which asked if the organisation has a policy preventing the use of their waste. The purpose of 3.1 was to obtain an indication of the extent to which bilateral symbiosis might be inhibited by company policy. Whereas 97% of respondents indicated their waste may be used by others, 11% indicated they have a policy which prevents use. To be consistent, the negative responses to question 2.3 should equal to or exceed the positive responses to question 3.1 but they are in fact less than equal. An explanation is that three of the four organisations that do have a policy preventing use of their waste are food manufacturers and the fourth is a pharmaceutical manufacturer. Such consumer businesses are particularly sensitive to issues of risk, liability and reputation (see below) and in the case of pharmaceuticals, for example, are controlled by strict regulations.[3] One respondent commented that they have policies in relation to their competitors, implying they will do nothing that aids them.[4] It is feasible that a company's formal policy prevents the use of specific types of waste, such as obsolete finished products, but does not prevent the use of others, such as raw materials that are out-of-specification, which could therefore be available for use. Although the issue of risk arises in relation to a relatively small proportion of respondents (11%), it is seen, nevertheless, to be a fundamental aspect of corporate ethos.

In the literature on industrial symbiosis, risk has been associated with the issue of trust. It was noted in Subsection 2.5.7 that there are substitutes in practice for the business dimension of trust; it is argued here that there are similar substitutes for perceived risk, at least in part. Broadly stated, two types of risk with regard to waste are thought to most concern managers in practice.[5] They are categorised here as 'process risk', that is, the user's risk in accepting waste and 'liability risk', that is, the generator's risk in supplying waste for use. For bilateral symbiosis to be a dependable strategy waste supplied by a generator must meet a specification that the user is willing to accept, a point made in general terms by Deutz & Gibbs (2009). From the user's perspective, if waste is not what is expected then it might, for example, disrupt the user's process or interact adversely with other inputs. The degree of process risk therefore depends principally on controlling the quality of waste, on the 'robustness' of the process and its capacity to tolerate unspecified inputs. This type of risk may cause managers to be circumspect about using waste, particularly if the saving in cost is not persuasive or supplies are unreliable. From the generator's perspective, liability may include statutory responsibility for the waste until it is unrecognisably transformed; unspecified, contingent, future liability for third party products containing the waste;

3 Imposed by the Therapeutic Goods Administration (TGA).

4 This company did not have any such reservations when I dealt with its waste during the late 1990s. I have come across a similar policy in other companies but it seems to be rare in Australia.

5 A view supported by my experience since 1989 in arranging bilateral symbiosis for manufacturers.

liability for supplying waste out of specification and diminution of reputation when some misfortune is brought to public attention. Being contingent, indeterminate and sometimes qualitative in character, liability risk is generally difficult to assess adequately and if recognised at all in practice, is likely to be subsumed by calculations of immediate savings in costs, commensurate with the precepts of short-termism, mentioned above. Difficulties in assessing contingent liabilities have been studied extensively in the context of corporate valuation, noted in Subsection 2.5.7; assessing liabilities such as those which might be attributable to bilateral symbiosis appear to be similar.

As a result of the fieldwork during Part 1, human resources and financial resources were thought to be determinants of corporate capacity to undertake a project. Respondents indicated that 94% of corporations would be willing to allocate human resources and 84% would be willing to allocate financial resources to bilateral symbiosis. These results signify adequate corporate capacity to undertake projects in-house and to the extent of allocating human resources, apply also to cooperating with a third party. Corporations seem less willing to finance the efforts of a third party, acting on its behalf, than to finance their own efforts to achieve much the same objective. This result is counterintuitive and there were no comments by respondents that might have provided an explanation for the anomaly. Proposals for the fieldwork planned in Phase 1 required prospective collaborators to allocate the human resources needed to carry out the work involved and fund their own participation in a project. As noted in Section 3.5, some declined to undertake trials because they did not have these resources available. The apparent discrepancy between these two sets of results suggests that willingness to undertake bilateral symbiosis in practice may not be as robust as it appears from the survey.

The third category of questions related to the physical assets and processes that manufacturers would make available to support industrial symbiosis. The results indicated strong willingness to change current handling and storage arrangements (92%), adopt new processes (81%) and install facilities on site (76%). There was less enthusiasm for manual processing; nevertheless, 68% of companies would be willing to re-direct their workforce. Based on experience,[6] these results indicate greater willingness than had been expected to support bilateral symbiosis in these ways. Although encouraging, they are viewed with circumspection, as explained below. Attempts were made to obtain research data that could be used for direct comparison but without success. However, the strategy of 'outsourcing' has a bearing on this issue. Literature on

6 In my business experience, manufacturers are very reluctant to change operating practices, increase wage costs or undertake extra management responsibilities. Even dealing with intractable waste such as blast furnace slag and spent pot liner (from smelting aluminium) is regarded as non-core activities.

the topic is mostly in the field of business management (Subsection 2.5.10). Essentially it is a strategy whereby companies contract third parties to carry out activities on their behalf that are not considered to be 'core' business. The operating principle is that profits will be maximised when all of a company's resources are focused on activities that earn revenue. There is controversy about what constitutes a non-core activity (e.g. Heikkila & Cordon 2002) and how outsourcing is accomplished (e.g. Barthelemy 2003) but to the extent that dealing with waste is regarded by manufacturers as a non-core activity, outsourcing would seem to be a more attractive option than allocating resources in house. The principal, evidentiary reason for being circumspect about the results mentioned above comes from interviews with waste management contractors. The business led by N5 is entirely based on outsource contracting (Subsection 6.3.1). Their customers are among the largest corporations in Australia and given suitably qualified employees, the business could potentially grow at a rate that suggests outsourcing will become increasingly commonplace. Similarly, interviewees N1 and N4 indicated that the direction of their respective businesses is towards offering what is tantamount to outsourcing services on a 'whole of group' basis. However, it appears in light of other findings that corporate willingness to instigate bilateral symbiosis may to some extent be subsumed, for example, by the issue of external infrastructure (Subsection 6.1.1).

8.3.4 Factors that Influence a decision to act

Of the five factors influencing a decision to facilitate the use of waste (Figure 5.9), 78% of respondents indicated that financial benefit has a major positive influence and a further 14% indicated it has a minor positive influence. This result emphasises again the imperative of financial justification above all other considerations, except perhaps acting legally (Subsection 8.3.2). The supremacy of financial considerations over those of the environment is particularly significant in that only 38% of respondents rated environmental benefit as a major positive influence. Although half rated it a minor positive influence, the dominant view seems to be that environmental benefit is not as important as financial benefit. This might seem paradoxical, given increasing concern for the environment in Australia, as illustrated, for example, by trends in state legislation (Section 1.3). One possible explanation for the corporate view is suggested by a comment made by K2 about the managers in Kalundborg to the effect that as individuals they are environmentalists but as employees they must achieve the best financial result they can for the corporation. Attempts to discover if this explanation is valid and if so, what circumstanced are which cause the transition to occur, did not lead to a satisfactory conclusion. No literature was found that appeared to deal directly with the topic. However, the phenomenon can be considered as a sort of conflict between personal values and corporate values, perceived in this case to be profit maximisation, which then opens the issue to other perspectives. For example, a similar conflict exists in the citizen-consumer dichotomy, predominantly discussed in the context of food consumption. Johnston (2008) discussed the competing ideologies of consumerism, characterised by self-interest and citizenship, viewed as a collective responsibility for social and ecological commons. This article examined the influence that might be brought to bear on corporate behaviour by the spending patterns of a hybrid citizen-consumer, a construct suggested as a reconciliation of the two ideologies. Findings from studying a particular case were that the influence was relatively superficial. This contrasts with a study done by Seyfang (2006) which examines the nexus between ecological citizenship and sustainable food consumption. In this case, the highly motivated ecological citizen exerted significant influence, as a consumer, over the behaviour of a particular food company. The notion of a citizen-consumer exercising purchasing power invokes circumstances involving (large scale) collective behaviour, albeit by people acting individually. Lockie (2009) examined this idea in the context of strategies for mobilising people as consumers, to express preferences as citizens; what he calls social agents. Collective behaviour seems to be an underlying feature of the citizen-consumer scenario, which possibly distinguishes it from the issue of how individual employees, such as the managers in Kalundborg, might influence an organisation from within. Literature on corporate social responsibility (CSR) might have produced useful insights on the influence between employee and employers, given that the strategy focuses on appropriate respect for the environment, among other issues, from a corporate perspective. Much of the research seems to relate to how the organisation influences employee behaviour, rather than the converse. However, articles by Greening and Turban (2000) and Backhaus and Stone (2002) discuss the influence that CSR (corporate social performance) has on attracting employees with strong social values. The implication one might draw from these studies is that a significant cohort of such people could influence further improvement in corporate behaviour. An article by Hemingway and Maclagan (2004) examines specifically the capacity of individual managers to influence corporate behaviour and concluded that where they have control over particular circumstances, they are able to impose their personal values. The authors suggest, furthermore, that where such individuals are ‘champions’ of CSR, it is probably not accurate to regard the corporation as agent but the individual instead. Although these and other studies examine the influential relationships between employees and the corporation, they do not explain the circumstances in which the values of an employee, as a citizen or social agent, become subordinated to those of the corporation, which may be less environmentally responsible. While this particular issue remains to be resolved satisfactorily, mention of CSR does introduce the question of how corporate reputation influences discussions about waste.

Results from the questionnaire indicate that corporate policy and a corporation's reaction to public perception of its behaviour exert a relatively weak influence on a decision to facilitate the use of waste (Figure 5.9). Being rated even less influential than environmental benefits, the results emphasise the dominance of financial considerations. Ironically, government is responsible for the only negative influence on decisions to use waste. The effort required to obtain approvals from the regulator to use waste appear to deter some respondents (16–22%) and is counter-balanced by similar proportions who regard obtaining approvals as a positive influence. Why the effort of obtaining approvals would be regarded as a positive influence is enigmatic since it is an expensive and protracted exercise (G1, Section 6.2). One feasible explanation is that such approvals justify the resources devoted to planning and the strategies developed as a result.

8.3.5 Strategies for action

The principal purpose of question 4.2 (Figure 5.10) was to gauge the likelihood that manufacturers would adopt bilateral symbiosis, assuming that it were possible and would benefit the company in whatever way the respondent thought worthwhile. The results indicate that generally, respondents are more likely to adopt bilateral symbiosis than not to do so. Given that 54% of respondents indicated an inclination towards deploying the necessary resources in house, yet 73% indicated an inclination toward collaborating with a third party, it seems that the former strategy is less attractive than the latter. These responses correlate with results obtained in Phase 1 (Section 3.3) and with those to question 4.3 discussed below, all of which tend to support the idea that third-party collaboration is preferred. There was no apparent reason suggested by the respondents why a significant proportion (32%) would probably maintain current arrangements, which is counterintuitive in light of the assumption on which the question was based, so the results were analysed further. Four respondents in the group represent all the aluminium smelters in the country, for which there is currently (2010) no alternative to indefinite storage on site, pending a viable means of permanent disposal. Two respondents are in the frame and truss industry which similarly has no current alternative but to dump scrap virgin timber. The group also includes five food manufacturers, some of whose waste is known to be used rather than dumped. The only respondent who definitely would continue with current arrangements works for a company that originally manufactured a range of spreads, jams and cordials but at the time of the survey it had begun reducing its range of products to cordials only. Waste from the new operations is a relatively small amount of wash-down water for which current disposal arrangements are satisfactory.

The reluctance to use resources in house, as distinct from relying on a third party, is indicated by responses to question 4.3, which sought to find out how the factors suggested in the question (Figure 5.11) might prevent respondents from trying to instigate bilateral symbiosis. The reasoning was that irrespective of what external facilities or (regulatory) inducements might exist, bilateral symbiosis is very unlikely to happen if it is strongly resisted by management or if the necessary resources are unavailable. The three topics of funding, human resources and relations with the regulator are shown to be significant determinants of viable bilateral symbiosis. The results indicated that all respondents would have some degree of difficulty with all three topics, although only 5% indicated that the difficulties would be insurmountable. Without diminishing the significance of funding or interaction with the regulator, the results draw attention to the lack of suitable human resources (in Australia) to undertake bilateral symbiosis. This is seen as a critical issue. Apart from isolated projects that have been instigated by managers acting on their own initiative (e.g. interviewees C1 and C2, Subsection 7.3.3) there is no apparent means by which the requisite knowledge and experience can be acquired. As reported in Subsection 6.3.2, the universities and colleges of TAFE do not offer relevant consulting services, except on highly specialised technical matters such as material characterisation or assessment of environmental impact. It would seem unlikely, therefore, that they can provide the necessary education (see below). Environmental consultants and the waste management industry appear to have no formal capacity to implement bilateral symbiosis so they are unlikely to supply relevant expertise for employment by manufacturers. The problem would be compounded in any organisation which lacked a mechanism for transferring knowledge and a suitable corporate culture, such as mentioned by C1 and C2 (Subsection 7.3.2). This observation raises the question of education about industrial symbiosis and industrial ecology more generally among manufacturers. It was noted in Subsection 2.3.2 that academics successfully promulgate knowledge among themselves but some have recognised the need to do more beyond the realms of academia. Lenzen and various co-authors (Lenzen & Smith 2000; Lenzen & Murray 2001a; Lenzen et al. 2001b) identified deficiencies in Australian tertiary curricula and provided educational materials for teachers and practitioners accordingly. Initiatives such as these and ad hoc modules in courses on environmental sciences offered by some universities are likely to be well short of what is required to meet the current needs of manufacturers.

8.3.6 Internal infrastructure

Analysing interviews with the representatives (C1, C2 and C3) of companies involved with bilateral symbiosis gave rise to the notion of an ‘internal infrastructure’ which comprises particular corporate characteristics and resources that are prerequisite for success. It is entirely within the power of a corporation to establish and maintain an appropriate internal infrastructure, as distinct from the 'external infrastructure' described in Subsection 6.1.1, over which it has no such power. Conclusions about the notions of an internal and an external infrastructure are summarised in Section 9.2.

Project champion

Literature on project champions seems to be unequivocal that the function is crucial, as noted in various ways by Heeres et al. (2004), Roberts (2004), and Mirata and Emtairah (2005), whether the champion be an individual or an organisation (Chertow [2007] and Baas & Huisingh [2008]). The results of this study provide further evidence that the role is crucial to a successful project. Although the early literature on Kalundborg (Engberg, 1993; Gertler 1995; Ehrenfeld & Gertler 1997) did not discuss the role of project champions, it was emphasised by K1 and K2 that senior managers in participating organisations performed, in effect, the role of project champions as they went about establishing the various relationships in the normal course of business activities. It was recorded in Subsection 7.3.3, that interviewees C1 and C2 emphasised that there has to be a single individual responsible for managing the process of bilateral symbiosis. Whether or not that person also instigated the project, they were unequivocal that, as the project champion, the person must have the authority to access resources, enlist cooperation from others in the organisation, make decisions and more generally, do whatever is required to achieve the objectives. The fact that C1 and C2 were both senior managers within their respective organisations and as such had the attributes mentioned above was recognised by each as a principal determinant of success. In contrast, C3 did not have the same status and hence the attributes of C1 and C2. The projects he is associated with are run by a committee and in the case of their largest waste stream, the process is still in its infancy after 12 years of operation.[7] Whether this contrast is coincidental or is generally substantive in relation to project development is moot but it does raise the question of which is the more effective way to manage bilateral symbiosis. On the basis of this, albeit limited, evidence it might seem that an individual with the requisite attributes acting as project champion is the more effective, especially in the short to medium term. However, the approach is vulnerable in unforeseen circumstances, such as an individual champion departing from the project, which are less likely to adversely affect a committee (e.g. Baas & Huisingh 2008).

7 As a point in contrast: between 1989 and 1992 a process was developed in Australia by Qubator Pty. Ltd. for converting this same waste into a range of ceramic products. The project was funded by three of the four international participants in the industry but was abandoned during the recession which began in 1992 for lack of further funding. Changes in corporate policy after the recession have precluded subsequent attempts to re-establish the project.

Corporate management

Two aspects of corporate management discussed during interviews seem to particularly inhibit the prospects for successful bilateral symbiosis. One is the ‘silo’ approach in which each part of the organisation operates independently of all the others and typically with minimal communication between them. The issue is canvassed widely in the literature on business management in which are described the sorts of barriers that would obstruct the effective performance of a project champion. For example, Harner (2010) discusses the dangers of silo-specific objectives, minimal communication between silos and overall monitoring in the context of managing the enterprise risk of financial institutions. Tyagi and Sawhney (2010) refer to silos and organisational barriers, as if the two ideas are comparable in adversely affecting the performance of product management in marketing. They conclude that the most effective way of improving performance is to dismantle the silos and remove the barriers. The affects of corporate structure and management are scantly addressed in the literature on industrial symbiosis, perhaps because its practical implementation at a suborganisational level has not so far seemed to be the focus of research interest. Hewes and Lyons (2008) discuss the roles of two project champions, each of whom were ‘external’ to the actual organisations that participated in the respective eco-industrial systems with which the champions were associated. The authors mention some of the issues these champions encountered but it is not directly apparent that the ‘silo syndrome’ was one of them. Chertow (2007) mentions fleetingly the role of a project champion, not in relation to barriers within an organisation but in the context of sustaining the function for the organisation in the face of generational change; that is, when an individual, as the champion, ceases to be involved with a project. This particular topic is inextricably connected to the other aspect of corporate management highlighted by the experiences of C1 and C2.

In each of the organisations that employ C1 and C2 there is a total absence of any effective mechanism for transferring to other employees the knowledge and experience, that is, the ‘intellectual assets’ accumulated by them in developing bilateral symbiosis. Both interviewees confirmed that their efforts were not recorded in any such way. Although C1 kept his boss informed generally of progress there was nobody in the organisation who ‘understudied’ the project or to whom C1 could pass on knowledge, in case he should become incapacitated or leave the company. An illustration of this scenario was provided by C2 who informed me two months after our interview that he had resigned from the company.[8] He was not replaced by another general manager which

8 I had been professionally involved with several of the company’s projects instigated by C1 which is why he called to let me know he was leaving.

resulted in the authority of the project champion's role being diminished. Instead, his formal responsibilities were divided between a new commercial manager, who had been the company's accountant and a new operations manager, who runs that part of the business which generates the waste. The new commercial manager took over (informal) responsibility for the projects C2 had instigated. The issues associated with generating 'corporate' knowledge, its preservation and use have been addressed in the corpus on business management, as recorded for example by Beckett (2001) who makes clear that building and conserving corporate memory are critical, though complicated tasks. He mentions findings by other researchers that the 'silo' company structure is a particular barrier to accomplishing these tasks. Clarke and Rollo (2001) make the point that knowledge is a social construct which cannot be managed in a similar way to physical assets. They distinguish between explicit knowledge, which is codified and the more 'valuable' tacit knowledge held by individuals, which is empirical, intuitive and best communicated face-to-face. These authors emphasise the pragmatic importance of converting tacit knowledge into what they call 'organisational knowledge' so that it is accessible to and usable by other employees; precisely what should have been done in the case of C1 and C2, if their efforts were to contribute broader, enduring benefit to their respective organisations.

Corporate culture

The influence of corporate culture on developing bilateral symbiosis was discussed during interviews in the context of attitudes towards innovation. Interviewees emphasised that an organisation has to be sufficiently flexible to allow a project champion to pursue unconventional, perhaps counterintuitive ideas and be willing to support those efforts. The corollary is that top management must tolerate mistakes without instilling fear of retribution or ridicule. Research has apparently not yet focused on how corporate ethos influences the instigation of bilateral symbiosis in practice; however, it is variously canvassed in the literature on business management. For example, Breaux et al. (2008) examine the relationship between abusive supervision and accountability. Their conclusion that the former adversely affects the latter tends to support the corollary. Encouragement of and support for innovation[9] invariably must emanate from the top management team (TMT), particularly the chief executive officer (CEO). Various contributions to the same corpus support the veracity of this view. For example, Daellenbach et al. (1999) conclude that strong commitment to innovation is very much determined by the predisposition of the CEO and the TMT. Elenkov and Maner (2005) examine the socio-cultural influences on the leadership of

9 In light of this research generally, it may be concluded that currently (2011) bilateral symbiosis is definitely innovative from a corporate perspective.

top management and its influence on innovation. They recommend behaviour likely to be most effective in different cultures (Russian, French, Scandinavian and German) but always in relation to leadership for innovation. Sarros et al. (2008) researched the interaction between corporate culture and what they called transitional leadership in the context of competition through corporate innovation. Their findings seemed to be somewhat indeterminate but they too emphasise the relationship between leadership (i.e. top management) and corporate culture and recommend further research to discover how they might be manipulated effectively for corporate advantage.

Corporate motivation

All three interviewees described emphatically how the prospect of reducing costs had been a strong motive for embarking on bilateral symbiosis. This accords with the results of the questionnaire (Section 5.2), which indicate that a clear perception of financial benefit and to a significantly lesser extent, environmental concerns, motivate management to take some form of action. It may be surmised from these results that without sufficient financial incentive, bilateral symbiosis is most unlikely to occur, as for example in the case of respondent 35 (Section 5.5). It is noted that a major ‘selling point’ for undertaking the trials proposed in Phase 1 (Section 3.4) was the potential for reducing costs but this was apparently not a sufficient inducement to participate. Several organisations declined because they could not allocate suitable human resources to the project (Section 3.5). This correlates with the preference of respondents to the questionnaire for a third party to arrange bilateral symbiosis. The issue segue to this preference is what resources exist outside the generator’s organisation that can be engaged to arrange bilateral symbiosis. It is addressed in the next section.

8.4 External infrastructure

The general results of Phase 1, the difficulties identified by the questionnaire (Section 5.8) and respondents’ preferences for cooperating with third parties, set the context for discussing responses to question 4.4, which canvassed the types of organisation that might be approached for assistance. Those listed in Figure 5.12 may be conceptualised as constituting the external infrastructure supporting bilateral symbiosis. Results of interviews, the telephone campaign (Section 6.3) and other fieldwork (Section 7.4) indicated that the infrastructure in NSW is so deficient in its capacity to provide relevant services as to be non-existent in practice.

8.4.1 Specialists in bilateral symbiosis

An organisation does not exist in Australia, such as the National Industrial Symbiosis Project (NISP) in the UK, which specialises in arranging bilateral symbiosis systematically on a national scale.[10] The absence is particularly significant in light of the result that respondents wanting project services are more likely to approach such an organisation than any other type, even though it is the type least likely to be approached for advice. Although this type of organisation was included hypothetically in the survey, to complete the conceptual range of infrastructure canvassed, in hindsight it would have been useful to be able to relate these results to similar studies in assessing the role specialists play in bilateral symbiosis. However, it seems that the literature is almost silent on the topic. Kincaid and Overcash (2001) show that specialised intervention can achieve potentially worthwhile results but the project they describe was proactive. That is to say, the researchers approached possible participants; they were not approached by industries seeking assistance. NISP operates in a similar way; it takes the initiative to introduce potential partners in a relationship rather than being approached to facilitate an arrangement. Mirata (2004) did an independent study of NISP in its early stages of national formation, which illustrated its proactive role as distinct from reacting to an approach by a potential participant in an arrangement. There is anecdotal evidence that in recent time organisations have taken the initiative in contacting NISP now that its reputation is well established but at least 50% of new matches are still generated proactively.[11] The Centre for Sustainable Resource Processing at Curtin University devised an integrated strategy to further develop the industrial ecosystem at Kwinana, near Perth in Western Australia (van Berkel 2005). It included an element similar to the preparation done by NISP for its workshops but the strategy as a whole included significant components of research on issues such as technological and economic feasibility, government policy and regulation, which NISP does not do. The strategy called for a range of resources that are usually located in a conurbation like Perth and would therefore be difficult to apply in circumstances represented, for example, by the eco-industrial system at Gladstone in Queensland which is more remote than Kwinana (van Berkel 2005). Another distinguishing feature is that whereas Kwinana has a diversity of industry and ownership, Gladstone is dominated the aluminium industry. One company owns the smelter and part-owns three other major operations in the area. The Botany Industrial Park in Sydney (Section 1.2) is in a similar situation in

10 NISP receives long-term government funding of £5–8 million per annum. There is no federal government funding available in Australia to support bilateral symbiosis nationally. The Sustainability Advantage program in NSW is funded by the state government but bilateral symbiosis is not part of the program

11 Personal communication with representatives of NISP at the 6th International Conference of the ISIE, Berkeley, June 2011.

that it entirely comprises the chemical industry. Neither of these areas is conducive to bilateral symbiosis owing to the likely similarity in waste streams and possible market competition between contiguous organisations.

8.4.2 The regulator

Respondents indicated that they are highly likely to seek advice from the regulator although it did not rate significantly as a provider of services such as project coordination and management. This result is consistent with an understanding that the regulator is a branch of state government that has specific responsibilities to licence and control the disposal of waste and deal with unauthorised activities (G1). Reiterating the procedure: every conceivable type of matter is classified as waste by the regulator; if waste is intended to be burnt or used on the land, instead of being dumped as landfill, the generator must apply to the regulator for what is known as a 'resource recovery exemption'. Seeking advice on this procedure and the law more generally explains the high likelihood that respondents would consult the regulator. However, in NSW the regulator can only provide advice about the law and the process; it cannot assist applicants in any other way, for example with trials, tests, types of analyses required or where to have reports prepared. Specifically, the regulator cannot provide advice on any matters pertaining to bilateral symbiosis and certainly cannot offer project services (R1). Part of the reason for this stance is philosophical: it was explained by R1 that the regulator must be seen to be impartial and treat every case referred to it in the same way, without prejudice. Part of the reason is also that the regulator does not have the resources, particularly qualified personnel, to do more than process applications. According to R1, the regulator's current (2010) approach to dealing with a deficient application is typically to request more information or reject it outright, without giving the applicant a clear indication of what is required. The regulator's impartiality is incontrovertibly part of good governance but providing better guidance to industry is compatible with that stance and ways of improving interaction between the regulator and industry would likely benefit both.

There is evidence from Europe that government can cooperate effectively with industry in this way. For example, von Malmborg (2004) establishes a theoretical understanding of local authorities in Sweden as either 'knowledge banks' or 'knowledge brokers'; the latter function being akin to what the Sustainability Advantage program does in NSW (Subsection 7.4.3). However, the regulator in NSW, being a statewide institution, is thought to have a significantly wider purview than the local authorities studied by von Malmborg and would consequently be less able to engage with individual organisations in such detail. There are references about government performing the sort of coordinating or steering functions discussed, for example, in relation to the INES project at Rotterdam Harbour (Boons & Baas 1997). However, this scenario and others describing government influence on industrial symbiosis (e.g. Costa et al. 2010), are not directly comparable to the involvement of government itself in facilitating bilateral symbiosis, as suggested in the survey. The approach taken to compliance in parts of the USA (e.g. US EPA 2001) is perhaps more likely to result in bilateral symbiosis but like the regulations in NSW, it too emanates from the perspective of command and control, which is not thought to engender the most effective cooperation that could possibly exist between industry and the authorities.

This discussion suggests that given appropriate legislation in NSW and preferably at the national level as well, the regulator could be a significant source of advice on instigating bilateral symbiosis. Given also its close association[12] with the Sustainability Advantage program, it also has the potential to cooperate more effectively with manufacturers in actually facilitating bilateral symbiosis. Building on the findings of this study to develop a comprehensive argument to support this view is beyond the scope of this research. It is noted, however, as mentioned in Section 8.6, that the federal government has passed legislation based on co-regulation for the first time ever in Australia. This is a significant departure from the traditional approach of command and control, which may be the harbinger of better governance generally with respect to the environment.

8.4.3 Waste management contractors

Waste management contractors seem similarly unenthusiastic about facilitating bilateral symbiosis for much the same reasons. All the interviewees said their company already does attempt to find uses for waste, if asked specifically by their customer to do so. Responses to such a request varied according to the company's resources but they would typically be haphazard and short lived. Interviewee S1 was fixated on the idea that finding uses for waste meant bringing it to his materials recovery facility (MRF) for sorting and subsequent sale of paper, plastics and metal. This is understandable given that his business is in municipal and commercial waste, but the approach is not conducive to bilateral symbiosis applied to manufacturing waste. Interviewee S2 could visualise a broader approach to finding uses for waste but like the national contractors interviewed, he had practically no capacity in-house to do what was required. When a tender for work necessitated an attempt to find a use for the waste, he would have to enlist external cooperation. Interviewees N1, N2, N3 and N4, each employed by a

12 At least in terms of ownership, both being originally sections of NSW Government DECCW, which since March 2011, has become the Office of Environment and Heritage in the Department of Premier and Cabinet.

national contractor, emphasised the same point about the dearth of financial and human resources to facilitate bilateral symbiosis. Undertaking any such initiative was at the discretion of the customer account manager, the regional manager or state manager, as the case may be. These interviewees made clear one way or another that the relevant person's primary responsibility is to win and manage traditional 'haul-and-dump' business so there is little capacity and less incentive to spend time on what would be perceived as resource-intensive, high-risk projects. Interviewee C1 corroborated this perspective with an anecdote about a tender he had requested from each of the four national waste management companies. He had specified terms of the contract that required the contractor to find uses for the company's principal waste streams. None even submitted a proposal to do so, which is why he set about doing the job himself (Subsection 7.4.3).

Interviewee N3 described an approach which sets his company apart from the traditional waste contractors. In principle, its fee structure encourages the instigation of bilateral symbiosis and their services support the concept. However, N3 commented that 'selling' to a customer the idea of funding such a project is extremely hard without being able to demonstrate cost savings, which they cannot do before the project is completed. Their company, like the other national companies, runs a 'very lean' operation in terms of human resources and does not have the capacity to instigate, on their own initiative, bilateral symbiosis on behalf of their customers. They attempted to do so once and lost about A$100,000 in the process. A particular characteristic of the company represented by N3 is that it restricts its customers to a few very large, generally multinational organisations. Although its business model has the most potential of all the national waste management contractors to facilitate bilateral symbiosis, it does not aspire to service the range of manufacturers that a systematic approach would require.

It seems that no part of the waste management industry is capable of providing systematically the services in NSW that would be required to facilitate bilateral symbiosis. This situation has particularly adverse implications for the development of an external infrastructure because waste management contractors collect and distribute almost all the waste from manufacturing and are therefore in a better position than any other type of organisation to know what waste streams exist, where they arise, where they have to go and the costs of disposal. This knowledge is the basis of bilateral symbiosis.

All the national waste transport companies also operate some form of processing facility such as a materials recovery facility (principally for municipal waste), mineral or edible oil re-processing and biological treatment plants for capturing energy as methane or producing ethanol. In this respect they approximate the resource recovery and waste treatment firms (RRWT) studied by Lyons (2005) in Texas, USA. He concludes that long-term survival of such firms depends on profitably exploiting new market opportunities but that they are unlikely to make a significant contribution to industrial symbiosis unless there is a fundamental change in society's approach to production and consumption. These constraints may be extended to include the government's approach. As N1 mentioned, his organisation would invest in much more infrastructure to process waste, if it had the 'right signals from government', which up to the time of our interview (December 2009) had not being given.

8.4.4 Sustainability Advantage program

The Sustainability Advantage program is run by the NSW Department of Environment, Climate Change and Water (DECCW).[13] In its current form (July 2011), its contribution to the instigation of systematic bilateral symbiosis is restricted by both policy and practice. With regard to policy, only organisations with more than 40 employees may join the program and must pay a fee of A$2000 in order to access its services, which are therefore not available to all manufacturers in NSW.[14] In practice, employees of DECCW working in the program are administrators and to a lesser extent, knowledge brokers as described by von Malmborg (2004); they do not (formally) contribute technical expertise. Consultants are appointed by DECCW to assess a member's performance in any of eight 'modules' of sustainable endeavour. As G2 mentioned, there is no obligation on the member's part to pursue the consultant's recommendations. Only one module deals with waste, which concentrates primarily on avoidance and minimisation but may deal peripherally with recycling, if that were a recommended option for disposal. From the perspective of systematic bilateral symbiosis, Sustainability Advantage could become the foundation of an effective external infrastructure along the lines taken by NISP in the UK (Subsection 7.4.1). It has some of the organisational characteristics which make NISP successful and has the critical attribute of government funding. However, its current form is deficient owing to the exclusive policies which underlie its operations, its limited capacity to procure competent advice on bilateral symbiosis and its total lack of capacity to provide related project services. Apart from the financial benefit of receiving consultants' advice costing more than the joining fee, there are few

---

13 Further to mentioning change of names etc. in the introduction, following the change of government after the NSW state election in March 2011, the DECCW was absorbed by the Department of Premier and Cabinet and became the Office of Environment and Heritage (OEH). As this change occurred after the fieldwork for this research had been completed, the original nomenclature is retained.

14 The interviewee mentioned during interview in January 2010 that the scope may be extended to small organisations that would be required to pay a smaller fee than A$2000 but would get access only to the resource recovery module.

other benefits outlined by G2 that accrue from membership of the program. There is no apparent reason, therefore, why participation should not be open to all manufacturers, as with NISP.

8.4.5 AIEN as a facilitator of bilateral symbiosis

The Industrial Ecosystem Development Project (IEDP) in North Carolina, USA (Kincaid & Overcash 2001) and the experience of NISP in the UK (Mirata 2004; interviewee F1) support the proposition that systematic bilateral symbiosis needs to be facilitated proactively in order to succeed. Each of these projects has two fundamentally important attributes: funding and the 'right' people. The IEDP was funded by the US EPA for a period of two years, at the end of which it was terminated, notwithstanding its success in identifying viable uses for waste. The workforce comprising one part-time manager and two part-time students was small but effective over an area of six counties, containing 30 local governments. NISP has been funded by central and regional government agencies for its entire existence and continues to be so. The project has no other sources of revenue and would collapse if government support were withdrawn,[15] without being replaced immediately (F1). At the end of 2010, NISP employed 50 people nationwide: all full-time, well-trained and skilled professionals (F1; Laybourn & Morrissey 2009).

AIEN has neither of these attributes nor does it have the political support and the organisational structure to perform the role of a proactive facilitator. AIEN is capable of promoting industrial symbiosis through conferences, workshops and meetings. It can also be instrumental in developing potentially useful databases, all of which are part of the NISP model but the likelihood of AIEN successfully facilitating systematic bilateral symbiosis, based on NISP or a similar model, appears to be remote, without providing the proactive human component to manage the process. This observation relates to the issue of an effective external infrastructure. Like the Sustainability Advantage program, AIEN could potentially be restructured to provide the necessary services required by manufacturers but in their current form, each organisation is deficient in attributes that I believe are crucial to achieving systematic bilateral symbiosis.

8.4.6 Academic institutions and environmental consultants

Respondents indicated that they are highly likely to seek advice but not project services from academic institutions. These responses are similar to those relating to the regulator but probably for different reasons, although literature on the topic is relatively sparse. Academic interest in how manufacturers actually instigate industrial symbiosis seems

15 This is exactly what happened when funding for NISP in Scotland was withdrawn at the end of 2010.

not to have materialised as a particular focus of research. Curtin University contributed academic expertise to several of the developments at Kwinana described, for example, by van Berkel et al. (2006) and Chertow (2007) who discussed the need for tools to identify hitherto unrecognised symbiosis. However, the ways in which relationships between academics and business managers are formed to facilitate industrial symbiosis are not discussed in such studies.

Examples of an academic institution given in the survey suggested a category of organisation that includes universities, colleges of technical and further education (TAFE), cooperative research centres (CRC), the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the like. The capacity of this category to provide advice or project services was found to be non-existent. It is emphasised that this view is formed from the perspective of a manufacturer who is seeking help with arranging bilateral symbiosis.[16] Fieldwork (Subsection 6.3.2) indicated that it is difficult in the first instance to contact someone with whom to discuss the issue of finding uses for industrial waste. None of the 13 academic organisation in NSW contacted during the telephone campaign has any formal capacity[17] to collaborate with a generator. One contact offered to undertake ad hoc research such as material characterisation but strictly on the basis of a fee for service and with no confidence of being able to contribute more broadly to a project. The colleges of TAFE were discovered to be strictly educational establishments. None offers courses related in any way to bilateral symbiosis and none conducts research.

Environmental consultants were rated highly by respondents for both advice and project services but in this sector their capacity to collaborate on bilateral symbiosis was found to be effectively non-existent. Not one of the consultants contacted during this research had any relevant capacity or even interest in the topic, largely it seems because the opportunities to make money are not readily apparent. A contact in one of the largest environmental consulting groups in Australia commented that the cost of setting up the requisite capacity is prohibitive and probably not worth the effort.[18] This dearth of expertise and interest compared with north-west Europe for example can be explained by an apparently general unfamiliarity among business managers in

16 It may not be valid in relation to the capacity of a particular organisation to undertake specific academic research commissioned by a manufacturer or third party, e.g. under the Sustainability Advantage program.

17 That is, a school, department or even a group that specialises in waste per se, industrial symbiosis or industrial ecology. Most universities contacted have a formal 'environmental capability'; but none deal with waste.

18 Fieldwork reference (telephone campaign) TS 19.

Australia with industrial symbiosis and the relatively few opportunities to develop eco-industrial systems.

8.5 Government influence

A particularly significant finding of this research is that the role of government is a critical, if not the determining, factor influencing the viability of systematic bilateral symbiosis. Responses to the questionnaire (Section 5.3) and all the interviewees (Sections 6.2 and 6.3) emphatically indentified government as having a major influence on waste disposal. Australia provides an excellent scenario for studying government influence because each state and territory is responsible for environmental protection within its own jurisdiction. Notwithstanding each is part of the same national culture, with shared values, environmental aspirations and the like, each jurisdiction operates independently and has a set of regulations that is different from all the others. At the time of writing (August 2011), there appears to be little, if anything, motivating state and territory governments to even begin talking about genuinely coordinating environmental regulation, so the likelihood is remote of any significant change within the foreseeable future.

From an operational perspective, governments exert their influence mainly through regulation and its enforcement. A detailed study of these phenomena is beyond the scope of this research. However, two aspects of regulation seem particularly influential: its capacity to enable bilateral symbiosis and paradoxically, its simultaneous capacity to inhibit it. The following two subsections illustrate the general circumstances substantiating this finding.[19] The broader issue of politics and policy are discussed in Subsection 8.5.3.

8.5.1 Enabling capacity of government regulation

The crux of this issue is the notion of a 'negative' value of waste induced typically by restrictions on disposal[20] and the instigation of levies on landfill. The underlying principle of the levies, explained by G1, is that the more it costs to dispose of waste the more likely a use for it will be found. The regulations in NSW are the most stringent of all the jurisdictions, not only in defining what constitutes waste but also what can

19 References to the relevant legislation of the various jurisdictions referred to in this section are given in Appendix 1.

20 For example, spent pot lining from aluminium smelting cannot be dumped and therefore is stored under cover, indefinitely, until an acceptable option for disposal is developed. Radioactive waste and chemicals such as PCBs are subject to similar restrictions.

be done with it and most importantly, the costs of disposal. A stark example of how regulation can influence bilateral symbiosis was given by C1 (Subsection 7.3.4), which is recounted here because it illustrates so emphatically the circumstances in point. The company employing C1 went to as lot of trouble and cost over a period of three years to find a use for their waste in NSW because the cost of dumping is so high. However, in Queensland where there was no levy at the time, identical waste was dumped because that was the cheapest option. Whether or not the same use for their waste in NSW is viable in Queensland was not discussed during our interview, since the issue was not relevant. However, it is noted that the levy in Queensland (August 2011) is only marginally higher than the levy was in NSW when C1 began the project. It may, therefore, still not be sufficient to stimulate the effort required to avoid dumping.

In Victoria the levy in metropolitan areas is currently A$44/tonne (September 2011). As of July 2010, South Australia introduced a levy in metropolitan areas of A$26/tonne and A$13/tonne in regional areas. In Western Australia the levy on solid waste to landfill is determined by a formula using a rate of A$12/cubic metre which yields a cost equivalent to using a lower rate, owing to lump-sum deductions included in the formula. It appears that in parts of Tasmania a voluntary levy of A$2/tonne may be collected but there is currently (June 2011) no legislated levy so effectively, there is none. These rates illustrate the capacity of regulation to establish what may be thought of as a 'negative' value of waste. The dominant reason revealed by the questionnaire for concern about waste and hence a willingness to find uses for it was the cost of disposal, a significant proportion of which is imposed by regulation in NSW. The literature suggests that reducing the cost of waste disposal is invariably the result of industrial symbiosis, even though it may not be described as the dominant motive for instigating it. For example, Zhu et al. (2007) frequently mention the elimination or reduction in waste disposal costs achieved by the Guitang Group in China. Since this symbiosis evolved over approximately four decades, it is more likely to have been motivated by commercial expedience than for reasons of environmental protection. However, it can be argued that many of the transactions at Kalundborg were stimulated by the exigencies of environmental protection but since these were not manifested as landfill levies at the time of being canvassed, management had some flexibility in deciding how to minimise consequential waste disposal costs (e.g. Jacobsen 2006). The situation in NSW is somewhat different in that managers are confronted with relatively high levies, which are legislated to increase at least until 2015, ostensibly to motivate the use of waste (G1). This may explain why managers are concerned about their situation with regard to waste. Even where there is a strong environmental imperative imposed on a generator to act in a particular way, such as desulphurisation of petroleum fuels at Kalundborg, invariably the most favourable economic option is adopted. Almost without exception, respondents to the questionnaire and every interviewee emphasised the dominance of financial considerations over all others, including environmental.

It was previously noted that all levies raised in NSW go into consolidated revenue used for general purposes but none is directly allocated to facilitating the use of waste. In contrast, levies raised in Victoria[21] and in South Australia[22] are allocated to various trusts or funds dedicated in some way to facilitating the use of waste and to environmental sustainability more broadly. Direct government support of this type is thought to be a crucial factor determining the success of industrial symbiosis generally. NISP in the UK is an outstanding example of what government support can achieve and there is evidence (e.g. N1 and AIEN) that such initiatives in NSW would also be more effective than simply increasing levies. The issue of 'unintended consequences' emerged from contemplating the NSW government's strategy in relation to landfill levies, without countervailing support for alternatives to dumping. The regulator assumes that generators will find uses for their waste but for those unable to do so, their options would be to continue operating in NSW, dump waste legally and pay the levy; dispose of their waste illegally; go out of business or relocate to another state, if not overseas, where environmental legislation is not so stringent. Maintaining the status quo does nothing to achieve environmental objectives, though contributions to government's consolidated revenues would continue. Illegal disposal is potentially harmful to the environment and certainly does not contribute to government revenue. Going out of business would probably alleviate environmental stress but may be detrimental to the NSW economy. Relocating the business would be detrimental to the economy and likely harm the environment at the new location, perhaps even more so. This suggests that regimes which stimulate the economy and also protect the environment effectively need to include measures that encourage an external infrastructure to facilitate the use of waste, such as NISP in the UK and have sufficiently flexible regulators to accommodate disparate, individual initiatives by generators to avoid environmental damage, as in Denmark for example. In such regimes unintended consequences are more likely to be avoided and economic activity thereby maintained while protecting the environment more effectively than in those which do not include such measures.

8.5.2 Inhibiting capacity of government regulation

Desrochers (2002) made the point that symbiosis at Kalundborg was successful due in large measure to the attitude of the authorities which was cooperative and flexible. The point was corroborated by comments during interviews with K1 and K2 in Kalundborg.

---

21 See, for example 'Purpose of landfill levies' at: www.epa.vic.gov.au/waste/landfill_levies.asp.

22 See, for example 'Grants' at: www.zerowaste.sa.gov.au/.

For example, K2 commented that:

> when we came up with a new idea … something we had to do and we had to ask the authorities for permission for it. Then they knew that we were doing a lot for benefit of the environment so it was easier to discuss and get it.

There is evidence that cooperation between manufacturers and the regulator in NSW is less than is desirable for systematic bilateral symbiosis. From the regulator's perspective, G1 was unequivocal about their role with regard to the private sector. The department regards policing industry as its primary function and to provide evidence for prosecution when necessary. Rules have been established and industry has to abide by them, irrespective of how effective the results might be. Several factors contribute to this position which may distinguish it from the situation at Kalundborg. Previous experience has caused the regulator to mistrust industry in general. Having jurisdiction over many more sites, dispersed over a much larger geographic area than Kalundborg, opportunities to build the rapport with individual organisations which permits flexibility are relatively rare. The point was also made by G1 that the department does not have the personnel, in terms of both numbers and expertise, to do much more than simply process applications for exemption from the regulations. The regulator does provide advice to assist organisations with their applications and some strategies for streamlining the process have been suggested at the AIEN conference in 2009 and at meetings between representatives of AIEN and the regulator. These initiatives are embryonic; their gestation will likely take years and when borne, will only relate specifically to applications for resource recovery exemptions. They do not constitute changes to the legislation or, as G1 put it: the 'rules of engagement', which would create the conditions for confidence and flexibility that are conducive to systematic bilateral symbiosis.

The relationship also seems problematic from industry's perspective. For example, as recorded in Subsections 6.3.1 and 7.3.4, interviewees N1, C1 and C3 commented on the respective difficulties they encountered in dealing with the regulator during their attempts to establish bilateral symbiosis. Since such operational aspects are seldom the main focus of research, there seem to be few references in the literature to the working relationship between manufacturers and the regulator. Although Schwarz and Steininger (1997) do not comment at this level in their studies of networks in Austria, they do indicate how the legal situation more broadly would tend to inhibit bilateral symbiosis, which it does in a way that is very similar to the situation in NSW. They mention, for example that:

> the general setting of the legal system on waste strongly influences the development of a recycling network … one finds that most re-usable (and marketable) residuals have to be considered under the restrictive waste law, regardless of whether they are actually disposed of or re-used. (Schwarz & Steininger 1997, p55)

Aside from the way regulations are administered in NSW, which G1, G2, C1 and C3 in various ways seem to suggest is as much a matter of personal attitude as it is of official responsibilities, legislation is incontrovertibly an overarching factor. Some crucial aspects of legislation are discussed in the next section.

8.5.3 Legislation

Evidence accumulated in this research supports the view that stringent legislation controlling the disposal of waste is a dominant factor in determining the viability of bilateral symbiosis, whether systematic or sporadic. Historically, waste was disposed of more or less indiscriminately until legislation was introduced to control industrial behaviour (e.g. Taylor et al. 2004; James 2009). Appropriate legislation is a necessary and perhaps the only way to create the 'negative' value for waste that stimulates initiatives to avoid disposal at landfill. The influence 'negative' value has on corporate decisions is well illustrated in the anecdote recounted by C1, previously mentioned about using waste generated in NSW but dumping identical material arising in Queensland, notwithstanding that opportunities exist there for using it. Legislation in NSW which 'ramps up' levies for landfill is expressly intended to increase the 'negative' value of waste and thereby create an incentive to find uses for it. Legislation can also support bilateral symbiosis in the context of facilitating external infrastructure. The Sustainability Advantage program in NSW, NISP in the UK and Kincaid's project in North Carolina, USA are examples of its capacity to do this.

Contemporaneously, legislation can inhibit industrial symbiosis and does so in NSW, as recounted by interviewees N1 and C3 and acknowledged by G1 (Section 6.2). Desrochers alludes to similar circumstances in parts of the USA where legislation would actually prevent some of the bilateral arrangements established in Kalundborg (Desrochers 2001). The situation he mentions raises the particular issue of defining waste in legislation. Substances traded in Kalundborg that Desrochers referred to would have been classified as hazardous in the USA and so prevented from being transferred from generator to user.[23] Based on the proposition that definitions are made from a specific point of view and for a particular purpose (Section 1.7), it would seem that the definition

23 A similar anomaly was mentioned by C3 after our interview: transporting spent pot liner (SPL), a waste contaminated with approximately 16% cryolite is restricted but the flux used in the process from which SPL arises contains approximately 60% cryolite and is transport without any restriction.

of what constitutes waste is an intractable problem. Legislated definitions in NSW, as in other states in Australia such as Victoria, are arbitrary and as inclusive as possible so the regulator can control everything that has the potential to harm the environment. A generator defines as waste anything it does not want and therefore intends to dispose of it. A potential user has the opposite view and purpose to a generator and with regard to the environment, the user's purpose would reasonably be thought to align with the regulator's objectives. In such circumstances, it seems undesirable for the regulator to frustrate, inhibit or even prevent the (legitimate) use of waste. Paradoxically, even the lack of suitable legislation can inhibit the use of waste. C3 mentioned a situation in which there was no legislation relevant to the project in hand and it took the company 18 months to gain approval as a result.

It is argued that environmental legislation in NSW would be more effective if emphasis on command and control were reduced in favour of co-regulation or some other approach which would permit a more flexible response to innovation. For example, Sinclair (1997) discusses the strategy of combining compatible features of self-regulation with those selected from command and control, which he suggests are the opposite extremes of a notional continuum of legislative possibilities. The approach is seen by Sinclair to produce various types of legislation that are more effective than command and control, while also avoiding perceived disadvantages of self-regulation. Co-regulation and variants of it are seen as part of such a continuum and have been enacted, for example, in Europe (e.g. Senden 2005) where countries such as Denmark, the Netherlands, Belgium and the UK appear to be the vanguard of legislation conducive to industrial symbiosis. It has been noted in Section 8.2 that the first legislation based on co-regulation in Australia was enacted by the federal parliament in June 2011.

8.6 Deconstruction of Kalundborg

The principal purpose of deconstructing the arrangements at Kalundborg was to discover what insights they could yield about developing systematic bilateral symbiosis in NSW. The project enabled the relevance of networks to be examined, particularly in relation to the attributes of close geographic and close mental proximity associated with industrial symbiosis (e.g. Chertow 2007; K1 and K2). It was also possible to reconcile the conventional scenario with Qubator's experience in arranging bilateral relationships, which was not constrained by such characteristics.

The issue of scale and time are crucially relevant to the deconstruction. As Andrews and Maurer (2001) point out, important detail may be missed at one scale but is detectable at a smaller scale. So it is with analysing the situation at Kalundborg, which is typically described on the scale of an entire eco-industrial system, replete with an established set of relationships between participants that predominantly ‘exchange’ wastes or energy but there is scant, if any, reference to the relevance of time (e.g. Ehrenfeld & Gertler 1997; Altman & van Berkel 2004; Harper & Graedel 2004). A different view of the same facts emerges when the Kalundborg example is analysed at the level of individual transactions. With regard to the temporal dimension: analysis of the projects in terms of when they began, when they ended and the affect termination had on the system as a whole, has also led to an interpretation which is significantly different from the conventional view. Taken together, these analyses provide useful insights to the feasibility of establishing systematic bilateral symbiosis in NSW, if not more widely.

8.6.1 The issue of a network

Given the comments on networks (Subsection 2.5.5), I argue that the physical system at Kalundborg is not a network, in the sense of comprising inter-dependant links between nodes (e.g. Rapoport 1986). It simply looks like such a network when all the projects are portrayed together graphically, as for example in Figure 7.1 (Chapter 7) or when described in terms of a coordinated system (e.g. Harper & Graedel 2004; Haskins 2006). Such representations do not show that each project was a bilateral transaction justified economically, environmentally and socially on its own merits. Crucially, they do not show that every project exists independently of all the others.[24] For example, if Asnaes stopped supplying steam to Novo Nordisk, the fish farm would not cease to be supplied with warm water. Notionally, an element of inter-dependence might be perceived in relation to the pipeline supplying water from Lake Tisso. It was constructed specifically to supply the oil refinery in 1961 and it is moot if subsequent projects using it would have been viable if it had not existed. Nonetheless, the pipeline does exist and it supplies independent projects; if Statoil ceases to use water from Lake Tisso, supplies to Asnaes will not be affected. Similarly, if Novo Nordisk ceased to use steam from Asnaes, that part of the reticulation system shared between them would still be used by Novozymes. This interpretation of the symbiosis at Kalundborg is illustrated in Figure 7.2 (Chapter 7). In practice, rather than being a true network, the situation at Kalundborg is simply an accumulation of bilateral arrangements. I contend that this scenario at Kalundborg constitutes a general model in theory for what might be thought of as physical industrial symbiosis.

24 Except, possibly, for the supply of water from Lake Tisso to Asnaes and Novozymes (projects 3 and 10 respectively), which may have depended on the existence of the pipeline supplying water to the oil refinery (project 1).

The attribute of close mental distance (Subsection 8.7.2) discussed with K1 and K2 during interviews describes the existence of a social system at Kalundborg among individuals, as distinct from the physical system between organisations mentioned above. This distinction is also reflected in the idea that the managers in Kalundborg may be environmentalists but as employees, they approached environmental issues strictly from a corporate (i.e. economic) perspective which may conflict with their personal views (K1 and K2). It seems that the social system is a true network, at least in relation to communication and the reciprocity of ideas, if not also with respect to mutual dependence. In light of these findings, I think it is useful to make a formal distinction between what might be called physical industrial symbiosis, which is bilateral symbiosis in practice and social industrial symbiosis. The managers in Kalundborg had no idea before 1989 that a system had been evolving since 1961 (K1 and K2).[25] This suggests that while a social network may help to facilitate industrial symbiosis, it is not a prerequisite. As the Kalundborg example demonstrates, bilateral symbiosis (i.e. the physical form) can occur independently of the social form. Researchers have studied the social aspects of industrial symbiosis (e.g. Hewes & Lyons 2008) and some have focused on specific issues such as trust and embeddedness (e.g. Boons 1998; Boons & Howard-Grenville 2009). This body of work clearly identifies true social networks with industrial symbiosis, which correlates with the findings of this research. However, a distinction does not appear to have been made between physical and social industrial symbiosis. I believe that making this distinction has ramifications for the development of industrial symbiosis: as bilateral physical symbiosis and contemporaneously as network social symbiosis directed towards changing attitudes in industry generally (e.g. Laybourn & Lombardi forthcoming), as much as towards facilitating physical arrangements.

A corollary to this distinction has emerged from analysing the relationships at Kalundborg: they are not in reality ‘exchanges’ as designated by some authors (e.g. Chertow 2007). An exchange implies that whatever passes from one party to the other is reciprocated or ‘swapped’ for the same or some similar thing from the other; for example, an exchange of information, an exchange of presents, an exchange of gunfire in battle. All 30 relationships at Kalundborg involve supplies by one party to another without a contemporaneous supply of anything similar in the opposite direction. As such, the relationships are properly described as transfers, being a more accurate indication of what took place than as exchanges. On the basis that nomenclature tends to engender a way of thinking and influence action (after Margulis 1997), I contend that transactions associated with bilateral symbiosis generally would better be thought of as transfers than as exchanges and that whatever (physical entity) passes from one

25 All the arrangements were bilateral and apparently not discussed collectively with other parties.

party (the transferor) to another (the transferee) is referred to as 'the transfer'. It seems that this generalisation may be used accurately in describing circumstances involving industrial symbiosis identified so far in the literature and might broaden its conceptual scope in both the physical and social forms mentioned above. It is recognised, however, that an argument might be made along the lines that while nothing of a similar nature is exchanged, what is received by the user is not a gift or something akin to a gift. In this view, it is assumed that the reciprocity intrinsic in an exchange takes the form of money, which is capable of being converted into other materials or services and thus may be construed as completing an exchange, notwithstanding those purchases may not be part of the original transaction, as is notionally the case in an exchange. The point might be extended philosophically to include the notion that the supplier of waste is receiving in exchange a 'release' from the burden of disposal. In the context of establishing a general understanding of bilateral symbiosis, I offer the countervailing point that a transfer may in practice be a gift, depending on its negative value (Section 1.17) and might in fact be the subject of payment by the transferor to the transferee, again depending on perceptions of value.[26] Furthermore, I contend that the underlying issue is to understand how waste is dealt with and that the usual image of an exchange rarely, if ever applies in practice. I make these points for a theoretical and a practical reason. In the context of bilateral symbiosis, there is according to the reasoning above, a significant difference between the nature of an exchange and that of a transfer. I believe that theoretically, 'transfer' is a more accurate and therefore more academically rigorous description of the circumstances than 'exchange'. More importantly, from a practical perspective, the idea of having to achieve an exchange in order to establish a beneficial relationship risks overlooking or neglecting valid opportunities, which may have been recognised had one's frame of mind been attuned to transactions rather than exchanges.

To summarise the principal points made in this section: the concept of industrial symbiosis that has evolved since 1989 does, in reality, conflate two fundamentally different processes, which are recognised as being distinct from one another on both theoretical and practical grounds. Physical industrial symbiosis, essentially bilateral symbiosis, is an arrangement between two organisations specifically and exclusively for the transfer of a physical 'entity' whether it is waste, energy or a resource such as water. The arrangement is not a network; it is simply a transaction. Social symbiosis is a true network; it exists essentially between people, on a personal level, even though participants in the network may represent their respective organisation. The purpose

26 It is quite normal in my business to pay the transferee, who then does something with the transfer that is totally unrelated in any way to the transferor.

of social symbiosis is to exchange knowledge, acquire information, discuss ideas and to share generally the benefits of fraternising with like-minded people.

A significant practical implication of this distinction is that each type of symbiosis can operate entirely independently of the other and in circumstances such as exist in NSW, necessarily must do so. For example, the long distances which typically separate many manufacturers from each other generally do not inhibit the transfer of physical entities. However, long distances may significantly inhibit, if not prevent, the face-to-face social contact described or implied in the academic literature as a characteristic of the conventional understanding of industrial symbiosis. The issue of trust, which is so intimately associated with conventional industrial symbiosis, may be a factor in social symbiosis but is shown to be irrelevant in the context of physical symbiosis (Subsection 8.7.3).

8.6.2 The process of evolution

A number of important issues were canvassed at meetings with K1 and K2 and in conversations during site visits. Every one of the 30 projects at Kalundborg was a bilateral arrangement conceived, assessed and instigated on a 'stand alone' basis, independently of any other. The only project that involved more than two participants was the steam line opened in 1982 (projects 8 and 9) but even this comprised (simultaneous) bilateral transactions. The overarching 'driver' for taking action with regard to waste was compliance with environmental regulations, even if these regulations were potential rather than actual. Commensurate with compliance, the determining factor for each project was economic benefit for the parties involved. Social and environmental benefits were secondary considerations in that if a project could not be justified on purely economic grounds, it would not have gone ahead (K1 and K2).

Deconstructing Kalundborg revealed that approximately 50% of all projects did not involve the transfer of waste. They were established to transfer raw materials, products, byproducts and to supply services, as shown in Figure 7.2 (Chapter 7). These arrangements were based on the transfer having inherent commercial value and were established according to normal commercial practice for the supply of goods and services. As such, these transactions would not typically be attributed to industrial symbiosis, which seems focused on dealing with waste. Since the situation at Kalundborg appears to have evolved as much from establishing commercial relationships as it has from arranging uses for waste, the question arises as to what does industrial symbiosis actually involve? Is it a general strategy for making industry more efficient economically or is it essentially a means of using waste, motivated primarily by environmental concerns, albeit justified by economic viability? The former scenario is simply efficient business practice with the superimposed exigence of co-location. Supplying steam for district heating or for industrial use is normal commerce. Asnaes supplying Statoil with de-ionised water is similarly a normal commercial undertaking. The latter scenario is intrinsically different in one crucial respect: it is predicated in some way on protecting the environment from harm and/or prolonging the resources and services it provides. The pipeline from Lake Tisso mitigated demand for ground water, as did construction of the rain water run-off collection basin built by Asnaes in 1995 (project 18) and the treatment plant built by the municipality of Kalundborg in 2004 to supply de-ionised water to Novozymes (project 22). Byproducts were derived from the de-sulphurisation of petroleum products at Statoil (projects 13 and 13A) in response to environmental legislation relating to fuels and the de-sulphurisation of flu gases at Asnaes (project 16) was a response to similar legislation. Neither organisation reformed their processes before they were 'induced' to do so by government influence. Other examples, such as Asnaes supplying fly-ash to Aalborg Portland Cement Company (project 5) enhance the point of distinguishing between transactions based on normal commercial practice and those relating specifically to the issue of waste. The (positive) value of a normal commercial product is determined according to market factors such as demand, supply, quality, substitution and notionally has a limit (e.g. Bernstein 2004). The (negative) value of waste is related to the costs of disposal,[27] which are directly influenced by environmental legislation as, for example, the imposition of landfill levies or threatening action to protect the environment. Notionally, there is no limit to the negative value that waste could attain as a consequence of government action; it can be set at whatever the regulator decides it should be. In the absence of a legislated imperative, waste has minimal, if any, negative value at all, as illustrated by the original situation at Kalundborg itself, before environmental protection was canvassed, all the waste was dumped, one way or another. The situation in Australia similarly illustrates the significance of government action, as recounted by C1. It has been possible to find a use for their waste generated in NSW, where the legislated landfill levy was approximately A$70/tonne (May 2011) but in the adjacent state of Queensland, where the company generates identical waste, there was no legislated landfill levy so the cheapest option was to dump it, which they did without compunction.

Deconstructing Kalundborg has reconciled the discrepancy between the attribute of geographic proximity, widely reported in the literature as a pre-condition for successful industrial symbiosis (e.g. Engberg 1993; Gertler 1995; Ehrenfeld & Gertler 1997), and Qubator's experience in which it has generally been irrelevant. In practice, the issue is a question of physical form. Steam has a relatively high value, on account of its

27 Or indefinite storage pending an acceptable means of disposal.

embodied energy, compared with water but it can only be transported in pipes and will not travel as far economically. For example, steam supplied by Asnaes to Novozymes is pumped a distance of about 3 km whereas water from Lake Tisso is piped economically approximately 15 km. Sludge arising from fermentation at Novo Industri (as it was in 1976) would have contained at least 80% water so the nutritional value of the biomass it contains as a soil enhancer (the part that is useful) is substantially diluted. Were it to be used at a single location, it might have been transported economically over a long distance via a pipeline. Since it is supplied to hundreds of farms, it can only be distributed by tanker which is a relatively expensive form of transport so geographic proximity has a major bearing on the economics of the system. In contrast, fly-ash and gypsum are both in solid form with relatively low moisture content (ambient or less) so the part that is useful is highly concentrated in each case and can therefore be transported economically over long distances by road or sea. There is a type of use, exemplified by the fish farm (project 6), which is wholly dependent on (very) close geographic proximity and is, at least notionally, the purest manifestation of symbiosis. The fish farm uses only part of the waste heat contained in the cooling water flowing back to the fjord from Asnaes power station. It diverts what it requires from the main channel so it must be located very close to the channel in order to do so. Unlike other projects at Kalundborg, the fish farm and the rain water run-off collection basin (project 18) had to be located on Asnaes' site, or very close to it, in order to be viable. It is noted that in neither case did the use make a significant difference to the manner in which the waste was disposed. That is to say, had the fish farm not existed, the heat it uses would simply have been dissipated in the fjord as happens anyway and had the basin not been constructed, the rainwater it captures would have continued to run off site, as it did previously.

From a theoretical perspective, resolving the issue of geographic proximity legitimises the view that industrial symbiosis is not limited spatially, as it is generally portrayed to be in the literature. A paper by Laybourn and Lombardi (forthcoming) based on their work with NISP in the UK similarly refutes the constraints of geographic proximity. In such circumstances, the environmental impacts of transportation need to be taken into account, and the transport of waste needs to be made as environmentally sustainable as possible. From a practical perspective, it is evident from this research that bilateral symbiosis is potentially viable in circumstances where manufacturers are not contiguous, where they are dispersed and isolated, such as in NSW (Rutherford 1966; Cardew 1982; Fagan in Connell 2000).

8.7 Findings in relation to theory

Industrial symbiosis is widely seen as a model for industry, principally manufacturing and utilities, to share resources and reduce disposal of waste to the environment. The model was derived from what was interpreted as a network of relationships at Kalundborg, and in a sense verified by similar arrangements 'discovered' in other part of the world (e.g. Desrochers 2002; Posch 2010). As a result of this research, I believe that conceptualising industrial symbiosis as a network characterised by close geographical and mental proximity, which facilitates simultaneously exchanges of ideas, knowledge and information, sharing resources and minimising the disposal of waste, is based on an inaccurate understanding of the Kalundborg situation and restricts the usefulness of the concept. The requirements for geographic and 'mental' proximity are cases in point. Geographic proximity is necessary for the reticulation of energy in the form of steam but it is not necessary when energy is reticulated in the form of electricity, as might be generated from methane produced in a biological reactor. Similarly, neither geographic nor mental proximity (Subsection 8.7.2) are necessary when trading products such as the fly-ash Asnaes power station at Kalundborg sends to Aalborg or the trout sent to France from the fish farm on the Asnaes site. I have found it useful to distinguish between two dimensions of industrial symbiosis: one is the social dimension which relates to sharing information and ideas; the other is a physical dimension, which relates to sharing resources and using waste. This research is situated in the physical dimension and concentrates on the issue of waste arising from existing manufacturers in geographic situations that do not resemble conventional notions of a proximate network. In this context, bilateral symbiosis has been proposed as a business strategy, essentially for managing waste. While attributes in the social dimension of a conventional network such as trust (Subsection 2.5.7) are suggested by some authors to be prerequisites for effective industrial symbiosis (e.g. Gibbs & Deutz 2007), the view developed in this research, discussed in Subsection 8.7.3, is that normal business practices can be substituted for them in bilateral symbiosis. However, it is suggested that some benefits in the social dimension, such as the dissemination of knowledge and elevating general awareness of environmental issues associated with waste, can be achieved by the model of bilateral symbiosis. The choice of analytical scale has emerged as critical for understanding the factors which influence bilateral symbiosis. It is particularly relevant to choosing the unit of study, discussed in Subsection 8.7.4 and in relation to understanding what actually constitutes waste, discussed in Subsection 8.7.5.

8.7.1 Bilateral symbiosis as an option for managing waste

Treating bilateral symbiosis specifically as an option for dealing with waste provides a basis for reconciling differences between the results of this research and the literature. Significant academic work has been done on ways to identify opportunities for establishing industrial symbiosis (e.g. Chertow 2007). The various approaches appear to be based on physical and technological attributes, informed primarily by the experiences at Kalundborg. An 'anchor' business that forms the 'heart' of the symbiosis is typically thought to be necessary, as are geographic and mental proximity between participants, collaboration between dissimilar industries and a network of relationships. Attempts to proliferate industrial symbiosis have concentrated on discovering locations where some rudimentary elements of industrial symbiosis exist that might be developed into a fully functioning eco-industrial system. My contention is that in the context of bilateral symbiosis as a strategy for managing waste, none of these attributes is a necessary precondition for a successful transaction. At least 11 of the 30 transactions at Kalundborg (Appendix 12) did not depend on these physical or technological attributes. None of Qubator's projects were dependent on these attributes. Results of this research indicate that suitable conditions for bilateral symbiosis are determined primarily by government legislation, particularly the imposition of levies or similar economic incentives to avoid dumping waste. Without creating a 'negative' value for waste, which government legislation does, or a surrogate for it, which only the government could provide, the prospect of systematic bilateral symbiosis becoming a reality in practice is, I believe, vanishingly remote.

8.7.2 The issue of mental proximity

The attributes of close mental distance between participants at Kalundborg (Section 7.2) and concomitant embeddedness of factors such as trust and risk have been discussed by some authors (e.g. Gibbs 2003; Boons & Howard-Grenville 2009). The consensus seems to be that knowledge among managers of each others' operations is an important, if not an essential feature of industrial symbiosis and that personal trust between individual actors is a necessary precondition for establishing relationships between organisations (e.g. Gibbs et al. 2005). I suggest it would be useful to examine the significance of close mental proximity separately from that of trust. Each may be thought of as exerting a different type of influence, neither of which, however, appears to be essential in practice for bilateral symbiosis. Evidence supporting this view is provided by Kincaid and NISP, acting as facilitators in a similar way to Qubator's operations. In all three examples, relationships are instigated between principals and may be consummated without their managers having any mental proximity at all. At interview, C1 mentioned there was a pre-existing commercial relationship between his company and the user of their waste but his account of their negotiations indicated that close mental proximity was not a feature of their relationship. It is apparent that close mental proximity may have helped facilitate the process of symbiosis in Kalundborg, however, according to K1 and K2, during the period of approximately 28 years between the first project in 1961 and the high school project in 1989, which revealed an apparent network, none of the managers knew that any other project but their own had been established. Although K1 mentioned that by the early 1980s, a few people 'suspected something was happening', this finding suggests that arrangements can be made without the need for close mental proximity. It may increase the likelihood of symbiosis occurring, particularly in the context of an eco-industrial system, but its absence from potential relationships should not, I believe, be regarded as negating the feasibility of developing some form of industrial symbiosis. It is argued that a competent third party, acting as an intermediary between a generator and a user, can substitute for close mental proximity in practice.

8.7.3 The issues of trust and risk

Fieldwork yielded scant evidence of the influence that trust has on the formation and maintenance of symbiotic relationships, in the way it has been described in the literature (Subsection 2.5.7). However, several interviewees raised the issue of risk, albeit from different points of view. In relation to processing waste for ultimate use, C3 mentioned serious concerns his organisation has about the commercial viability of a third party, on which they depend totally for disposal of their waste. If that processor fails, C3 indicated their options are uncomfortably limited and very unattractive. From the perspective of a waste management contractor, N3 discussed the propensity of customers to devolve the risks of waste disposal onto the contractor. When processes needed to be developed to make waste fit for purpose, customers were not willing to accept any 'entrepreneurial' risk at all, even though it was their waste being dealt with. This emphasis on risk rather than trust is not surprising, given that all the interviewees were managers of business operations in which risk is the dominant issue; it is a part of business where miscalculation may well lose money. The perception of risk may be mitigated by a sense of trust between individual managers but contracts between corporations are the governing factors and they are drafted specifically to obviate reliance on trust. References to risk prompted the idea that analysing the two issues from different perspectives, as separate phenomena, might explain why relationships can develop in practice without the semblance of trust that is recorded in the literature as being necessary for their existence. It is apposite to consider also in this context the distinction I have suggested between physical and social symbiosis (Subsection 8.6.1).

It emphasises the differences between a corporate perspective and that of an individual; some of which are summarised in Table 8.1, as an example of the approach. As with the issue of close mental proximity (Subsection 8.7.2), I contend that understanding the details discussed here with regard to using waste may encourage, rather than deter, attempts to develop symbiosis in circumstances which might otherwise have been neglected.

Table 8.1 – Characteristics of physical and social symbiosis

	Perspective	Attributes	Features
Physical symbiosis	Corporate	Perception of risk	Strategies
		Formality	Contracts
		Concept of core business	Policies
			Procedures
			Outsourcing
Social symbiosis	Individual	Perception of trust	Networks
		Informality	
		Emotions	
		Irrationality	

8.7.4 Scale in relation to unit of study

The issue of scale is relevant to analysing other aspects of industrial symbiosis; specifically selecting an appropriate unit of study, which I see as crucial to understanding the process of bilateral symbiosis. Conceptualising the corporation as place (after McDowell 2001), studies of eco-industrial systems reported in the literature (Subsection 2.4.2 *et seq.*) are analysed at the spatial level of the organisation or higher. However, as O'Neill (1999) and Andrews (2001) point out, organisations are made up of people who may act differently, as individuals, to the way the organisation acts, or purports to act, as a whole. This observation is at the core of the postmodernist debate about corporate moral responsibility (e.g. Wilmot 2001), which revolves around the extent to which an organisation, viewed as a diversity of associations between individuals, is held to be a single entity. McDowell (2001) discusses much the same issue from the perspective of spatial scales at the various levels of corporation, networks and body[28] but in the context of social relations. She also invokes postmodernism as the basis for thinking in terms of ever changing, rather than static, phenomena. With

28 In this context I understand her reference to 'body' means an individual, in relation to a corporate entity, as well as the embodiment of various emotions and behaviour etc.

regard to orienting the survey towards the individual, of the 32 questions posed in the questionnaire, one canvassed corporate policy and six canvassed the status of waste disposal from a corporate standpoint. The other 25 canvassed responses specifically from the viewpoint of a senior operations manager or a plant manager. This focus on senior management was prompted by the observation that decisions relating to trials in Phase 1 were all made by individual managers, not by the corporation. My business experience accords with what O'Neill (1999) found: that individual managers are key decision-makers, as particularly emphasised on occasions when bilateral symbiosis was proven to be commercially viable but the projects did not proceed due to the whim of a senior manager. The focus is enhanced by reference to individual conduct in interviews with N2 and N3, for example (Subsection 6.3.1) and by the observation that the efforts of C1 and C2, acting as individuals on their own initiative to establish bilateral symbiosis, were not pursuant to carrying out instructions or company policy. The nature and significance of their actions would likely not have been detected by analysis at the corporate level, although the results of their efforts might have been recorded. The proposition is that individual human actors have an informal but nevertheless determining influence on the process and results of bilateral symbiosis. The argument is that studying such events at the level of individual human actors yields information about bilateral symbiosis that would likely be more accurate in theory and more useful in practice than would be derived from observations at a corporate or higher level. A similar case can be made in relations to selecting an appropriate temporal scale. As demonstrated by deconstructing the arrangements at Kalundborg (Section 7.2), a fundamentally different understanding emerges of what constitutes industrial symbiosis than is suggested, for example, by Desrochers (2002), Altman and van Berkel (2004) and Chertow (2008). These accounts do not give an accurate temporal analysis of how relationships evolved at Kalundborg and perhaps as a result, the role of bilateral symbiosis as the mechanism of development has not been advocated as a viable means of expanding its deployment in practice.

8.7.5 Scale in relation to waste

The question of what constitutes waste is addressed in Section 1.7 but there remains to be discussed the significance of scale in the context of waste and the concomitant concept of a 'market' as representing a means of disposal. As with an appropriate unit of study, the scale on which waste itself is viewed is, I believe, critical to understanding, theoretically, the mechanisms of bilateral symbiosis as well as its practice. The point is illustrated by the deconstruction of Kalundborg which, as previously noted, reveals that 14 of the 30 transactions involve products or services rather than waste and all were achieved through bilateral negotiations, as distinct from the network approach implied by typical portrayals of the system.

This research has brought to light what may be viewed as a weakness in the market approach to dealing with waste in Australia. An example of the situation is provided by the legislation in NSW, which does not recognise the distinction between large scale, homogenous, widely distributed 'standard' recyclables for which there is assumed to be a general market and small scale, point-source waste for which there may only be one or at best a few, possibly remote users. In general terms, the concept of a 'market' is understood, in this context, to constitute a number of willing sellers in contact with a sufficient number of willing buyers to create a demand, brought about by the scarcity of goods and services, for which payment is made accordingly to the supplier. It might be thought that such conditions exist with respect to standard recyclables such as glass, paper, some forms of timber and increasingly in NSW, organic waste for composting. However, from the generator's point of view, the concept is distorted in practice. A supplier, i.e. the generator of waste, invariably pays the notional 'buyer' i.e. a user or processor, to accept the waste. Although the waste may subsequently be processed and may pass through an established trading system in which the processor becomes a seller in the conventional sense, the original demand is created by the generators, in so much as they must dispose of waste and doing so for use is cheaper than dumping it. In a practical sense, the market may be 'contrived' by regulation, which might require certain materials to be collected or prevent them from being sent to landfill. Glass is a case in point. Stock piles arise from time to time because there is insufficient demand to match supply.[29] Some point-source wastes such as molasses and brewers grain have attained the status of byproducts which are sold directly to a sufficient number of buyers to constitute a genuine market demand in the accepted sense of the phrase. Other point-sources of manufacturing waste do not fit the rubric of a market, whether genuine or contrived. There may only be one manufacturer in the state and literally one or maybe two willing users in the country.[30] Although individual sites may produce small quantities of waste compared with standard recyclables, a large number of such sites, for example those in NSW, can produce comparable amounts of heterogeneous waste, which is potentially more harmful to the environment. A corollary in practice is that the more limited the options for use, the more difficult it will likely be to establish bilateral symbiosis.

29 See for example GDH report for the Packaging Stewardship Forum 2008 at: www.afgc.org.au/psf/glass-recovery-a-recycling.html and Clean-up Australia fact sheet at: www.cleanup.org.au/PDF/au/cua_glass_recycling_factsheet_final.pdf.

30 For example, scrap therapeutic confectionary is generated in Sydney by the only manufacturer in Australia. It is supplied to a piggery in western Victoria because it is one of only two within 'economic distance' which has a liquid feeding system and is willing to accept the material. The same situation exists for waste gelatine from the manufacture of pharmaceutical products. Scrap confectionary had also been used to make ethanol but the user ran out of storage space so they could no longer accept it. Expanded perlite is produced in Sydney at the only site in Australia. There is one potential user of their scrap but they refuse to accept it.

From a theoretical perspective, the idea emerges from this discussion that the conventional economic concept of 'demand' is not an accurate surrogate for 'use' in the context of waste. More broadly, the analogy of a 'market' can be misleading, when it is construed conventionally as a (notional) forum in which the value of transactions between (adequately informed) buyers and sellers is governed by the scarcity of products or services traded. It is evident from the findings of this study that transactions involving industrial waste are not likely to resemble those in a conventional market. Generators of waste almost invariably have to pay to dispose of it, yet they are analogous to suppliers who, in a conventional market, are invariably paid to provide goods or services. Conversely, the users or intermediate processors of waste are typically paid for receiving it, notwithstanding they are analogous to buyers in a conventional market, who always pay. It is also suggested that neither the generator nor the user is likely to be adequately informed about all the potential options to dispose of a particular waste. Another deficiency of the conventional analogy is that it does not enable a distinction to be made easily, should it be useful, between a generator of waste and intermediate processors who might be required to make it fit for purpose before end use. In light of these observations, I suggest that the notion of a 'transaction system' involving possessors, as well as generators and end users, would be a sound basis for theoretical analysis and empirical studies in practice.

A notional framework for such a system would comprise a series of intermediary processors ($IP_{1...n}$) between a generator of waste and a user. IP_1 accepts the original waste from the generator and produces from it a usable fraction and a subsidiary waste fraction. The usable fraction is supplied to a user; the subsidiary waste fraction is supplied to IP_2 for further processing. The routine is repeated by IP_2 and so on until all the original waste is used except for a residual fraction for which there is no known or feasible use. From an analytical standpoint, I contend that any set of arrangements for the disposal of waste could be contrived or understood with reference to such a system, for which there is no theoretical limit to the value of 'n'. In practice, the number of intermediate processors would depend on the type of waste involved and would certainly be limited by economic constraints. For example, preparing scrap timber for use as mulch for landscaping or as furnish in the manufacture of particle board may only require one intermediate processor. In contrast, dealing with electrical and electronic waste (known as 'e-waste' in Australia) involves various consecutive stages of materials reclamation. They are typically carried out at different sites, by more than one organisation, and include collection, sorting, consolidation, separation, stripping, shredding, granulation, leaching and smelting, each of which requires a particular process. I suggest that using the framework outlined here to analyse the treatment of e-waste would be significantly more informative than applying conventional concepts of industrial symbiosis.

The last point in this subsection about scale relates to the assumption, derived from the experiences at Kalundborg, that organisations must be dissimilar for industrial symbiosis to be successful as a waste disposal strategy (e.g. Chertow 2007). The same issue is reflected in Gibbs' discussion of technical barriers to symbiosis (2003) among which he cites the lack of fit between local potential participants.[31] The conventional reasoning underling this assumption is that two organisations in the same or similar industries will generate such similar waste that they could not use each other's output. The reasoning seems logical on the scale of an industry; however, the assumption would likely obscure opportunities that might be viable, if viewed at a finer scale of the actual waste itself. The general proposition can be illustrated by a scenario in which several generators may consolidate similar waste streams in order to make it more attractive to a large user that would not consider small or fragmented supplies. Similarly, two or more sites might each generate the same waste in quantities that, individually, are uneconomic to process for ultimate use by others, if not re-use by the generators. However, consolidating the output might create an economically viable quantity for processing, perhaps by one of the original generators, on site, or by an independent processor. It might be argued that participants in the same market would not collaborate in this way for fear of eroding their competitive advantage. The counterpoint is that disposing of waste is generally not regarded as affecting market competition, although it may well affect profitability, so any opportunity to reduce operating costs will likely be considered favourably, even if it means collaborating with a competitor. The frame and truss industry on the Central Coast of NSW[32] is a practical example of such a scenario. At least six manufacturers each dump timber off-cuts which are long enough to be finger-jointed[33] but none can justify purchasing the equipment required for their own use. Were these waste streams to be combined and processed 'communally', products could have been created as substitute for those made from new timber. Another example of the scenario relates to scrap yeast 'walls', arising as sludge that used to be dumped to sewer from a site in Sydney. It is now processed on that site to produce a product for animal nutrition and the demand is such that the same waste from its competitor in Melbourne could also be used. There may be many variations of

31 It is noted that 'fit' is an intrinsic part of the selection process for bilateral symbiosis, which can potentially be viable over long distances, thereby overcoming this barrier.

32 The Central Coast area is approximately equidistant between Sydney and Newcastle (Figure 1.1, Chapter 1).

33 A process in which interlocking 'V' shaped slots are cut into the ends of the off-cuts (across the grain), which are glued together, end to end, to form a continuous length.

the scenario but the essential point is that the choice of scale should not inadvertently obliterate the potential for bilateral symbiosis or viable opportunities in practice.

8.8 Industrial ecology, symbioses and sustainability

During the 45 years of my working life before I started this project, at least 20 of which were spent collaborating with senior manufacturing managers in running a business practising bilateral symbiosis, I had not once heard of industrial ecology and had no understanding at all of what sustainability meant, in an industrial sense. Thankfully, a little of that ignorance has been dispelled, though it took years of pondering to form even a rudimentary understanding of what industrial ecology actually is. It seems there are almost as many opinions on the topic as there are commentators,[1] however, one characteristic is clear and constant – its ambit is continually changing. Socolow et al. (1994) edited a compendium of papers delivered in 1992 at a workshop held at Snowmass, Colorado, USA, organised by the Global Change Institute. The book covers six main topics, including issues such as definitions, toxicity of the environment, vulnerability, industrial ecology in corporations and tools for analysis, principally life cycle assessment. In 2011, the 6th Conference of the International Society for Industrial Ecology included papers on buildings and infrastructure systems, transportation and logistics, food and agriculture systems, sustainable cities and urban metabolism in addition to the 'traditional' topics such as lifecycle methodology and material flow analysis.[2]

So it is with industrial symbiosis, itself a small part of industrial ecology that is changing commensurately and seemingly in ways which enhance its influence on reducing harm to the environment. As discussed in Subsection 2.5.4, the phrase was originally used as a simile, a name for the industrial ecosystem that had been discovered at Kalundborg and is still used that way among the serving and retired managers in Kalundborg. It was construed by academics in the 1990s as a metaphor albeit conceptually identical to that for industrial ecology, in respect to how a biota functions. In accordance with a perception of (biological) symbiosis, 'conventional industrial symbiosis' recognised notional constraints such as dissimilar organisations, independent ownership and geographic proximity. When academic interest expanded beyond the techno-structural realm in the early 2000s (Subsection 2.4.3), further 'constraining' issues were introduced to the general debate, including close mental proximity, trust and risk.

1 My view is that industrial ecology is the study of human relationships with the environment, analysed from the perspective of industry.

2 ISIE 2011 Programme, Clark Kerr Campus, University of California, Berkeley, 7–10 June 2011.

This research challenges some of these basic precepts, particularly as they relate to using waste. The deconstruction of Kalundborg demonstrated that bilateral symbiosis was the only mechanism by which the situation evolved and thereby negates the perceived necessity for a network; a notion that is totally at odds with my business experience. Similarly, deconstruction shows that close geographic proximity is by no means a prerequisite for using all waste, though it may certainly apply to some low-value, large bulk-volume waste streams. Findings from the fieldwork are that close mental proximity is also not necessary and that concepts of trust and risk can be accommodated by normal commercial practices. It has even been shown that the conventional notion that organisations must be dissimilar in order to use waste is not necessarily the case. Contemplating the significance of these and other findings led to the concepts of physical (bilateral) symbiosis and social (network) symbiosis. Physical symbiosis is associated with the transfer of waste, water, energy and the like, which essentially is achieved by way of transactions between organisations. Social symbiosis is associated with networks of cooperative relationships between people, acting essentially as individuals, who exchange ideas, knowledge, advice and the like in order to further their efforts to improve the environmental performance of the organisations they represent.

Much of the discussion during the 8th Industrial Symbiosis Research Symposium[3] was about the definition of industrial symbiosis and what it includes. Aside from bilateral symbiosis[4] and social symbiosis, another variant, internal symbiosis, was suggested to recognise that ownership is actually irrelevant to using waste. In the context of conventional industrial symbiosis, circumstances of a single site or common ownership of several sites are each seen as analogous to a single organism in biological symbiosis, which by definition cannot have a symbiotic relationship with itself. However, in regard to using waste, either circumstance may potentially be an opportunity for bilateral symbiosis, particularly multiple sites under the same ownership that might generate waste which could be used between them.[5] Such a scenario is, in effect, identical to the conventional concept but is excluded from it, merely as a consequence of conforming to a metaphor.

3 Held in San Francisco, California USA on 5–6 June 2011.

4 Which is gaining some 'mainstream' recognition since I talked about the idea at the 6th ISRS in Kalundborg in 2009.

5 Qubator investigated exactly this scenario with Mars in Australia. The group owned a factory that generated effluent from processing food for humans, which was treated in a series of biological reaction ponds. In some of these, fish were grown that could be used in a pet food factory, also owned by the group. The project was technically feasible but required more land than was available so I did not proceed.

What then may be said of the future? Industrial ecology seems to be proliferating in ways that accord with its mantra of multidisciplinary cooperation. More importantly, people outside academia are increasingly taking an interest in the field, most notably among those who influence the formation of policy, which one way or another improves corporate environmental performance. As might be expected after reading the article on tropes by McManus and Gibbs (2008), the conventional metaphor of industrial symbiosis seems to be somewhat strained, to the extent that parts are being reformed, as similes, into a series of concepts relating to particular phenomena, bilateral symbiosis and social symbiosis being among them. It may be argued that, in the long term (of decades), new manufacturing facilities should (must) be organised along the lines of eco-industrial parks that exploit to the maximum extent feasible, these and other relevant concepts of effective arrangements. In the foreseeable future, though, we must contend with current arrangements. Manufacturing waste in NSW arises from widely dispersed, relatively small sites, for which perhaps bilateral symbiosis is potentially the only alternative to landfill and ever increasing costs of disposal. The strategy has been shown to work very effectively in certain circumstances, as summarised in the next chapter. However, current circumstances in NSW and Australia more generally are not conducive to using manufacturing waste in this way and, therefore, do need to be changed (by people) in order to reduce the harm that landfill does to the environment.

Chapter 9
Conclusions

Waste therapeutic confectionary (production scrap at the ethanol plant in Bomaderry, NSW)
Source: Manildra Pty Ltd

Scrap confectionary

In March 1996, I was told that scrap chocolate from Nestlé's factory in Lane Cove, Sydney, was going to landfill so I suggested to senior management on site a proposal to find uses for the scrap. This was an entirely novel idea and in their view, hardly worth pursuing as they believed they were only dumping about 4 tonnes of scrap per month. By the beginning of May 1996, I had arranged to supply the scrap for stock food, mainly cattle and pigs, at various sites between 200 km and 1300 km distant from Sydney. Within four months, 80 tonnes of scrap had been distributed and Qubator continued to distribute 20–50 tonnes a month until the plant closed in June 1998. By then, the plant manager at Lane Cove had been transferred to Nestlé's factory at Blacktown, also in Sydney, where therapeutic confectionery is manufactured. Scrap arising at this factory was also being sent to landfill but the problem of disposal was more complicated than with chocolate. Being therapeutic, the products contained ingredients such as menthol and eucalyptus oil, use of which is regulated by the Therapeutic Drugs Administration (TGA) of the federal government. The TGA also stipulates standards for disposal of scrap, which conventionally could only be met by inordinately expensive means of destruction.

The scrap arises in two forms: production scrap comprises large-lump, unwrapped material from purging pipes, spillage and miss-formulations. Scrap finished product is typically small-lump, wrapped material that has been rejected. In 1998, scrap arose in approximately equal amounts of about 15 tonnes each per month. Trials in stock feed for ruminants, which was the predominant use for the chocolate, indicated that it was not suitable for that purpose, mainly owing to its physical form and apparent unpalatability for cattle. After six months of unsuccessful research on potential uses, I realised that the high carbohydrate content of the scrap, typically about 95% by weight, might be suitable for making ethanol. In September 1998, laboratory trials had been successfully carried out at a plant owned by Manildra Pty Ltd in Bomaderry, about 160 km south of Sydney. However, the scrap could not be used until a new plant, then under construction, had been completed. Negotiations resumed in February 1999 and by September that year, the ethanol plant was receiving all the production scrap from Nestle. Supplies continued uninterrupted until April 2007 when Manildra expanded the plant and in the process, removed equipment necessary for processing the scrap. By this time, trials that I had arranged for using production scrap at a piggery in Victoria, as a back-up alternative to ethanol, proved successful so there was a 'seamless' transition in disposal. In view of the arrangements with Manildra, I looked for other sources of similar scrap and in December 1999, contacted 3M Pharmaceuticals at Thornleigh in Sydney where they packed their own brands of product manufactured for them by Nestlé. After 12 months negotiating arrangements supplies to Manildra began in December 2000 and subsequently to the piggery, which have continued ever since. However, the plant will close in April 2012 when production will go offshore.

There remained the problem of product security associated with wrapped scrap, which, from Nestlé's point of view, had prevented its disposal in the same way as production scrap. On three occasions between 1999 and 2003, Qubator submitted proposals to successive site managers for preparing wrapped scrap in Sydney before transporting it. Each had been rejected for operational reasons and because savings in cost did not compare well with corporate requirement for return on investment. The problem was eventually solved in May 2003 when Qubator began supplying wrapped scrap to a plant at Camellia in Sydney, owned by EarthPower Technologies Sydney Pty Ltd, which two months previously had begun receiving food waste for the production of methane used to generate electricity on site and the production of fertiliser.

9.1 Summary of the research

This project began in August 2005, in effect, as applied research at the interface between theory and practice, which concentrated on the potential of bilateral symbiosis as a viable, systematic option for disposing of manufacturing waste. The review in Section 2.4 shows that the topic has not been examined to any significant extent in the literature, especially not in relation to manufacturing, as structured in a way that is typical in Australia. As described in Chapter 3, Part 1 addressed an initial aim of this research to develop an approach to implementing bilateral symbiosis, at the site level of scale and testing it accordingly. An equally significant, though subsequent, aim was to examine the influence of regulation because views expressed in the literature about what motivates industrial symbiosis seemed to be at odds with those I had formed during 20 years experience actually facilitating bilateral symbiosis for a living.

By the end of 2007 it had become clear that trials intended to further the initial aim were not going to be feasible, at least within the period available for this research. Reasons for abandoning Phase 1 raised fundamental questions about the views of manufacturing managers in NSW. These views were thought to be germane to understanding the potential for bilateral symbiosis and hence became the focus of subsequent fieldwork. So began Phase 2, as described in Chapters 4–6. The aims were to canvass the factors that influence management decisions about disposing of waste and to assess various capabilities with respect to bilateral symbiosis. Pursuing these aims required a different methodology to that used in Phase 1 and has resulted, unexpectedly, in an entirely different story to that envisaged at the outset six years ago. The conclusions formed as a result of this work suggest modifications to the theory on industrial symbiosis that may accelerate the recognition and subsequent realisation of its potential as an effective waste management strategy in practice. The next part of this chapter summarises the principal findings of the research and the conclusions drawn from them relating to the prospects for bilateral symbiosis in NSW. It then suggests how these and other conclusions relate to the theory on industrial symbiosis generally. The final section outlines the limitations of this work and suggests further research.

9.2 Principal findings

The principal findings are that government action and an effective infrastructure are the dominant factors which determine the prospects for establishing systematic bilateral symbiosis. With regard to the influence of government, it was found that whether perceived or actual, environmental regulations stimulated the industrial ecosystem at Kalundborg (Subsection 8.6.2). Regulations prevent the indiscriminate disposal of waste in NSW by restricting what can be done with it and consequently have motivated successful though apparently limited, sporadic bilateral symbiosis in the state. NISP in the UK is successful because it offers relief from the exigencies of environmental legislation. It is wholly dependent on government funding as was the Kincaid project in the USA. The influence of government could not be illustrated more starkly than in Australia where there are eight state and territory jurisdictions, and one federal jurisdiction. Each state and territory is responsible, independently, for protecting the environment within their own boundary. The state of Queensland, which until 1 July 2011 had no levies on landfill, shares a border with NSW which has the highest levies in the country. It was emphasised by interviewee C1 that while bilateral symbiosis has worked well for his company in NSW and would be technically possible elsewhere, it is not economically feasible in Queensland. A similar situation exists in Western Australia where environmental legislation is not conducive to bilateral symbiosis.

The primary 'driver' for bilateral symbiosis created by regulation is the negative value it creates for waste, determined by levies on solid waste sent to landfill and liquids dumped to sewer or sent to specialised treatment plants (Subsection 8.3.2). Responses to the questionnaire made it clear that the cost of waste disposal is a major concern for management and all interviewees were unequivocal that financial considerations dominate management decisions. The overt intention of the regulator is to make the cost of disposal so high that generators will be powerfully motivated to find alternative uses. A doubling in landfill levies by 2015 has been legislated in NSW specifically to achieve this objective. This strategy is based on the assumption that manufacturers are actually capable of finding uses for the waste they generate. However, findings of this research indicate that many will not be capable of doing so, even if they were willing to try.

Attempting to divert waste from landfill is only part of the regulator's function in protecting the environment. It also regulates the handling, transport and treatment of waste generally. The legislation has been drafted according to the principle of command and control, which allows the regulator minimal flexibility in carrying out its responsibilities. It is apparent also that the legislation was not designed to achieve the objectives of using waste. In practice, some of the regulations derived from the legislation have the effect of actually inhibiting bilateral symbiosis. In an attempt to overcome some of these difficulties, the protocol for resource recovery exemption was introduced, specifically in relation to applying waste to the land (for beneficiation) or to incinerating it. However, even the protocol has its limitations. For example, it does not distinguish incineration, the burning of waste indiscriminately comingled, from engineered fuels, which are designed for defined purposes by combining segregated waste streams according to predetermined specifications.

Aside from the issue of inimical legislation, the motives of government policy in NSW are profoundly conflicted, which is seen to detract from its capacity in general to facilitate the use of waste and to adversely affect the potential for systematic bilateral symbiosis, in particular. Ostensibly, landfill levies are a strategy to protect the environment by inducing generators to avoid (legal) dumping. However, the government has a vested interest in waste going to landfill since the levies go into consolidated revenue, for general purposes. There is evidence that the levies are seen by people in manufacturing and in the waste management industry as nothing more than a strategy to raise revenue. The perception of an ulterior motive is reinforced by the fact that the government does not hypothecate funds to help facilitate bilateral symbiosis, as NISP is funded in the UK for example, or provide funds for projects more broadly that make use of waste.

A critical concept exemplified by NISP is that of an external infrastructure which can facilitate arrangements between individual generators and users of waste. Findings of this research lead to the conclusion that without competent intermediation, the likelihood of achieving systematic bilateral symbiosis on a national or even a statewide scale is vanishingly remote (as the Kincaid project demonstrated). It was thought originally that ad hoc autogenous bilateral symbiosis might potentially become sufficiently widespread to constitute a systematic, sustainable way of using waste. The conclusion is that this approach is not viable in the current or foreseeable circumstances. Although the results of Phase 1 were inconclusive, they did indicate that some of the largest organisations in NSW are disinclined to instigate bilateral symbiosis themselves. Responses to the questionnaire were interpreted as tending to corroborate this position. As outlined in Section 7.3, autogenous bilateral symbiosis requires the existence of an internal infrastructure. Results suggested that its features are not commonly present in manufacturing organisations, particularly an effective project champion, which the findings (Subsections 2.5.9 and 7.3.3) indicate is crucial, in one form or another, to the success of any initiative, as indeed C1 and C2 were for their projects.

What then of the prospects for an external infrastructure? Responses to the questionnaire indicated that managers would seek assistance from various types of organisation to help them establish bilateral symbiosis. Canvassing a selection of organisations from each type revealed that none was capable of providing the necessary services. The conclusions are that:

- No suitable external infrastructure currently (2011) exists in Australia
- The likelihood of suitable external infrastructure being established in NSW by 2015 is vanishingly remote

- Without that infrastructure, organisations unable or unwilling to establish autogenous bilateral symbiosis will have to continue dumping waste or consider options to cease manufacturing in NSW.

Although financial issues were not originally a focal topic of this research, results of the fieldwork have led to the finding that money dominates almost every aspect of bilateral symbiosis (e.g. Subsection 8.3.2). Financial considerations outweigh environmental consideration for all actors in the private sector canvassed by questionnaire or by interview. The issue of money is a dominant consideration also for the regulator in its role of protecting the environment.[6] There seem to be few references recorded in the literature (Sections 2.4 and 2.5) that relate directly to these issues but those that do (e.g. with regard to Kalundborg), tend to support the general conclusion drawn from this work that in a market economy such as exists in Australia, where profitability is the dominant measure of corporate success, bilateral symbiosis will very likely not succeed unless it can be justified financially, notwithstanding the influence that might be exerted by non-financial considerations such as reputation and issues associated with corporate social responsibility.

9.3 Contribution to theory

9.3.1 Types of symbiosis

A distinction has been made in this thesis between bilateral symbiosis and social symbiosis. Recapping previous comments, the conventional perspective of industrial symbiosis, it conflates the notion of using waste and/or sharing resources with the notion of a network of relationships and holds that the former notion is in some way contingent on the latter (Section 2.4). Findings of this research demonstrate that a contingent relationship need not exist and that the two notions are amenable to analysis as independent, though possibly, related phenomena. I contend that circumstances in practice can be represented accurately by considering the two notions separately and that doing so yields a more refined and versatile understanding of the phenomena than might be derived from the conventional perspective. Bilateral symbiosis deals with the physical transfers that take place between organisations, for the purpose of using waste. Transfers are characterised by features such as formality, the exigencies of complying with environmental regulations, financial considerations, unidirectional flows and the existence of contracts or similar agreements. The concept of social symbiosis relates to networks of relationships formed between people, as

6 Even the regulator is affected by financial issues is so far as they restrict resources available for carrying out its functions.

independent individuals, employed by corporations pursuing issues that might be mutually beneficial in relation to the environment or sustainable development more generally. Social symbiosis is characterised by features such as informality, reciprocity, sharing information or knowledge and emotional factors like trust or respect. As a result of making this distinction, it has been possible to explain theoretically why and how bilateral symbiosis can be an effective strategy beyond the constraints of geographic proximity that characterise the conventional view of industrial symbiosis. It also helps to explain the sort of phenomenon that has been observed in NISP (UK) whereby individuals attend multiple workshops run by the program, even though the organisations they represent have never instigated bilateral symbiosis.[7]

9.3.2 Identifying opportunities

Industrial symbiosis became a focus of academic interest in the early 1990s, after the Danish national press published articles in 1989 about the situation at Kalundborg, where the term originated as a simile, a name for the collection of arrangements that had evolved there since 1961. Researchers seem to have concentrated their attetion since then on studies of simular situations in other parts of the world such as in the Austrian province of Styria (Schwartz & Steininger 1997), at Kwinana in Western Australia (Van Berkle 2005) and Rotterdam Harbour in the Netherlands (Baas 2008). The approach generally seems to have been either to conduct case studies for their own sake or to establish characteristics that could help identify opportunities in hitherto undiscovered locations. In so far as predictive results have been achieved at all, by researchers such as Chertow (2007), they have tended to focus on physical indicators associated with conventional industrial symbiosis like geographic proximity, embryonic networks and technological compatibility. The findings of this research are that in relation to (systematic) bilateral symbiosis the principal factors which determine whether or not it will occur are conducible government regulations and the existence of a competent means to facilitate it, such as an external infrastructure. Unless these two factors exist, other factors such as structural relationships between participants and technological compatibility are seen to be immaterial.[8] It is suggested that research on opportunities in the context of sustainable development should include examination of these factors, particularly when bilateral symbiosis is contemplated.

7 Personal communication with Dr Rachel Lombardi, a representative of NISP at the 6th Conference of the International Society for Industrial Ecology, Berkeley, USA, June 2011.

8 It is noted, however, that technological issues may become material, if it is otherwise feasible to arrange bilateral symbiosis.

9.3.3 The significance of scale

Selecting individual managers as the principal unit of study has led to significant findings that would likely not have been revealed in a study at corporate or higher level. It has been found that individual managers, acting at a sub-corporate level,[9] will ultimately decide what is to be done about waste. Instances have been described which illustrate their capacity to exert significant influential in practice and act independently in ways that may not conform to the relevant theory or in accordance with corporate intention. These observations relate to the issue of agency, raised in the context of networks generally (Subsections 2.5.5) and more specifically in the context of this research (Subsection 8.3.4).

As mentioned above, current theory on industrial symbiosis has typically been derived from studies of structural, technological and economic issues. These are characteristic of corporate entities such as a power station, a manufacturer operating within an eco-industrial network or with elements such as reticulation systems. On such a scale, the influence of managers and other employees, is obscured and is therefore not prominent in theory, notwithstanding some articles that examine the issue (Subsection 2.4.4). Based on the findings of this research, it is suggested that studying the role and influence of individual managers, at a sub-corporate level (similar to work by O'Neill 1999 and McDowell 2001), would yield valuable insights about using waste.

An appropriate choice of scale is also crucial to understanding the characteristics of an actual waste stream and the concomitant concept of a market[10] (Subsection 8.7.5). Waste streams such as glass, timber, plastic and fly-ash may be represented as homogeneous when aggregated on a state or national scale but at the scale of an individual user each waste stream is markedly heterogeneous with differentiated uses that are likely mutually exclusive. Aside from issues associated with using multi-sourced, dispersed waste streams such as glass, paper, plastic or timber, results of this study indicate that a user may not necessarily be found for every waste stream generated by manufacturers, which makes the NSW government's strategy on levies particularly problematic from the generator's point of view. In the context of theoretical bilateral symbiosis, it is suggested that a scale be used at which characteristics such as composition, form, microbiological stability and frequency of arising can be analysed.

Conventional industrial symbiosis is usually studied at the geographic scale of an eco-

9 That is, without requiring approval by the board of directors, which would elevate the issue to a corporate level rather than it remaining at a management level.

10 For bilateral symbiosis a market might in practice be a single user or at best a couple.

industrial park or a situation like Kalundborg, although some studies have been done at the level of subnational regions (Subsection 2.4.3). Where boundaries are not defined specifically, for example by ownership of a park or by legislation, they are generally inferred principally from the distances over which it is technically and economically feasible to reticulate fluids or transport large-volume, low-value waste. Social characteristics, such as 'mental distance', trust and various forms of embeddedness, are also generally understood to be functions of geographic scale. From a theoretical perspective, if systematic bilateral symbiosis is to contribute meaningfully to sustainable development, it should be deployed at least statewide and potentially could be extended to a national scale. Extending the geographic scale increases the likelihood of identifying feasible opportunities to link potential users with a generator. Countervailing issues include transport, microbiological stability and trans-jurisdictional issues such as permits but it should not be presumed that bilateral symbiosis is not feasible on a large geographic scale.

9.3.4 Theorising bilateral symbiosis

Deconstructing the evolution of industrial symbiosis at Kalundborg and reconstructing it chronologically, in reference to the subject of each transaction, as shown in Figure 7.2 (Chapter 7), provided sound theoretical grounds for arguing that bilateral symbiosis is the fundamental mechanism by which physical transfers of waste are organised. Deconstruction facilitated the development of a nomenclature that enables unambiguous descriptions of phenomena and revealed that the significance of some features changed, when they were analysed from a temporal perspective. For instance, it is argued that the inter-related topics of mental proximity (Subsection 8.6.1), trust and risk (Subsection 8.7.3) do not have the significance accorded to them in the literature on conventional industrial symbiosis. Close mental proximity (Subsection 2.4.1 *et seq.*) had originally been identified by Christensen and subsequently stated by others as a prerequisite for the symbiosis at Kalundborg. The attribute may have been conducive to establishing arrangements made after 1989, when the symbiosis was revealed, but close mental proximity, at least in relation to the symbiosis, could not have existed before that date because none of the managers knew about the existence of other projects. The experiences of NISP, C1 and C3 indicate that close mental proximity is not necessary to facilitate successful bilateral symbiosis.

Trust seems typically to be theorised in the relevant literature as a peculiar and indispensable attribute of industrial symbiosis (Subsection 2.5.7). While business in general might depend ultimately on various manifestations of trust, such as confidence in a particular trading system or the expectation that contractual obligations will be met, the deconstruction of Kalundborg and the experiences recounted by C1 and C3 suggest that bilateral symbiosis can operate satisfactorily on the basis of a conventional supply arrangement, established by normal techniques of negotiation, agreement and contract, without relying on the attributes of close personal associations. In light of this conclusion, it is suggested that an apparent absence of trust in theory should not be construed necessarily as an inhibition to bilateral symbiosis. Some aspects of risk are intrinsically associated with using waste, as suggested for example by C3 but as with trust, theorisation at an appropriate scale would indicate that managing the risks of bilateral symbiosis is no different to managing the risks of any similar function of supply and demand in manufacturing. The general conclusion drawn from these views about trust is that bilateral symbiosis may be established through normal commercial practices and should therefore not be treated theoretically as having the particular attributes of a unique or even a special process.

9.4 Suggestions for further work

Redirection of this research in 2007 necessarily introduced new topics to the scope of study and concomitant limitations on the extent to which some of them could be addressed, given the resources and time available. Two particularly interesting cases in point are the political dimension and the apparent disjuncture between the values of employees as individuals and corporate behaviour.

The centrality of legislation and some of its principal shortcomings in NSW have been demonstrated. The corollary from a practical standpoint is to study the processes by which environmental policy is established in the various jurisdictions with a view to rectifying deficiencies, introducing flexibility and coordinating regulations between all states and territories. In this context, it is suggested that simultaneous studies of each jurisdiction in Australia, undertaken at discrete intervals of say, five years[11] for a minimum period of three intervals, would make a useful contribution to the theory on policy formation, particularly as it relates to industrial ecology more broadly.

The general topic of corporate behaviour is beyond the scope of this study. However, some findings indicated an apparent disassociation between the views of individuals as private citizens and their actions on behalf of their employer and hence the behaviour of the employer itself. Work has been done by social scientists on some aspects of this issue (Subsection 8.3.4) but there is seemingly very little about the causes of disassociation or when it occurs. The topic of corporate behaviour generally is not well represented in the

11 The life of a state or territory government is between three and four years so intervals of five years would enable the effects of any transition between governments to be recorded.

literature on industrial symbiosis (Andrews 2001). This is possibly because industrial symbiosis and industrial ecology more broadly had been studied, at least until the early 2000s, predominantly by engineers and physical scientists (McManus & Gibbs 2008) and perhaps to a lesser extent by researchers with a strong statistical orientation such as Fischer-Kowalski and Amann (2001) and Lenzen and Murray (2003). Results of this study suggest that further research on the circumstances of disassociation and its ramifications for corporate behaviour in the context of industrial ecology would lead to a better understand of what influences people in a corporate environment to behave in the ways they do and hence help to improve corporate environmental performance. This suggestion implies collaborative research among different disciplines, which is by no means a novel approach. Andrews (2001) canvassed it in relation to corporate behaviour; Tansey (2006) alludes to it in discussing the economic ramifications of industrial ecology; it is implicit in the observations on complexity by Ehrenfeld (2009) and apparently it was practised by Kitzes et al. (2009) in compiling their agenda for national accounts of ecological footprint. Nevertheless, the suggestion is made again here as, in practice, the consequences of disassociation seem to be significant.

A principal finding is the absence of a competent external infrastructure to facilitate the use of waste in the foreseeable future. On the basis that some generators will have very few options to avoid landfill levies, it is suggested that further work be done to test and refine the procedures developed in Phase 1. Autogenous bilateral symbiosis might be a viable strategy for some organisations in Australia or elsewhere, in which case the procedures could be useful.

9.5 Final comments

At the beginning of this thesis I stated a tenet underlying the research that what actually happens in practice is the critical determinant of sustainable development. The phrase 'in practice' recurs time and again throughout the text by way of emphasising this perspective. After all the theorising about the many facets of industrial symbiosis in the context of waste, the guts of the topic is the issue of what – in practice – generators are actually willing and more significantly, are able to do with what they produce. Adequate research, for practical purposes, on the corporate capacity to accomplish bilateral symbiosis, either autogenously or facilitated, does not appear to have been recorded in the relevant literature. Academically, this may seem a small, perhaps inconsequential, deficiency or omission but in the context of achieving sustainable development, I contend that its significance is crucial and must be rectified.

Findings of this study indicate that government regulations motivate corporate action but achieving systematic bilateral symbiosis in NSW will require appropriate infrastructure. As yet, there is none. Despite the urgent necessity for companies to become more sustainable, the likelihood of this requirement being met in the foreseeable future is remote, given that government policy is flawed, that waste management businesses are focused on other objectives and that appropriate consulting services or research facilities do not exist.

This study is situated at the interface between academia and practice. In such a notional place, each direction can be viewed with equanimity and the observations balanced impartially, invaluable faculties of academic research that neither governments nor organisations in the private sector can bring to bear. Yet managers in both those sectors need a clear indication of what will work – something academics are eminently capable of producing. To maintain the existing approach to manufacturing merely passes on the difficulties of attaining sustainability to future generations, whose time to deal with them will be manifestly shorter than ours. Alternatively, we can do something now to bring about change for the better. There can be little doubt in light of this research that bilateral symbiosis is a viable strategy that can contribute significantly to improving sustainability but it or any other strategy that improves corporate environmental performance will have to be supported by appropriate government policies and environmental regulations. Considerable adjustment must be made and there are already some signs of movement in the right direction. Progress will likely be slow and will be difficult to mobilise politically but at least we know *how* to make a difference.[12]

12 Soon after I began research for this project, I mentioned to Andrew Jones, an erstwhile client who runs a very successful agricultural enterprise in Queensland, that I had started a PhD. He said I was mad but exhorted me nonetheless to 'make a difference'! That pretty much sums up all the various reasons for getting this far and with a bit of luck, somewhat further …

Epilogue

At the end of June 2011, EarthPower closed it doors, ostensibly for a couple of weeks while issues of occupational health and safety were addressed. By the middle of September 2011, they were still shut and Nestlé had accumulated approximately 25 tonnes of wrapped scrap, pending their re-opening. Although EarthPower remained closed indefinitely, from Nestlé's point of view the situation had been manageable except for two batches of scrap finished product that they had to dispose of on behalf of a customer. Their options were incineration, at a minimum cost of $2/kg or landfill for a total cost of $0.2/kg. They decided to send the scrap to landfill. It is ironic that this option was offered to Nestlé by Veolia, a company that owns 50% of EarthPower. The cost of landfill was significantly less than the cost of sending scrap to EarthPower, a difference that management at Nestlé could not ignore. Management were also rationalising all their waste disposal contract for the site and so it was that Qubator's longest lasting, continuous relationship of more than 15 years formally came to an end.

On 12 September 2011, I visited the foundry mentioned in the vignette for Chapter 2, now owned by Broens Autocast and Forge. I did not have an image for the vignette and had arranged to photograph the DISA plant. I met the general manager who told me they send their bag-house dust to landfill and asked if I could find a use for it.

Life is endlessly fascinating!

Appendices

Appendix 1: Definitions of waste given in relevant state or territory legislation

Jurisdiction	Reference	Definition of waste
New South Wales	Environmental Guidelines: Assessment, Classification & Management of Liquid and Non-liquid Wastes. Department of Environment and Conservation NSW Government 2007	Waste: As defined in the *Waste Minimisation and Management Act 1995* and the *Protection of the Environment Operations Act 1997*: 'waste includes: (a) any substance (whether solid, liquid or gaseous) that is discharged, emitted or deposited in the environment in such volume, constituency or manner as to cause an alteration in the environment, or (b) any discarded, rejected, unwanted, surplus or abandoned substance, or (c) any otherwise discarded, rejected, unwanted, surplus or abandoned substance intended for sale or for recycling, reprocessing, recovery or purification by a separate operation from that which produced the substance, or (d) any substance prescribed by the regulations to be waste for the purposes of this Act. A substance is not precluded from being waste for the purposes of this Act merely because it can be reprocessed, re-used or recycled.'
Australian Capital Territory	*Waste Minimisation Act 2001*	*Waste* includes the following: (a) any substance (whether solid, liquid or gaseous) that is discharged, emitted or deposited in the environment in such volume, constituency or manner as to cause an alteration in the environment; (b) any discarded, rejected, unwanted, surplus or abandoned substance, whether or not intended for sale, recycling, reprocessing, recovery or purification by a separate operation from that which produced it; (c) any other substance declared by regulation to be waste.

Jurisdiction	Reference	Definition of waste
Victoria	Environment Protection (Industrial Waste Resource) Regulations 2009 S.R. No. 77/2009	For the purposes of the *Environment Protection Act 1970*, these Regulations prescribe industrial waste to be – (a) category A waste; (b) category B waste; (c) category C waste; (d) Schedule 1 industrial waste … described as follows: **Category A waste:** is prescribed industrial waste – (a) that can be classified as dangerous goods under the *Dangerous Goods Act 1985* and falls within one or more of the following classes under that Act – (a) Class 1 (Explosive); Class 4.1 (Flammable solid); Class 4.2 (Spontaneously combustible); Class 4.3 (Dangerous when wet); Class 5.1 (Oxidising); Class 5.2 (Organic Peroxide); Class 6.1 (Toxic); Class 6.2 (Infectious); Class 8 (Corrosive); or (b) that generates gases that can be classified as Class 2.3 (Toxic Gas) dangerous goods under the *Dangerous Goods Act 1985* when it comes into contact with air or water; or (c) with any contaminant concentration greater than the category A contaminant concentrations specified in the Solid Industrial Waste Thresholds, except for prescribed industrial waste that is contaminated soil; or (d) with any leachable concentration greater than the category A leachable concentrations specified in the Solid Industrial Waste Thresholds, except for prescribed industrial waste that is contaminated soil; or (e) that is contaminated soil with – (i) any contaminant concentration greater than the category A contaminant concentrations specified in the Soil Thresholds; or (ii) any leachable concentration greater than the category A leachable concentrations specified in the Soil Thresholds; or category A leachable concentrations; or (c) that the Authority has classified as category B waste in accordance with Part 2. (2) This clause does not apply to prescribed industrial waste that is category A waste under clause 1.

Jurisdiction	Reference	Definition of waste
		(f) that is liquid waste other than (i) trade waste; or (ii) industrial waste water managed in accordance with specifications acceptable to the Authority; or (g) that the Authority has classified as category A waste in accordance with Part 2. Category A waste. **2 Category B waste** (1) Subject to subclause (2), category B waste is prescribed industrial waste (a) with (i) any contaminant concentration greater than the category B contaminant concentrations specified in the Solid Industrial Waste Thresholds, but not exceeding the category A contaminant concentrations, except for prescribed industrial waste that is contaminated soil; or (ii) any leachable concentration greater than the category B leachable concentrations specified in the Solid Industrial Waste Thresholds, but not exceeding the category A leachable concentrations, except for prescribed industrial waste that is contaminated soil; or (b) that is contaminated soil with (i) any contaminant concentration greater than the category B contaminant concentrations specified in the Soil Thresholds, but not exceeding the category A contaminant concentrations; or (ii) any leachable concentration greater than the category B leachable concentrations specified in the Soil Thresholds, but not exceeding the (c) that the Authority has classified as category B waste in accordance with Part 2. (2) This clause does not apply to prescribed industrial waste that is category A waste under clause 1. **3 Category C waste** (1) Subject to subclause (2), category C waste is prescribed industrial waste (a) with (i) any contaminant concentration greater than the category C contaminant concentrations specified in the Solid Industrial Waste Thresholds, but not exceeding the category B contaminant concentrations, except for prescribed industrial waste that is contaminated soil; or

Jurisdiction	Reference	Definition of waste
		(ii) any leachable concentration greater than the category C leachable concentrations specified in the Solid Industrial Waste Thresholds, but not exceeding the category B leachable concentrations, except for prescribed industrial waste that is contaminated soil; or (b) that is contaminated soil with (i) any contaminant concentration greater than the category C contaminant concentrations specified in the Soil Thresholds, but not exceeding the category B contaminant concentrations; or (ii) any leachable concentration greater than the category C leachable concentrations specified in the Soil Thresholds, but not exceeding the category B leachable concentrations; or (c) that is waste asbestos that is packaged in accordance with Asbestos – Transport and Disposal; or (d) that the Authority has classified as category C waste in accordance with Part 2. This clause does not apply to prescribed industrial waste that is category A waste under clause 1 or category B waste under clause 2. Schedule 1 – Industrial Wastes Biosolids managed in accordance with specifications acceptable to the Authority; Bitumen or asphalt; Brick; Cardboard; Commercial food waste; Concrete; Formed metal components; Glass; Green waste; Industrial waste water managed in accordance with specifications acceptable to the Authority; Paper; Plastic; Textiles; Timber
Tasmania	*The Environmental Management and Pollution Control Act 1994* (Latest amendment 7/2008)	**'waste'** means any – **(a)** discarded, rejected, unwanted, surplus or abandoned matter, whether of any value or not; or **(b)** discarded, rejected, unwanted, surplus or abandoned matter, whether of any value or not, intended **(i)** for recycling, reprocessing, recovery, reuse or purification by a separate operation from that which produced the matter; or **(ii)** for sale.

Jurisdiction	Reference	Definition of waste
South Australia	*Environment Protection Act 1993* (Version: 1.2.2010)	***waste*** means – (a) any discarded, rejected, abandoned, unwanted or surplus matter, whether or not intended for sale or for recycling, reprocessing, recovery or purification by a separate operation from that which produced the matter; or (b) anything declared by regulation (after consultation under section 5A) or by an environment protection policy to be waste, whether of value or not.
Western Australia	*Waste Avoidance and Resource Recovery Act 2007*	Cl 3.1… ***local government waste*** means – (a) waste from residential sources; and (b) any other waste of a kind prescribed by the regulations for the purposes of this paragraph, but does not include sewage or waste of a kind prescribed by the regulations as excluded for the purposes of this definition.
Northern Territory	*Waste Management and Pollution Control Act* (In force 18 March 2009)	***waste*** means: (a) a solid, a liquid or a gas; or (b) a mixture of such substances that is or are left over, surplus or an unwanted by-product from any activity (whether or not the substance is of value) and includes a prescribed substance or class of substances.
Queensland	*Environmental Protection Act 1994* (As in force 10 June 2011)	(1) *Waste* includes any thing, other than a resource approved under subsection (4), that is (a) left over, or an unwanted by-product, from an industrial, commercial, domestic or other activity; or (b) surplus to the industrial, commercial, domestic or other activity generating the waste. *Example of paragraph (a)* – abandoned or discarded material from an activity is left over, or an unwanted by-product, from the activity. (2) *Waste* can be a gas, liquid, solid or energy, or a combination of any of them. (3) A thing can be waste whether or not it is of value. (4) The administering authority may approve a resource, or a stated type of resource, for subsection (1) if it considers the resource, or type of resource, has a beneficial use other than disposal. *Example of beneficial use for subsection (4)* – re-using or recycling a resource

Appendix 2: Various definitions of waste that illustrate diversity of meanings and purposes

Perspective	Reference	Definition/comment
Public health policy	Aaron 2008	What, exactly, is wasteful health care spending? Everyone would agree that a costly intervention that is always useless or that harms patients is wasteful. Even care that is expected to help but turns out to be ineffective may be judged to be wasteful – but only in the trivial sense that fire insurance on a house that never burns down is ex post facto wasteful, when one disregards the peace of mind fostered by protection against risk. To be meaningful, however, a definition of waste must rest on an ex ante perspective: What is the expected value of outcomes for definable classes of patients?
Public health policy	Fuchs 2009	Medical waste is defined as any intervention that has no possible benefit for the patient or in which the potential risk to the patient is greater than potential benefit. Economic waste is defined as any intervention for which the value of expected benefit is less than expected costs.
Economic	Martin & Towill 2000	Lead-time needs to be minimised in lean manufacturing as by definition, excess time is waste and leanness calls for the elimination of all waste.
Economic	Hicks et al. 2004	In lean manufacturing, waste may be considered to be any activity which consumes resources or creates cost without producing any form of offsetting value stream. Ohno (1988), the founder of the Toyota Production System, described seven general types of waste: 1. Making too many items or making items too early causes the waste of overproduction. This situation leads to excessive lead-times and storage times with increased inventory; 2. Any time that materials or components are not having value added to them is described as the waste of waiting; 3. The movement of materials within the factory adds cost but not value. This is known as the waste of transportation; 4. The use of a large expensive machine instead of several small ones leads to pressure to run the machine as much as possible rather than only when needed. This is known as the waste of inappropriate processing, which may lead to poor layout, extra transportation and poor communication;

Perspective	Reference	Definition/comment
Economic	Hicks et al. 2004	5. Inventory tends to increase lead-times, reduces flexibility and prevents the rapid identification of problems. This is described as the waste of unnecessary inventory; 6. The waste of unnecessary motions relates to ergonomics. If operators have to bend and stretch it may lead to quality and productivity problems; 7. The cost of defects includes internal failure (scrap, rework and delay) as well as external failure (re pairs, warranty cost and lost custom). Waste may arise from individual processes or relationships between processes. Wastes 4 and 6 result from individual processes. Wastes 1, 2, 3 and 5 above arise from relationships between processes. Waste 7, defects, emanate from either individual processes or relationships between processes.
Theorising social economics	McCormick 1986	… waste is conceived of in terms of lost output. This idea can be summarized in the following definition: Resources are wasted if their absence would not reduce the output of society, or if their reallocation would increase the output of society. Neo-institutional social value theory provides a useful framework for an analysis of waste. It does so by providing a clear statement of social value, one that allows us to inquire into the worth of different types of economic activities. It is then only a small step to define waste as ***the application of resources in a direction other than 'forward,' i.e. for invidious or non-instrumental purposes.*** Resources used for such purposes create no social value, and hence must be considered wasted from society's point of view. The essence of this definition is simply this: In allocating its scarce resources, each society must decide not only how much to produce but also what it will produce. In deciding what to produce, the society is influenced by a variety of considerations, including its historical baggage in the form of tradition, ceremony and the social structures that they encompass. As a result, resources are devoted to 'past preserving' activities or to other things that do not contribute to the development of the culture. The resources that are thus squandered are considered wasted. This notion is implicit in Veblen as he defined waste as that which 'does not serve human life or human well-being on the whole'. (Veblen, 1953, p781)

Perspective	Reference	Definition/comment
Commercial	Hicks et al. 2004	Bicheno identifies ‘new’ wastes: the waste of untapped human potential; the waste of inappropriate systems that add cost without adding value; … wasted customer time and the waste of defecting customers – it may cost many more times to acquire a customer than it does to retain one. [Quoted from Bicheno (2000) The Lean Tool Box; PICSIE Books, Buckingham UK]
Environmental law	Van de Walle et al. 2005	… the Court is quite clear that the notion of ‘discarding’ is decisive in determining whether a material constitutes waste. It reiterates that this notion must be interpreted in the light of the Waste Framework Directive’s aim of protection of the environment and human health as expressed in its third recital, and in light of the standards and principles set out under Article 174(2) of the EC Treaty, and so ‘cannot be interpreted restrictively’. The Court has absolutely no difficulty in concluding that accidentally spilled hydrocarbons are akin to a ‘production residue’, which ‘must be considered to be a burden which the holder seeks to ‘discard’ and are ‘therefore substances which the holder did not intend to produce and which he ‘discards’, albeit involuntarily, at the time of the production or distribution operations which relate to them’. The Court then goes on to state that, due to the fact that leaked fuel cannot be separated from contaminated soil, and having regard to the aim of the Directive and to heading Q4 of Annex I thereto, ‘[T]he same classification as ‘waste’ within the meaning of Directive 75/442 applies to soil contaminated as the result of an accidental spill of hydrocarbons’.
Academic	Pongracz & Pohjola 2004	The essence of the legal definitions is that the owner does not want it; thus waste exists only where it is not wanted … Based on the four waste classes, one can conclude that a thing is waste since: • It has no Purpose, either because it has never been assigned one, or because it has not been assigned a new one after the first was fulfilled. • It is not performing in respect to its Purpose either because a deficiency in its Structure, or it does not have the proper State (=functionality). • The owners failed, or did not use the thing for its assigned Purpose.

Perspective	Reference	Definition/comment
Academic	Pongracz & Pohjola 2004	Using this concept, waste can be defined as (Pongrácz, 2002): **Definition 1.** Waste is a man-made thing that has no Purpose; or is not able to perform with respect to its Purpose. One may ask that why a perfectly useful thing should be considered waste? Suppose that the manager of a company is taking inventory of stock. The inventory finds aged spare parts in the storeroom and the machines to which they apply have been replaced long ago. Almost certainly, this company will discard these spare parts because they have no Purpose for them. For a company who still has the machines to which they apply, these spare parts are valuable and have a Purpose. This example also illustrates the dynamism of the concept of waste. The same thing may be waste or non-waste for different groups, in different places and at different times. It can be argued that waste can be recognised either as a thing with a given Purpose but without an owner, or simply as a thing without a specified Purpose. Waste as outlined in Definition 1 can be further refined to (Pongrácz and Pohjola, 1999a): **Definition 3.** Waste is a man-made thing, which in a given time and place, in its actual Structure and State, is not useful to its owner, or an output that does not have any owner.

Appendix 3: Texts that illustrate the holism of industrial ecology

Topic	Reference	Description
General scope of industrial ecology	Lifset (2007)	Editorial commentary on a key question: '… how to expand the boundaries of industrial ecology productively without having the field loose its identity'.
Social analysis	Ashton (2008)	Empirical studies of trust and communication in industrial symbiosis, Barceloneta, Puerto Rico
Social analysis	Domenech & Davies (2009)	Explores the potential of Social Network Analysis and network theory to provide a methodology and framework for understanding the complexity of industrial symbiosis.
Producer responsibility	Deutz (2009)	Examining relationships between ecologicl modernisation and industrial ecology to understand the attributes of relevant EU legislation
Leadership and trust	Hewes & Lyons (2008)	Studies of two champions (Lowitt at Devens, USA and Christensen at Komsomolske & Cherkassey, Ukraine) focusing on their role in establishing eco-industrial parks.
Theorising analysis	Randles (2007)	Combines into a single analytical framework literature on human geography, business ethics and industrial ecology relating to scale, transnational corporations and ethics related to industrial ecology.
Agent analysis	Andrews (2001)	Examines the role and influence of individuals in the context of industrial ecology. Andrews suggests that analysts should distinguish between agency on the scale of an individual and agency on the scale of an organisation.
Politics	Cohen & Howard (2006)	Suggests industrial ecologists assess political relations with the world at large and presents five criteria for doing so.
Ecological economics	Kronenberg (2006)	Analyses links between ecological economic and industrial ecology and suggests they are closely related. The conclusion is that the former has the broader purview and therefore subsumes the latter.

Appendix 4: Comments on biological symbiosis

The first definition of symbiosis was given in 1873 by Heinrich Anton de Bary, a German mycologist who used the phrase to mean: 'the living together of differently named organisms' (e.g. Margulis 1998). Although no single definition is universally accepted by modern researchers in the biological sciences (e.g. Lewin 1982; Goff 1982; Saffo 1992; Smith 2001) symbiosis does have two specific, generally accepted characteristic:

> One is the existence of a relationship between two organisms, each one being of a different species from the other. Such organisms are sometimes called symbions or symbionts.

The other is that the symbions are in physical contact with one another.

While there seems to be no controversy about these characteristics, the extent to which the (imputed) purpose of the relationship defines the existence of symbiosis is disputed. I suggest that it would be more accurate to think in terms of 'consequence' rather than purpose since volition by the symbions seemingly cannot be established irrefutably. Five categories of symbiosis have been established with reference to the benefit, or otherwise, of the relationship to each of the symbions. A representation of these categories is shown below in which: '+' denotes benefit to the species; '0' denotes no positive or negative effect; '–' denotes an undesirable effect of the interaction (J. Meyer 1998; Dept. of Entomology, NC State University www.cals.ncsu.edu/course/ent591k/symbiosis.html).

	+	Parasitism	Commensalism	Mutualism
Species A	0		Neutralism	Commensalism
	–	Competition		Parasitism
		-	0	+
			Species B	

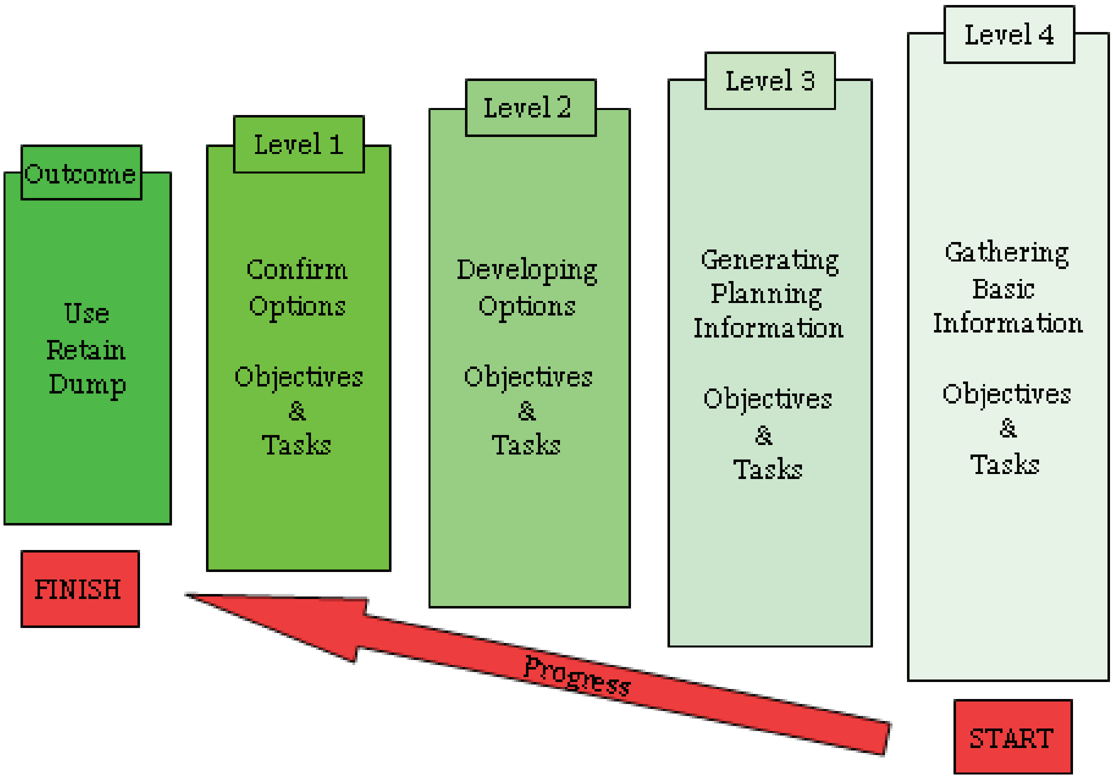
Appendix 5: Procedure for Instigating autogenous bilateral symbiosis

As outlined in Section 3.2, the entire procedure, that is, the project breakdown structure (PBS) developed for bilateral symbiosis in this study comprises three elements: the project breakdown objectives (PBO), the task groups (TG) and the kybosh conditions (KC). Further details about these elements are given in this appendix.

Project Breakdown Objectives (PBO)

The PBO defines all the objectives that need to be met in order to decide what the outcome of a project will be. Stating the possible outcomes and defining the objectives that guide progress towards achieving those outcomes are the first and most important tasks in planning a project. The PBO is the foundation of the procedure; it is analogous to the design of a building in that beginning construction without a design will inevitably result in wasting time and money. It is noted that the PBO does not define tasks or actions, that is, the actual work that needs to be done during the project. The objectives are allocated to 'Levels', which are only intended to indicate a degree of detail (Figure A5.1). The levels do not necessarily represent the order in which objectives are achieved, nor do they represent a strictly sequential relationship in time. However, it is generally more efficient to achieve objectives on a higher level first as they may be precursors to related objectives on lower levels (see tagging, rule 4 below).

Figure A5.1 – General Structure of the Procedures



Compiling the PBO involves one maxim and four rules. The maxim is: Build the PBO, with all the relevant objectives for a project, before starting work. It is much cheaper to change a spreadsheet than it is to abandon futile work.

The rules are:

1. Start at the left hand side of the spread sheet (Figure A5.2) with all possible outcomes, not just those that are desired or expected.
2. To the right of the outcomes, set the objectives at Level 1 to be the accumulation of all the information needed to decide what outcomes are possible, irrespective of whether or not they are desired. Tag Level 1 objectives with a single digit, which serves no other purpose than identification.
3. Set objectives on each level progressively to the right of Level 1 to represent successively finer degrees of detail until a level is reached at which the objective cannot (practically) be further subdivided.
4. Tag each objective to identify its unique relationship to an objective at the next level to the left in the PBO. The number of digits in a tag indicates the Level at which an objective is located. The digits themselves indicate a direct, lineal relationship to an objective at Level 1.

Task Group (TG)

Every objective in the PBO requires work to be done to achieve it. The TG contains the tasks associated with each objective. These are tagged in exactly the same way as the objective to which they relate. Figure A5.2 gives an example of a PBO with tasks allocated.

Kybosh[1] Conditions (KC)

In applying the procedure, circumstances may be encountered that prevent the achievement of a particular objective and hence block permanently further progress in that direction of development. I refer to these circumstances as kybosh conditions because of their terminal influence on progress. They are identified by reference to the objectives they might frustrate and are tagged in the same way.

1 Kybosh is an English word of unknown origin meaning variously to put an end to something, to finish it off for ever, to stymie, to ruin irretrievably. Its first recorded use in literature was by Dickens in the 1830s.

Examples of such conditions are given in figure A5.3 for level 2 and in Figure A5.4 for level 4. Conditions at level 3 have been omitted because they add nothing new to the example. By the time level 1 is reached, all actual and potential kybosh conditions should have been dealt with.

Figure A5.2 - Example of Project Breakdown Objectives

(TG = the group of tasks necessary to achieve a specified objective)

Deciding Outcomes	Confirming Options Level 1 - Objectives	Work Level 1 (TG)	Developing Options Level 2 - Objectives	Work Level 2 (TG)	Planning Information Level 3 - Objectives	Work Level 3 (TG)	Basic Information Level 4 - Objectives	Work Level 4 (TG)
							Obtain various analyses:	
Use Waste	1 - Completed assessment of commercial viability	TG 1	1.1 - Confirm User(s)	TG 1. 1	1.1.1 - Complete technical analysis	TG 1.1.1	1.1.1.1 - Bulk	TG 1.1.1.1
Reprocess			1.2 - Complete financial analysis	TG 1.2	1.1.2 - Identified potential uses	TG 1.1.2	1.1.1.2 - Nutritional	TG 1.1.1.2
			1.3 - Complete analysis of commercial risk	TG 1.3	1.1.3 - Identifed potential users	TG 1.1.3	1.1.1.3 - Environmental	TG 1.1.1.3
Store Indefiitely			1.4 - Complete analysis of project sustainability	TG 1.4			1.1.1.4 - Soil	TG 1.1.1.4
			1.5 - Complete trials	TG 1.5			Obtain details of waste:	
Dump							1.1.1.5 - Inventory (quantity, form, etc.)	TG 1.1.1.5
			1.6 - Complete arrangements for processing before disposal	TG 1.6				
							1.1.1.6 - Current disposal (method, handling, cost etc.)	TG 1.1.1.6
	2 - Completed assessment of enviromental issues	TG2	2.1 - Confirm compliance with all regulations	TG 2.1	2.1.1 - Confirmed compliance - government regulations	TG2.1.1		
			2.2 - Complete assessment of environmental issues	TG 2.2	2.1.2 - Obtained permits, etc.	TG 2.1.2		
					2.1.3 - Confirmed compliance - generator's regulations	TG 2.1.3		
					2.1.4 - Confirmed compliance - user's regulations	TG 2.1.4		
					2.2.1 - Complete Life Cycle Assessment (or similar)	TG 2.2.1		
	3 - Complete assessment of commercial arrangements	TG 3	3.1 - Confirm Transport arrangements	TG 2.3	3.1.1 - Analysis of transport options	TG3.1.1		
			3.2 - Confirm Operations	TG 3.1	3.2.1 - Arrangements for administration	TG 3.2.1		
			3.3 - Complete negotiations on agreements	TG 3.2	3.2.2 - Quality Assurance (verification, tracking, certification)	TG3.2.2		
					3.3.1 - Draft suppler/user agreements	TG 3.3.1		

Figure A5.3 - Example of Level 2 Kybosh Conditions

(KC = Kybosh conditions)

Developing Options Level 2 - Objectives	KC Level 2	Conditions for Actual Kybosh	Conditions for Potential Kybosh
1.1 - Confirm User(s)	KC 1.1	No users available	
1.2 - Complete financial analysis	KC 1.2	Option is not financially viable	
1.3 - Complete analysis of commercial risk	KC 1.3	Option deemed to be too risky	
1.4 - Complete analysis of project sustainability	KC 1.4		Option does not satisfy minimum cond's of sustainability to justify effort
1.5 - Complete trials	KC 1.5	Trials fail beyond recovery	Trials fail but there is potential to recover
1.6 - Complete arrangements for processing before disposal	KC 1.6	Suitable process unavailable	Suitable process needs to be developed or adapted from a different purpose.
2.1 - Confirm compliance with all regulations	KC 2.1	Unable to comply with regulations or obtain permits etc.	Unable to comply with regulations but negotiation is a possibility.
2.2 - Complete assessment of environmental issues	KC 2.2	Unable to satisfy environmental exigencies.	

Figure A5.4 - Example of Level 4 Kybosh Conditions

(KC = Kybosh conditions)

Basic Information Level 4 - Objectives	KC Level 4	Actual Kybosh	Potential Kybosh
Obtain various analyses:			
1.1.1.1 - Bulk	KC 1.1.1.1	Excessive presence of toxic substances	Incomplete bulk analysis - identified components do not equal 100%
1.1.1.2 - Nutritional	KC 1.1.1.2	Presence of toxic substances; biological contamination e.g. aflatoxins, tripsin inhibitors	Insufficient nutrients e.g. energy, protein
1.1.1.3 - Environmental	KC 1.1.1.3		Analytes exceed regulation levels e.g. fats; TCLP;
1.1.1.4 - Soil	KC 1.1.1.4		
Obtain details of waste:			
1.1.1.5 - Inventory (quantity, form, etc.)	KC 1.1.1.5		Quantity too small to be viable for reuse
1.1.1.6 - Current disposal (method, handling, cost etc.)	KC 1.1.1.6	Disposal so cheap that alternative uses are not financially viable	

Appendix 6: Companies approached to conduct trials for Phase 1

Organisation	Date first approached	Date Declined	Reasons
Lend Lease	18/4/2007	30/7/2007	Abandoned – environmental manager too busy to get involved
Nestle Australia	21/6/07	7/2/08	Project too academic; they do not have the resources required for it; cannot see the benefit to nestle; they already manage their waste satisfactorily.
Johnson & Johnson	20/7/07	20/7/2007	Decision to close the plant in 2009 so no time or interest in conduction trials.
Mirvac	27/7/07	27/7/2007	Not interested in what happens to their waste after it leaves the site
Leighton Holdings	27/7/07	27/7/2007	No one responsible for environmental issues.
O-I Glass	30/7/07	30/7/07	Pre-occupied with other projects for the next two years at least.
CSR Ltd.	1/8/07	20/2/2008	No response to repeated follow-up before trials for Phase 1 were abandoned.
James Hardie	1/8/07	19/11/2007	They could not see the value to James Hardie; they eventually did their own project.
Thales Australia	9/8/07	30/8/2007	No waste to be concerned about other than extremely hazardous materials that are intractable and unsuitable for a project.
Rio Tinto	10/8/07	29/8/2007	No interest in the project owing to current bid to purchase Alcan.
Alliance Recycling (BlueScope Steel)	23/8/07	19/10/07	They rely on third parties.
Fairfield City Council	13/9/07	26/10/2007	No people available to work on the project.
Bunnings Hardware	5/3/08	17/3/08	Existing commercial agreements preclude alternative approaches hence no interest.

Appendix 7: The questionnaire used in Phase 2

The University of Sydney

NSW 2006 AUSTRALIA
Discipline of Geography
School of Geosciences, Madsen Building
NSW 2006 AUSTRALIA
Telephone +61 2 9351 2912; Facsimile +61 2 9351 0184

Questionnaire about Using Industrial Waste
Information for Participants

Introduction to the questionnaire

The purpose of this questionnaire is to gather information about the potential for using industrial waste, instead of dumping it.

The views of senior line managers such as plant managers, production managers and operations managers are being canvassed on the basis that this level of management has by far the greatest influence over what actually happens to waste in practice.

The information will be used in research for a PhD thesis on the practical implementation of a management strategy known as 'Industrial Symbiosis' (see below). The work is being done by Robin Branson (researcher) under the supervision of Dr Phil McManus (02 9351 4242) in the School of Geosciences at the University of Sydney.

Industrial Symbiosis is defined as a relationship between two different, unrelated manufacturing organisations in which the waste from one of them is used as an input to the process of the other. The benefits are that costs of disposal for the generator of the waste are reduced, the cost to the user of inputs is reduced and 'pressure' on the environment is reduced because it does not have to 'absorb' the material for which dumping has been postponed while it is used again, if not avoided altogether.

That, at least, is the theory. The underlying question is: Can the theory be applied more widely in practice than it is currently and if so then what is the most effective way of making Industrial Symbiosis happen?

There are locations where Industrial Symbiosis has operated very successfully in practice, most notably at Kalundborg in Denmark, which inspired the theory in the first place. However, in this and other locations the practice evolved over many decades and under very particular circumstances that are not typical of industrial activity generally. The academic task is to find a way to accelerate the process of evolution or more likely, circumvent it altogether by developing processes and tools which do the same job more quickly.

Recycling 'tradable' waste such as scrap metal, plastic, cellulose fibre, brewer's grain and the like is a form of Industrial Symbiosis that has certainly been a feature of manufacturing for at least 150 years. However, the range of 'tradeable' waste is limited in comparison with the variety and amount of waste that could be used, even though it may not satisfy a broad market in the way that tradeable waste does.

The meaning of terms

For the purpose of this questionnaire, 'management' means someone such as the plant manager, site manager or operations manager who has the authority to commit capital and or people's time to the general task of waste disposal. The focus of this research is on the views of people who work at the production level of the organisation and on what actually happens from day to day. However, several questions do relate to corporate policy.

'Waste' refers to the residues of industrial activity as distinct from office or canteen waste, for example. The term includes: solid and liquid residues from production, bag house dust, effluent and sludge from a trade waste treatment plant, discarded raw materials and scrap finished product. Except in question 2.4, 'waste' means only the stuff arising on your site.

This questionnaire does not formally include waste heat, gas and vapour that are discharged into the atmosphere. However, if you wish to include such waste please do so by commenting accordingly in the relevant columns.

For the sake of avoiding repetition, the phrase 'industrial symbiosis' is shortened to 'symbiosis'.

Assumptions

The researcher assumes that your company generates waste of some sort which is either disposed of off site or is stored on site pending an acceptable means of disposal.

Nothing about your views on waste has been assumed to be obvious or has been taken for granted. Some questions may therefore seem naïve or trivial but answers to them will be helpful none the less.

When responding to the questionnaire, please assume that your waste can be used by another organisation, however improbable that may seem to you now.

Structure of the questionnaire

The questions relate to factors that influence the disposal of waste. In the first three parts and part five they are posed in a way that would generally require a 'Yes/No' answer (indicated by 'X'), with the option to add comments and contact information, if you want to. Please add comments if a straight 'yes' or 'no' is an inadequate response to the question and you have time to elaborate. If you want to answer a question with both 'yes **and** no' please mark both options and add comments that qualify each option. Questions in the fourth part require a comparative response. There are 32 questions in all which, it is expected, will take no more than 20 minutes to answer.

Part 1 – 10 questions deal with what currently happens to your waste and whether or not its disposal is a topic of irritation or concern in general.

Part 2 – eight questions deal with management's views on alternatives to dumping waste and what options would be attractive, if any.

Part 3 – six questions deal with the organisation's capacity to support the implementation of symbiosis, if it wanted to do so.

Part 4 – four questions deal with factors that may influence the company's position with respect to waste and its preference for particular strategies.

Part 5 – four questions deal with following up this questionnaire; whether or not you would be willing to discuss your responses with the researcher to provide more detail.

Confidentiality

Information gathered in the course of this research will be confidential and seen in its raw form only by the researcher and the supervisor. It will be held in secure storage when not being used and is required to be retained intact for a minimum of seven years.

Results of this research will be recorded in a PhD thesis and may eventually be published. If this were to happen, no information identifying an individual person or organisation will be included in the publication without first obtaining written consent to do so.

Responding to this Questionnaire

This questionnaire is being sent to a relatively small number of respondents so your contribution would be particularly appreciated. However, participation is entirely voluntary.

If you would like to contact the researcher for any reason, please call Robin Branson on (02) 9427 0614 or send a fax to (02) 9427 1984 or an email to rbra5085@usyd.edu.au

Any person with concerns or complaints about the conduct of a research study can contact the Senior Ethics Officer, Ethics Administration, University of Sydney on (02) 9351 4811 (Telephone); (02) 9351 6706 (Facsimile) or gbriody@mail.usyd.edu.au (Email).

Part 1 – Questions about the current output of industrial waste

This part deals with what currently happens to your waste and whether or not its disposal is a topic of irritation or concern in general.

		Yes	No	And/or comment
1.1	Is any type of waste from your site being used by another organisation unrelated to yours?			
1.2	Is any type of waste from your site going to land fill?			
1.3	Is any type of waste from your site currently being destroyed e.g. by incineration?			
1.4	Is effluent currently being discharged to sewer?			
1.5	Is industrial waste being stored indefinitely on site pending the availability of a suitable means of disposal?			
1.6	Does the current cost of disposal concern management? (If you wish, please state what the concerns are).			
1.7	Is the cost of disposal expected to increase within the next five years?			
1.8	Are future costs of disposal likely to concern management? (If you wish, please state what the concerns are).			
1.9	Is the disposal of waste influenced in any way by the regulations of any statutory authority e.g. an EPA or local water authority? (If you wish, please state how regulations influence disposal).			
1.10	Do you expect the influence of regulations by statutory authorities to become more stringent within the next five years in a way that will make waste disposal more difficult and /or more expensive? (If you wish, please state what ways regulatory influence might be more stringent).			

Part 2 – Questions about alternatives to dumping waste

This part deals with management's views on alternatives to dumping waste and what options would be attractive, if any.

		Yes	No	And/or comment
2.1	In principle, would management consider undertaking initiatives that reduced the **current cost** of disposal by more than 5% of its present amount? If 'No' please state the minimum percentage reduction at which management would do so, if at all.			
2.2	In principle, would management consider undertaking initiatives within the next five years that would reduce the **expected future costs** of disposal by more than 5% of the expected future increases referred to in question 1.7? If 'No' please state the minimum percentage reduction at which management would do so, if at all.			
2.3	Would management allow waste to be used by another organisation, if that organisation were able to do so and the arrangements were permitted by the relevant authorities?			
2.4	Would management be willing to use waste from another organisation as an input to its processes, if it were technically able to do so, at an advantageous cost and the arrangements were permitted by the relevant authorities?			
2.5	Is management concerned about the impact that disposal of their waste has on the environment?			
2.6	Does management have a formal assessment of the environmental impact, caused by the current means of disposal that has been prepared by an independent organisation?			
2.7	Does management have an informal assessment (e.g. prepared 'in-house') of the environmental impact caused by the current means of disposal?			
2.8	Would management accept an increase in costs in order to reduce the environmental impact of its waste disposal?			

Part 3 – Questions about capacity

This part deals with the organisation's capacity to support the implementation of symbiosis, if it wanted to do so.

Note: With the exception of question 3.1, please assume that corporate policy and regulatory authorities do not prevent the use of waste and that industrial symbiosis would yield a net benefit to the organisation.

		Yes	No	And/or comment
3.1	Does the organisation have a policy that prevents its waste from being used by another organisation?			
3.2	In principle, would management be willing and able to allocate **human** resources to establishing symbiosis on its own behalf, if a potential benefit to the organisation could be demonstrated?			
3.3	In principle, would management be willing and able to allocate **financial** resources to establishing symbiosis on its own behalf, if a potential benefit to the organisation could be demonstrated?			
3.4	In principle, would management be willing to **co-operate** with a 3rd party who can organise symbiosis on its behalf, if a potential benefit to the organisation could be demonstrated?			
3.5	In principle, would management be willing and able to **finance** the efforts of a 3rd party who can organise symbiosis referred to in question 3.4?			
3.6	Please indicate, for each action separately, if management would be willing to undertake the following actions to facilitate the use of waste, assuming there was a net benefit in doing so.			
	Change storage and handling arrangements			
	Manual processing such as un-packing			
	Other processing to make waste fit for use			
	Install on site infrastructure (e.g. for processing, storage, handling)			

Part 4 – Questions about strategy

This part deals with factors that may influence the company's position with respect to waste and its preference for particular strategies.

Note: The format in this part is different to the three previous parts.

		Major negative	Minor negative.	Neutral	Minor positive	Major positive
4.1	Please indicate the influence each of the following factors would have on deciding to facilitate the use of waste:					
	Financial benefit to the organisation					
	Environmental benefit					
	Corporate philosophy					
	Public perception of corporate behaviour					
	The effort of obtaining approval from relevant authorities, if required.					

		Certainly would not	Probably Would not	Neutral	Probably would	Certainly would
4.2	Assuming that symbiosis were possible and would benefit the company in what ever way you think worthwhile, please indicate the likelihood of adopting the following strategies:					
	Maintain the current arrangements for waste disposal					
	Establish symbiosis using the company's own financial and human resources					
	Co-operate with a 3rd party that can establish industrial symbiosis on the company's behalf					

		Insurmountable difficulty	Major difficulty	Minor difficulty	No problem
4.3	Assuming that you wanted to establish symbiosis yourself, please indicate the extent to which each of the following factors would prevent you from trying to do so.				
	Negotiating within the organisation for approval to establish symbiosis				
	Applying for funding approval within the organisation.				
	No people available to work part time on the project (say, 6 hours a week for 12 months).				
	Lack of knowledge and/or experience needed for the project.				
	Negotiating with regulatory authorities for approval to establish symbiosis				

	Note: more than one service may apply	Advice	Project management	To do the whole project
4.4	**Assuming** that you wanted to establish symbiosis, **in co-operation with a third party**, please indicate the likelihood that you would approach each of the following **types** of organisation for the various services suggested.			
	A waste management contractor			
	An institution such as a University, TAFE or an appropriate CRC			
	An 'environmental' consultant			
	A manager of facilities such as waste transfer stations and dump sites.			
	An organisation that specialises in establishing symbiosis.			
	A regulatory authority such as the EPA			

Part 5 – Questions about following up this questionnaire

If the answer to any of the following questions is 'Yes' please provide your name, a phone number or email address so the researcher can get in touch.

		Yes	No	Phone No. and/or email address
5.1	Are you willing to discuss with the researcher your responses to these questions by phone or by email?			
5.2	Research for this thesis will include trials of a model (a set of procedures) for establishing symbiosis. Would you be willing to consider a proposal to participate in such a trial?			
5.3	In principle, would you be interested in joining an industry specific group or network that dealt with issues relating to the use of industrial waste and symbiosis generally?			
5.4	Are there any questions you would like to ask about symbiosis in general and/or this research in particular?			

Appendix 8: Responses to Questionnaire (Q1)

			Yes or other response = 1; No, blank or a/b (ambigious or blank) = blank																					
	Nov	for	1.1		1.2		1.3		1.4			1.5		1.6		1.7		1.8		1.9		1.10		
Q'aire #	2008	Calcs	y	n	y	n	y	n	y	n	a/b	y	n	y	n	y	n	y	n	y	n	y	n	
2	1	1	1		1			1	1				1	1		1		1		1		1		
3	1	1	1		1			1	1				1	1		1		1		1		1		
4	1	1	1		1		1		1			1		1		1		1		1		1		
6		1	1		1		1		1				1	1		1			1	1		1		
7	1	1	1		1			1		1		1			1	1			1	1		1		
8	1	1	1		1		1		1				1	1		1		1		1		1		
9	1	1	1		1			1	1				1	1		1		1		1		1		
11	1	1	1		1		1		1				1	1		1		1		1		1		
12	1	1	1		1			1		1			1	1		1		1		1		1		
13	1	1	1		1			1	1				1	1		1		1		1			1	
14	1	1	1		1			1	1				1	1		1		1		1		1		
16	1	1	1		1			1	1				1		1	1			1		1	1		
17	1	1	1		1			1	1			1		1		1		1		1		1		
19	1	1	1		1		1		1				1		1	1		1		1		1		
20	1	1		1	1		1			1			1		1		1		1	1		1		
21	1	1	1		1		1		1				1	1		1		1		1			1	
25		1	1		1			1		1		1		1			1		1	1			1	
26		1	1		1		1			1		1		1		1		1		1		1		
27		1		1	1			1	1				1	1			1	1		1		1		
29		1		1	1			1	1				1	1		1		1		1			1	
30		1	1		1			1	1			1		1		1		1		1		1		
32		1	1		1			1	1				1		1	1			1		1	1		
33		1		1	1			1		1			1	1		1		1		1		1		
34		1	1		1			1	1				1	1		1		1		1			1	
35		1	1		1		1			1		1		1		1		1		1		1		
37		1	1		1			1	1				1		1	1			1	1		1		
38		1	1		1			1	1			1			1	1		1		1		1		
39		1	1		1		1		1				1		1	1			1		1	1		
41		1	1		1			1	1				1	1		1		1		1		1		
42		1	1		1		1		1				1	1		1		1		1		1		
43		1	1		1			1	1				1	1		1		1		1		1		
45		1	1		1			1	1			1		1		1		1			1	1		
F1		1	1		1			1		1			1	1		1		1			1	1		
F2		1	1		1		1		1				1		1		1	1			1		1	
F3		1		1	1			1			1		1	1		1		1		1		1		
F4		1	1		1			1		1			1	1		1		1			1	1		
F5		1		1	1			1		1			1	1		1		1			1	1		
Totals		37	31	6	37	0	12	25	26	10	1	9	28	28	9	33	4	29	8	29	8	31	6	
%			84	16	100	0	32	68	70	27	3	24	76	76	24	89	11	78	22	78	22	84	16	

Appendix 8 Continued – Responses to Questionnaire (Q2)

	Yes or other response = 1; No, blank or a/b (ambigious or blank) = blank																					
	2.1			2.2			2.3		2.4			2.5		2.6			2.7			2.8		
Q'aire #	y	n	a/b	y	n	a/b	y	n	y	n	a/b	y	n	y	n	a/b	y	n	a/b	y	n	a/b
2	1			1			1		1			1			1			1			1	
3	1			1			1		1			1			1			1			1	
4		1		1			1		1			1			1		1					1
6	1			1			1			1		1		1			1					
7	1			1			1		1			1			1		1			1		
8	1			1			1		1			1			1		1			1		
9	1			1			1			1		1			1		1				1	
11	1			1			1		1			1			1			1				1
12		1			1		1		1			1		1				1			1	
13	1			1			1		1			1			1			1			1	
14			1	1			1		1			1			1			1		1		
16	1			1				1	1				1		1			1			1	
17	1			1			1		1			1			1		1				1	
19	1			1			1		1			1			1				1	1		
20	1				1		1		1			1				1	1			1		
21	1			1			1		1			1		1			1			1		
25	1			1			1				1	1				1			1		1	
26	1			1			1		1			1			1		1			1		
27	1				1		1		1				1		1			1			1	
29	1			1			1			1		1			1			1		1		
30	1			1			1		1			1			1		1			1		
32	1					1	1		1				1		1			1			1	
33	1			1			1		1			1				1		1			1	
34		1			1		1		1			1			1		1				1	
35	1				1		1		1			1		1			1				1	
37	1			1			1			1		1		1			1				1	
38		1		1			1		1			1			1		1				1	
39	1			1			1			1		1			1		1				1	
41	1			1			1		1			1			1		1				1	
42	1			1			1		1			1			1		1			1		
43	1			1			1			1		1		1			1			1		
45	1			1			1		1				1		1			1			1	
F1	1			1			1		1			1			1		1			1		
F2	1			1			1			1		1			1			1			1	
F3	1			1			1		1			1			1			1		1		
F4	1			1			1		1			1			1			1		1		
F5		1				1	1		1			1			1			1			1	
Totals	31	5	1	30	5	2	36	1	29	7	1	33	4	6	28	3	19	16	2	14	20	2
%	84	14	3	81	14	5	97	3	78	19	3	89	11	16	76	8	51	43	5	38	54	5

Appendix 8 Continued – Responses to Questionnaire (Q3)

	Yes or other response = 1; No, blank or a/b (ambigious or blank) = blank																									
	3.1			3.2		3.3			3.4			3.5			3.61			3.62			3.63			3.64		
Q'aire #	y	n	a/b	y	n	y	n	a/b	y	n	a/b	y	n	a/b	y	n	a/b	y	n	a/b	y	n	a/b	y	n	a/b
2		1		1		1			1			.	1		1			1			1			1		
3		1		1		1			1			1			1			1			1			1		
4		1		1		1			1			1			1			1			1			1		
6			1	1		1			1			1			1			1			1			1		
7		1		1		1			1			.	1		1			.	1		1			1		
8		1		1				1	1					1	1			.	1				1			1
9		1			1	1			1			.	1		1			1			1			1		
11		1		1				1	1					1	1			1			1			1		
12		1		1		1			1			1			1			1			1			1		
13		1		1		1			1			1			1			1			1			1		
14		1		1		1			1			1			1			1			1			1		
16		1		1		1			1			1			1			.	1		1			1		
17		1		1		1			1			1			1			1			1			1		
19		1		1		1			1			1			1			1			1				1	
20	1			1		1			1			1			1					1	1			1		
21		1			1		1			1			1		1			1				1			1	
25		1		1		1			1					1	1				1				1			1
26		1		1		1			1			1			1			1			1			1		
27		1		1		1			1				1		1			1			1			1		
29	1			1		1			1			1			1			1			1			1		
30		1		1		1			1			1			1			1			1			1		
32		1		1				1			1		1				1			1			1			1
33		1		1		1			1					1	1			1				1		1		
34		1		1		1			1			1			1			1			1			1		
35		1		1		1			1			1			1				1		1			1		
37		1		1		1			1			1			1			1			1			1		
38			1	1		1			1			1			1			1			1			1		
39	1			1		1			1				1				1			1			1			1
41		1		1		1				1			1		1				1		1			1		
42		1		1		1			1				1		1			1			1			1		
43	1			1		1					1			1			1			1			1			1
45		1			1		1		1				1		1				1		1					1
F1		1		1			1		1				1		1			1			1					
F2		1		1		1			1			1			1			1			1			1		
F3		1		1		1			1			1			1			1			1			1		
F4		1		1		1			1			1			1			1			1			1		
F5		1		1		1			1				1		1				1		1			1		
Totals	4	31	2	34	3	31	3	3	33	2	2	20	12	5	34	0	3	25	8	4	30	2	5	28	2	6
%	11	84	5	92	8	84	8	8	89	5	5	54	32	14	92	0	8	68	22	11	81	5	14	76	5	16

Appendix 8 Continued – Responses to Questionnaire (Q4.1)

	Yes or other response = 1; No, blank or a/b (ambigious or blank) = blank																								
	4.11					4.12					4.13					4.14					4.15				
Q'aire #	ma-	mi-	neu	mi+	ma+	ma-	mi-	neu	mi+	ma+	ma-	mi-	neu	mi+	ma+	ma-	mi-	neu	mi+	ma+	ma-	mi-	neu	mi+	ma+
2				1					1				1						1				1		
3					1					1					1					1					1
4					1				1					1					1		1				
6					1				1						1				1				1		
7					1				1					1				1			1				
8					1					1					1					1		1			
9					1					1				1				1					1		
11					1				1					1					1						1
12					1					1					1					1		1			
13					1				1					1					1			1			
14					1				1					1					1			1			
16					1			1					1					1					1		
17					1					1				1						1					1
19					1					1					1					1				1	
20					1				1					1					1				1		
21			1					1							1					1			1		
25				1					1				1						1		1				
26					1				1				1						1		1				
27					1				1					1					1				1		
29					1				1				1					1			1				
30			1							1				1					1					1	
32					1			1					1						1			1			
33					1					1					1					1		1			
34					1					1					1					1					1
35					1					1					1					1			1		
37					1				1					1				1							1
38					1					1					1					1				1	
39				1					1					1					1				1		
41					1					1					1					1					1
42					1				1					1					1				1		
43																									
45					1			1					1					1			1				
F1					1				1					1					1				1		
F2					1					1					1				1				1		
F3				1					1					1				1				1			
F4					1					1				1					1					1	
F5				1					1				1					1				1			
Totals	0	0	2	5	29	0	0	4	18	14	0	0	8	16	12	0	0	8	17	11	6	8	12	4	6
%	0	0	5	14	78	0	0	11	49	38	0	0	22	43	32	0	0	22	46	30	16	22	32	11	16

Appendix 8 Continued – Responses to Questionnaire (Q4.2)

	Yes or other response = 1; No, blank or a/b (ambigious or blank) = blank														
	4.21					4.22					4.23				
Q'aire #	ma-	mi-	neu	mi+	ma+	ma-	mi-	neu	mi+	ma+	ma-	mi-	neu	mi+	ma+
2			1				1						1		
3		1					1							1	
4		1							1					1	
6			1						1					1	
7		1							1					1	
8					1		1							1	
9	1								1					1	
11				1				1					1		
12				1			1					1			
13	1									1				1	
14		1							1					1	
16			1						1				1		
17				1					1					1	
19	1								1					1	
20			1							1					1
21				1		1					1				
25				1			1							1	
26				1			1							1	
27			1						1					1	
29		1							1					1	
30				1				1						1	
32		1							1					1	
33	1									1					1
34			1					1							1
35				1				1							1
37	1								1						1
38				1					1					1	
39		1							1					1	
41				1				1				1			
42		1							1				1		
43															
45			1			1									1
F1	1						1								1
F2	1								1				1		
F3				1				1					1		
F4		1						1						1	
F5				1					1					1	
Totals	7	9	7	12	1	2	7	7	17	3	1	2	6	20	7
%	19	24	19	32	3	5	19	19	46	8	3	5	16	54	19

Appendix 8 Continued – Responses to Questionnaire (Q4.3)

	Yes or other response = 1; No, blank or a/b (ambigious or blank) = blank																			
	4.31				4.32				4.33				4.34				4.35			
Q'aire #	id	mad	mid	np	id	mad	mid	np	id	mad	mid	np	id	mad	mid	np	id	mad	mid	np
2			1					1				1				1			1	
3				1							1				1				1	
4			1					1		1					1			1		
6			1				1				1			1					1	
7		1					1				1				1			1		
8			1			1				1				1				1		
9				1		1					1				1			1		
11			1			1					1				1				1	
12			1				1			1						1				1
13			1				1				1				1				1	
14			1				1				1				1			1		
16			1				1				1				1				1	
17				1			1				1					1				1
19			1			1					1				1				1	
20			1				1					1			1				1	
21	1				1				1							1				1
25			1			1					1			1				1		
26		1					1				1			1			1			
27			1				1			1					1			1		
29			1				1			1					1			1		
30			1				1			1				1						1
32		1				1				1					1			1		
33		1				1				1				1					1	
34				1				1			1				1				1	
35				1			1					1		1					1	
37			1			1						1			1			1		
38				1			1				1				1				1	
39			1				1				1				1				1	
41			1								1					1			1	
42			1			1					1			1				1		
43																				
45	1					1			1					1				1		
F1			1			1					1				1				1	
F2				1			1					1			1				1	
F3			1				1			1					1				1	
F4				1			1				1				1					1
F5			1			1				1				1				1		
Totals	2	4	22	8	1	12	18	3	2	10	19	5	0	10	21	5	1	13	17	5
%	5	11	59	22	3	32	49	8	5	27	51	14	0	27	57	14	3	35	46	14

Appendix 8 Continued – Responses to Questionnaire (Q4.4)

	Yes or other response = 1; No, blank or a/b (ambigious or blank) = blank																							
	4.41				4.42				4.43				4.44				4.45				4.46			
Q'aire #	adv	pm	tp	a/b	adv	pm	tp	a/b	adv	pm	tp	a/b	adv	pm	tp	a/b	adv	pm	tp	a/b	adv	pm	tp	a/b
2	1				1					1			1					1			1			
3	1				1				1				1						1		1			
4	1					1			1				1						1		1			
6	1	1	1		1				1	1			1				1	1	1		1			
7		1			1				1					1				1			1			
8			1		1				1				1					1			1			
9			1		1				1				.	1			1				1			
11	1				1					1			1				1				1			
12	1				1				1				1						1		1			
13	1						1			1			1						1		1			
14			1		1					1			1						1		1			
16	1				1				1				1				1				1			
17			1		1				1					1				1			1			
19	1				1				1	1	1		1				1	1	1		1			
20			1		1				1				1				1				1			
21				1				1				1				1			1					1
25			1		1				1					1				1			1			
26			1		1				1					1				1			1			
27	1				1				1				1				1				1			
29	1				1				1				1					1			1			
30		1			1				1	1				1	1			1	1		1			
32		1				1			1					1			1				1			
33	1				1					1			1						1					1
34	1				1				1					1							1			
35	1				1					1			1					1			1			
37		1			1					1				1					1		1			
38		1			1				1					1					1		1			
39	1	1			1	1							1				1	1			1			
41																								
42	1	1	1		1				1	1	1						1				1			
43																								
45				1				1				1				1				1				1
F1	1				1				1				1				1				1			
F2				1	1							1				1				1				1
F3	1	1	1		1				1	1	1		1				1				1			
F4	1				1				1				1					1			1			
F5	1				1				1				1				1				1			
Totals	20	9	10	3	30	3	1	2	24	12	3	3	21	10	1	3	13	13	12	2	31	0	0	4
%	54	24	27	8	81	8	3	5	65	32	8	8	57	27	3	8	35	35	32	5	84	0	0	11

Appendix 8 Continued – Responses to Questionnaire (Q5)

	5.1		5.2			5.3		5.4		
Q'aire #	y	n	y	n	a/b	y	n	y	n	a/b
2	1		1			1			1	
3	1		1			1			1	
4	1		1			1			1	
6	1			1					1	
7	1		1			1			1	
8	1			1		1			1	
9	1		1			1		1		
11	1			1			1		1	
12	1		1			1			1	
13	1		1			1			1	
14	1		1			1			1	
16	1			1		1			1	
17	1		1			1			1	
19	1		1			1			1	
20	1		1			1			1	
21		1		1			1		1	
25	1		1			1				
26	1			1		1			1	
27		1		1			1		1	
29	1		1			1			1	
30	1		1			1			1	
32	1			1		1		1		
33		1		1			1		1	
34	1		1			1			1	
35	1		1			1		1		
37	1		1				1		1	
38	1		1			1			1	
39	1		1			1			1	
41	1		1			1			1	
42	1		1			1			1	
43	1			1			1		1	
45	1				1		1			1
F1	1			1			1		1	
F2	1		1			1			1	
F3	1		1			1			1	
F4	1		1			1			1	
F5		1		1			1		1	
Totals	33	4	24	12	1	27	9	3	32	1
%	89	11	65	32	3	73	#	8	86	3

Appendix 9: Sets of questions used for semi-structured interviews

Type of organisation	Topics canvassed
DECCW – Regulator	1. Principal issues that the regulator must deal with in relation to industrial waste 2. Current policy/thinking underlying the regulations for the disposal of industrial waste. 3. The regulator's objectives for dealing with industrial waste. 4. Likely developments in the regulations governing the disposal of industrial waste. 5. Difficulties/ obstacles faced by regulators in performing their function or achieving their objectives.
DECCW – Sustainability Advantage	1. Current initiatives specifically supporting the use of industrial waste: a. What is the initiative/program? b. Duration of participation. c. Criteria for selecting participants and continuing support, d. Funding for participants in SA e. Duration of and funding for SA 2. What happens when the current initiative expires 3. Is the initiative vulnerable to a change of government? 4. Future initiatives proposed or being planned to specifically support the use of industrial waste. 5. Policy/thinking underlying these initiatives 6. Allocation of revenue from tip fees to support the use of waste
Waste Disposal Contractors	1. Services currently offered by the company to find uses for waste which would otherwise be dumped: a. What are they? b. How are they made available? c. What resources are used? d. How are they funded? e. How would a client find the right person to approach? 2. Services relating to bilateral symbiosis that the company plans to offer in the future:

Type of organisation	Topics canvassed
Companies engaged in bilateral symbiosis.	1. Factors that motivated initiative(s) to find uses for waste. 2. The resources that were committed to the initiative(s). 3. The time it took to achieve satisfactory results. 4. The results of the initiative(s). 5. The difficulties that had to be overcome. 6. The extent to which the experience and knowledge gained from the initiative(s) have been transferred to other factories in the group

Appendix 10: Various definitions/descriptions of industrial ecology

(Arranged in chronological order from the earliest to the most recent)

Author (s)	Definitions/description	Reference
R Wood M Lenzen	Industrial ecology examines interactions among the environment, the economy, and technology. Although particular interactions or life cycles are often a focus, holistic measurements are also key to understanding the metabolism of our societies.	*Journal of Industrial Ecology* (2009) Vol. 13, No. 2
Hewes A & Lyons, D I	Industrial ecology (IE) is emerging as an important strategy in the attempt to develop industrial and consumptions systems that are more environmentally benign. Although the principles of IE are gradually finding an audience among leaders in industry, academia and government agencies … it is more a set of related ideas than a unified theory. While IE related studies run the gamut from firm level studies focusing on green design and green accounting to the study of global material flows … in essence, IE argues that industrial activity needs to be transformed into a more integrated model: an industrial ecosystem. Here raw material extraction and waste generation is minimized since waste serves as the raw material for another process.	*Regional Studies* (2008) Vol. 42, No. 10 p1330
Deutz P Lyons D I	Industrial ecology is a collective term for a number of business-centered systems-oriented approaches to improve the eco-efficiency of industry … Employing ecological metaphors, industrial ecology asks questions about the sustainability of the current industrial paradigm. In essence, it argues that the traditional model of industrial activity where individual manufacturing processes take in raw materials and generate products to be sold plus waste for disposal needs to be transformed into a more integrated 'closed-loop' model: an industrial ecosystem …	*Regional Studies* (2008) Vol. 40, No. 10 p1295
Deutz P Gibbs D	IE is a business-oriented initiative aiming to decrease the impact of business on the environment by promoting the 'win–win' of eco-efficiency, i.e. that environmental savings (for example, reducing material and energy consumption) can also bring cost savings. IE is characterized by its promotion of 'industrial ecosystems', involving inter-company cooperation, derived from a metaphor with natural ecosystems …	*Regional Studies* (2008) Vol. 42, No. 10 p1315

Author (s)	Definitions/description	Reference
Basu A J van Zyl D A J	Industrial ecology (IE) is an emerging field, which covers the study of physical, chemical, and biological interactions and interrelationships both within and between industrial and ecological systems [1]. Implementing an IE framework incorporates the strategy of cleaner production and pollution prevention in industrial activities. The application of IE principles to mining and mineral processing is therefore a logical step. This framework also promotes understanding of the impacts of industrial systems on their environment. This framework paper addresses two major concepts: 1) IE, and (2) cleaner production for achieving sustainable development (SD) in the context of the mining and minerals industry.	*Journal of Cleaner Production* (2006) Vol. 14, p 299
Dewulf, J Van Langehove, H	The embedding of a technology in the industrial metabolism is the research area of industrial ecology (Graedel and Allenby, 1996; Lowe et al, 1997). If one aims at quantifying environmental sustainability of technology, one should integrate industrial ecology principles in the development of environmental sustainability indicators.	*Resources Conservation & Recycling* (2005) Vol. 43 p 420
Gibbs D Deutz P Proctor A	IE attempts to understand the potential for environmental improvement in industry using an analogy of industrial systems to natural ecological systems … Processes and industries are seen as interacting systems rather than as comprising of isolated components in a system of linear flows. (p.172) IE essentially represents a development for dealing with localized environmental impacts. Rather than focusing upon concepts such as cleaner production and eco-efficiency, which are concerned with reducing material inputs and reducing waste at the level of the firm … (p.173)	*Regional Studies* (2005) Vol. 39, No. 2 p172 & 173
E Cohen-Rosenthal	The goal (of industrial ecology), at the minimum, is to generate the least damage in industrial and ecological systems through the optimal circulation for materials and energy. Highest value use with the least dissipation of resources forms the core of systematic application of industrial ecology.	*Journal of Cleaner Production* (2004) Vol. 12 p 1111

Author (s)	Definitions/description	Reference
Roberts B H	If production and consumption methods in human controlled systems could be made to mimic the efficiencies of natural and biological systems, then greater sustainability would ensue and a means would emerge to address the growing amount of waste produced by industry and consumption-driven society. To this end, we need to identify new uses and innovative techniques for using waste materials. This is the domain of industrial ecology; that is, systems that utilise the emissions and waste flows of industry and consumption.	*Journal of Cleaner Production* (2004) Vol. 12 p 998
Bringezu S	The core of industrial ecology as an emerging scientific field is the study of industrial metabolism.	*Perspectives on Industrial Ecology*; Greenleaf Publishing Ltd (2003) Eds. Bourg D & Erkman S. Ch. 1- Industrial Ecology and Material Flow Analysis; p.20
Graedel T E Allenby B R	The essence of industrial ecology can, however, be briefly stated: Industrial ecology is the means by which humanity can deliberately and rationally approach and maintain sustainability, given continued economic, cultural and technological evolution. The concept requires that an industrial system be viewed not in isolation from its surrounding systems but in concert with then. It is a system view in which one seeks to optimize the total materials cycle from virgin materials, to finished material, to component, to product, to obsolete product and to ultimate disposal. Factors to be optimized include resources, energy and capital.	*Industrial Ecology* – Second Edition, Prentice Hall 2003, p 18
Seager T P & Theis T L	Therefore, for the purposes of this paper, industrial ecology shall be defined as a field of study (or branch of science) concerned with the inter-relationships of human industrial systems and their environments.	*Journal of Cleaner Production* (2002) Vol. 10 p 226

Author (s)	Definitions/description	Reference
Erkman S	As yet, there is no standard definition of industrial ecology and a number of authors do not make a clear difference between industrial metabolism and industrial ecology ... However, whatever the definitions may be, all authors more or less agree on at least three key elements of the industrial ecology/ metabolism perspective: 1. It is a systemic, comprehensive, integrated view of all the components of the industrial economy and their relations with the biosphere. 2. It emphasizes the biophysical substratum of human activities, i.e. the complex patterns of material flows within and outside the industrial system, in contrast with current approaches which mostly consider the economy in terms of abstract monetary units, or alternatively, energy flows. 3. It considers technological dynamics, i.e. the long term evolution (technological trajectories) of clusters of key technologies as a crucial (but not exclusive) element for the transition from the actual unsustainable industrial system to a viable industrial ecosystem.	*Journal of Cleaner Production* (1997) Vol. 5 No. 1-2 p 1
Boons F A A & Bass L W	We will argue that the concept of industrial ecology essentially calls for an integrated approach towards the environmental effects of industrial processes, rather than aiming at the reduction of the effects of separate industrial processes.	*Journal of Cleaner Production* (1997) Vol. 5, No. 1-2, p 79
Gertler N	Industrial ecology is an approach to economic activity and development modeled on this cyclic structure of natural ecosystems, in which the **flow** of materials **and** energy into and out of the industrial system is greatly reduced. The ecosystem ideal involves complete loop-closing, such that only limited amounts of energy are required as inputs to the industrial system. While such complete closure may be difficult to achieve in practice, industrial ecology guides development in that direction.	M.Sc. Thesis – Industrial Ecosystems: Developing Sustainable Industrial Structures. MIT; 27/06/1995, p 12; Available at: www.p2pays.org/ref/36/35538.pdf
Kirschner E	Industrial ecology applies the principles of natural systems – such as carrying capacity, material flows, resilience, and connectivity – to man-made systems.	*Chemical & Engineering News*, (1995), Vol. 73, No. 8. (20 Feb) p 15
Ehrenfeld J R	Industrial ecology is a large analytical framework that serves mostly to identify and enumerate the myriad flows of materials and technological artifacts within a web of producers and consumers.	*The Greening of Industrial Ecosystems*, Eds. B. R. Allenby and D. J. Richards. National Academy Press, Washington, DC, (1994), pp228-41.

Author (s)	Definitions/description	Reference
Ausubel J	Industrial ecology is the totality or the pattern of relationships between different industrial activities, their products and the environment. Analytically, industrial ecology is the network of all industrial processes as they may interact with each other and live off each other, economically and also in the sense of direct use of each other's material and energy wastes.	*Technology in Society* (1994), Vol. 16, No. 2, p 140
Allenby B	To manage the earth's resources in such a way as to approach and maintain a global carrying capacity for our species which is both desirable and sustainable over time, given continued evolution of technology and quality of life. The study of what this entails, especially in terms of existing (objective) and desirable (normative) patterns, is industrial ecology.	Allenby. B. R. 1993. Quoted in The Industrial Ecology Reader, Eds. R. Cote and J. Hall. Dalhousie University, Halifax, (1994), p. 7.
R Socolow, C Andrews, F. Berkhout V. Thomas. (Editors)	The goal of industrial ecology is the evolution of the world's industrial activity into sustainable and environmentally benign systems. As a field of study, it requires a long-range view and a deep analysis of the environmental implications of today's industrial systems and a creative approach to the design of services, products and government policy.	*Flysheet of Industrial Ecology and Global Change*. (Record of the Global Change Institute meeting held at Snowmass, Co. in 1992), Cambridge University Press, UK (1994)
Allenby & Richards, Editors	Industrial Ecology is the study of the flows of materials and energy in industrial and consumer activities, of the effects of these flows on the environment and of the influences of economic, political, regulatory and social factors on the flow, use and transformation of resources. The objective of industrial ecology is to understand better how we can integrate environmental concerns into our economic activities.	*The Greening of Industrial Ecosystems,* National Academy of Engineering (1994) (Preface p.v)
Tibbs H B C	Industrial ecology involves designing industrial infrastructures as if they were a series of interlocking manmade ecosystems interfacing with the natural global ecosystem. Industrial ecology takes the pattern of the natural environment as a model for solving environmental problems, creating a new paradigm for the industrial system as a process.	*Whole Earth Review*, (1992), Vol. 77(Winter) No. p4.
Ayres R U	The metabolism of industry is the whole integrated collection of physical processes that convert raw materials and energy, plus labour, into finished products and wastes in a more or less steady-state condition.	*Technology and Environment,* Eds. J. H. Ausubel and H. E. Sladovich; National Academy Press, (1989), p. 23-49.

Appendix 11: Details and results of the telephone campaign

The campaign took place between 29 June and 24 August 2010.

Key	
Successful	Spoke to the 'right' person – appropriate assistance available for bilateral symbiosis.
Unsuccessful	Spoke to the 'right' person but the organisation does not provide appropriate assistance for bilateral symbiosis.
Unsatisfactory	No response to messages or follow-up calls – contact subsequently abandoned.
TT	Total duration of all phone calls, in minutes
TC	Total number of phone calls made to an organisation.

Organisation	Phone Number	Result	Comment
Universities etc.			
Sydney	02 9351 2222	Unsatisfactory TT = 13 TC = 2	29/6/2010 – Call referred by Linda to environmental scientists; no response; mailbox full; hung up. 8/7/2010 – Call referred by Linda to Jodie Gonzales, Institute of Sustainable Solutions; answering machine message: Jodie no longer with ISS so contact 9351 7637. Danny suggested calling Sam Mostyn 0402 280 700; no answer, left message. No response.
New South Wales	02 9385 1000	Unsatisfactory TT = 4 TC = 1	29/6/2010 – Call referred to Prof. Chris Winder, School of Risk and Safety Sciences; not available; left message. No response.
UTS	02 9514 2000	TT = 11 TC = 5	29/6/2010 – Call referred to Research and Information Office (ROI); no answer; left message. 1/7/2010 – Jenny from ROI called and left a message to call them. 10/9/2010 – Called Cathy who took my details. Lean Caruso called and left a message.

Organisation	Phone Number	Result	Comment
UTS	02 9514 2000	TT = 11 TC = 5	13/9/2010 – Called Lean who referred me to the Institute of Sustainable Futures (ISF). Called ISF – no answer. 14/9/2010 – Called ISF – no answer again; abandoned contact
Macquarie	02 9850 7111	Unsatisfactory TT = 4 TC = 1	29/6/2010 – Call referred to the Science Faculty then to Gunnella Murphy, Graduate School of the Environment. Not available; left message.
Wollongong	02 4221 3555	Unsatisfactory TT = 6 TC = 1	29/6/2010 – Call referred to Engineering department then to Prof. Siva Sivakumar, Environmental engineer; not available; phone receptionist suggested contact by email.
Newcastle	02 4921 6025	Unsuccessful TT = 16 (approx) TC = 2	29/6/2010 – Pro Vice Chancellors office referred call to the School of Engineering; referred again to John Lucas, Chemical Engineer who works in land remediation; not available; left message. 30/6/2010 – John Lucas called: will undertake laboratory scale scientific assessment of soil remediation and similar work; limited human resources.
Canberra (UC)	02 6201 5111	Unsatisfactory TT = 11 TC = 2	30/6/2010 – Call referred to Marion Kingdom who suggested contacting the Alumni Area; Tracey Doherty, alumni events officer suggested environmental sciences. Called Department of Environmental Sciences; call referred to Dr Jim Horne or Adrian Davey; both not available; left message.
Western Sydney	02 9852 5222	Unsatisfactory TT = 5 TC = 1	30/6/2010 – Call referred to Engineering; contact undertook to find someone to call me and suggested contacting Sasha Alexander or Jonathan Allen, Department of Industrial Design. No one did and the contacts were not followed up because industrial design was thought to be too remote from industrial symbiosis.
Charles Sturt	02 6051 9850	Unsuccessful TT = 6 TC = 2	30/6/2010 – Called School of Environmental Sciences; phone receptionist will get someone to call. 1/7/2010 – someone called; they cannot help.

Organisation	Phone Number	Result	Comment
ANU	02 6125 5111	Unsatisfactory TT = 6 TC = 1	30/6/2010 – Call referred to School of Environment and Society then referred to ANUGreen, water & energy; no answer, mailbox full, hung up.
Southern Cross	02 6620 3000	Unsatisfactory TT = 6 TC = 1	08/7/2010 – Call to Lismore campus referred to environmental sciences; receptionist did not know who should take the call and suggested contacting the department by email.
CSIRO	1300 363 400	Unsatisfactory TT = 3 (approx) TC = 1	08/7/2010 – Phone receptionist suggested sending and email to general enquiries; the organisation will not respond without an email.
TAFE	1300 360 601	Unsuccessful TT = 32 TC = 3	08/7/2010 – Initial call answered automatically and put on hold; hung up after 5 minutes. Tried again, call answered automatically then referred to Kim at Head Office. She knew of no one who could help so suggested I contact Department of Education which oversees TAFE. Call taken by Cathy who spent 30 minutes searching databases for likely contacts but none were identified.
Consultants etc.			
Aecom	02 8295 3600	Unsatisfactory TT = 5 TC = 3	19/7/2010 – Call referred to the Environmental Group then to Josh Laskie 8295 4489; not available; left message. 20/7/2010 – Called Josh Laskie; not available. 27/7/2010 – Called Josh Laskie: he does not know of anyone in the organisation in Australia who facilitates industrial symbiosis. Send him an email and he will circulate it. Email sent 1600hrs on 27/7. 24/8/2010 – No response yet to the email sent 27/7.
Australian Waste Recyclers	02 9833 7034	Unsuccessful TT = 4 TC = 1	19/7/2010 – Call taken by Matt: the treat waste liquid and powder, they don't find uses for it.

Organisation	Phone Number	Result	Comment
Conacher Environmental Group	02 4324 7888	Unsuccessful TT = 1 TC = 1	19/7/2010 – Call taken by Fiona: they don't find uses for waste; try Douglas Partners (see below).
Environ Australia	02 9954 8100	Unsuccessful TT = 21 TC = 2	19/7/2010 – Call taken by Sharon: they are environmental consultants; they don't deal with waste; she will ask Sara Arthur to call me. 20/7/2010 – Sara Arthur (02 99548114) called: She knows of no organisation or person facilitating industrial symbiosis. She suggested I contact John Cook, a retired CEO in the waste management industry who is now a consultant and is very knowledgeable about industrial waste.
John Cook	02 9929 0520	Unsuccessful TT = N/a TC = 1	20/7/2010 – Call taken by John: he knows of no organisation or person facilitating industrial symbiosis in Australia.
GHD (Sydney)	02 9239 7100	Unsuccessful TT = 22 TC = 3	19/7/2010 – Call referred to David Chubb, head of the Environment Department; he referred me to David Gamble who runs the Waste Group (9239 7354). 20/7/2010 – Called David Gamble; not available. 22/7/2010 – Called David Gamble: GHD works mostly with municipal clients. They might try to find a use for waste but do not have the resources to facilitate industrial symbiosis. In any event, they do not deal with the private sector.
Douglas Partners (referral)	02 9809 0666	Unsuccessful TT = 7 TC = 1	19/7/2010 – Call taken by Nizam: they are an engineering company specialising in contamination; they don't deal with waste, per se.
Safe Waste Industries	1800 460 112	Unsatisfactory TT = 1 TC = 1	20/7/2010 – Call answered by a recorded message for an Auto Car Wash; no facility to leave a message; call abandoned.

Organisation	Phone Number	Result	Comment
Worley Parsons	02 8923 6866	Unsuccessful TT = 3 (approx) TC = 2	24/8/2010 – Call referred to Rob McQueen; not available. 25/8/2010 – Call taken by Rob McQueen: They advise on municipal waste and co-generation plants etc. They do not facilitate industrial symbiosis, and particularly would not do the research on uses etc. that such work involves.

Appendix 12: Chronological evolution of bilateral symbiosis at Kalundborg

(Sources include personal correspondence with Jørgen Christensen and Mogens Olesen, all of which is gratefully acknowledged)

Notes to Appendix 12

1 European Court of Justice.

2 Personal communication (email 16th May 2009) to Robin Branson from Mogens P. Olesen, retired Managing Director of Asnaes Power Station.

3 Personal correspondence 4 September 2010.

4 Source: UK Government Post Nate 84, October 1996 found at www.parliament.uk/documents/pn084.pdf

Year & Proj. #	Supplier	User	Material	Type (from the supplier's perspective)	Comments
1961 1	Kalundborg Municipality (KM)	The Oil Refinery (Veedol)	Water from Lake Tisso.	Raw Material	Veedol needed water for processing and cooling. Insufficient was available from conventional ground water (artesian) sources so arrangements were made to supply surface water via infrastructure, built by KM but financed by Veedol.
1972 2	The Oil Refinery (Esso)	Gyproc Manufacturer	Gas	Waste	Gyproc was a new enterprise. It was supplied only with flare gas which it bought cheaply. The transaction was motivated by a consulting engineer who persuaded Gyproc to contact the oil refinery. The supply of flare gas ceased in 1995. It was replaced initially with commercial supplies of propane from the refinery and subsequently with natural gas when the town was connected to the (national?) reticulation system.
1973 3	Kalundborg Municipality	Asnaes Power Station	Water from Lake Tisso	Raw material	Asnaes needed water for processing and cooling. Insufficient was available from conventional ground water (artesian) sources so arrangements were made to share the supply of surface water with Veedol.
1976 4	Novo Industri	Local Farms	Biomass residue of fermentation	Waste	Novo were prevented by the government from dumping sludge into the sea so they started suppling a few farms. The number rapidly grew into hundreds and the system of disposal remains unchanged (2010).

Year & Proj. #	Supplier	User	Material	Type (from the supplier's perspective)	Comments
1979 5	Asnaes Power Station	Aalborg Portland Cement Company	Fly ash	Waste	Before 1979 the fly ash was dumped. A very little was used for light concrete blocks. By 1979 Asnaes needed more space for dumping but it was difficult to get permission. Asnaes convinced the Danish cement industry that they should use it as an input because it produced cheaper and better cement. (It helped that Poland had started to sell cheap cement in Denmark).[2] It started supplying the Aalborg Portland Cement Company, the only cement manufacturer in Denmark which is approximately 170 km from Kalundborg by sea and approximately 200 km by road and sea.
1980 6	Asnaes Power Station	Fish Farm	Waste heat	Waste	Un-contaminated sea water (used for cooling) returned to the fjord at approximately 8 degrees C above ambient water temperature. The enterprise started as a small 'un-employment' project in which two biologists tried breeding trout in a few tanks on the quay side. The project was successful so the system was expanded and privatised.
1981 7	Asnaes Power Station	Kalundborg Municipality	Hot water for community heating	Product	Many places in Denmark have had district heating for decades before this project. An area of Copenhagen has had district heating, based of steam supplied by an electricity producer, since the early 1900s.
1982 8	Asnaes Power Station	Novo Industri (NI)	Steam	Product	NI originally had its own boilers but with rapid growth of the plant they became inadequate. NI saved a lot of money by using steam from Asnaes.

Year & Proj. #	Supplier	User	Material	Type (from the supplier's perspective)	Comments
1982 9	Asnaes Power Station	The Oil Refinery (Now Statoil)	Steam	Product	Esso (as it was then) originally had its own boilers but it became more cost effective to use steam from Asnaes.
1987 10	Kalundborg Municipality	Novo Industri (the part that became Novozymes)	Water from Lake Tisso	Raw material	The cooling water was used in enzyme production as well as pharmaceutical production which continued after the de-merger at Novozymes and at Novo Nordisk.
1987 11	The Oil Refinery (Statoil)	Asnaes Power Station	Cooling water	Waste	Before this arrangement, Statoil disposed of their cooling water to sewer without any cleaning; there was no reason to clean it. The water was subsequently purified at the power station for boiler make-up. Its slightly elevated temperature from the refinery would have been an advantage for this process.
1989 12	Novo Nordisk (NN) (ex Novo Industri)	Pig Farms	Yeast slurry	Waste	The yeast slurry was a small fraction of the biomass arising from enzyme production and was included in the biomass for distribution to farms. NN decided to keep the slurry separate and sell it as stock food, thereby generating income.
1990 13	The Oil Refinery (Statoil)	Kemira Denmark at Fredericia, Jutland	Liquid sulphur	By-product	Legislation required the supply of low sulphur oil for domestic heating and for vehicles. The Klaus Process was originally chosen specifically because it was the most reliable available at the time and the liquid sulphur produced had a market value for making sulphuric acid, a precursor for making fertiliser (See 2001). It was supplied to Kemira in Jutland, 86 km by sea and according to Brattebo, the arrangement ceased in 1992. Christensen[3] believes supplies to Kemira may have lasted longer than two years and that other users may have been supplied until the process changed in 2001.

Year & Proj. #	Supplier	User	Material	Type (from the supplier's perspective)	Comments
1991 14	The Oil Refinery (Statoil)	Asnaes Power Station	Technical Water	Waste	This comes from Statoil's waste water treatment plant.
1992 15	The Oil Refinery (Statoil)	Asnaes Power Station	Gas	Waste	The flare gas was bought by Asnaes (as it was by Gyproc) to supplement its fuel supplies. Statoil was motivated to sell it because it 'did not look good' to be wasting energy. Asnaes stopped using flare gas in 1997 (JC email 19/5/2011) because the supply became too unreliable as Statoil reduced its wastage and Asnaes had no other sources of gas to compensate for low supplies from Statoil. Subsequently, Statoil made use of the flare gas themselves.
1993 16	Asnaes Power Station	Gyproc Manufacturer	Gypsum (calcium sulphate)	By-product	Environmental legislation curtailed the discharge of sulphur compounds into the atmosphere. Asnaes deliberately chose a de-sox system that produced a saleable product instead of one that simply prepared as waste for dumping.
1995 17	Novo Nordisk (Originally part of Novo Industri)	Kalundborg Municipality (Waste water treatment plant)	Aqueous Effluent	Service	Novo Nordisk introduced a two-stage water treatment process. The first takes place at their own treatment plant, the second is done by KM. Novo pays KM for the service.
1995 18	The Oil Refinery (Statoil) and Asnaes Power Station	Asnaes Power Station	Water	Waste	Surface run-off drainage water is collected from both sites via a re-use basin constructed by Asnaes. The re-use basin was installed to act as a buffer to balance variation between supply and demand.
1998 19	Kalundborg Municipality (Waste water treatment plant)	Bioteknisk Jordrens – Soilrem	Sewage sludge	Waste	The sludge is used by Soilrem for bioremediation of contaminated soils. Previously the sludge was sent to farmers who were paid to receive it. Soilrem is also paid to receive it but the total cost of disposal is less.

Year & Proj. #	Supplier	User	Material	Type (from the supplier's perspective)	Comments
1999 20	Asnaes Power Station	Orimulsion (UK)	Fly ash – from which is recovered nickel & vanadium	Waste	In 1997 the power station converted 50% of its fuel to Orimulsion, comprising bitumen mined from the Orinoco belt in northern Venezuela emulsified with 30% water and 0.2% surfactant (nonylphenol ethoxylate). It contains 2.7% sulphur, 300 mg/g vanadium and 65 mg/kg nickel[4]. The ash from burning Orimulsion was sent to the UK for processing. The only reason for using Orimulsion was its cheapness compared with coal. The prices increased after a few years so Asnaes stopped using it. The recovery of heavy metals also stopped. From: www.allbusiness.com/mining/oil-gas-extraction-crude-petroleum-natural/826433-1.html – SK Power, Denmark, for 1.6m t/y for the 650 MW Asnaes plant, under a provisional three-year contract signed in 1996. A longer term contract is being negotiated. With Denmark applying one of the strictest environmental laws in Europe, SK Power had been testing the Orimulsion since 1994.
2000 8A	Asnaes Power Station	Novo Nordisk (Originally part of Novo Industri)	Steam	Product	This was simply the installation of another pipeline, duplicating that installed in 1982 to cater for increased demand.
2001 13A	The Oil Refinery (Statoil)	Fertiliser Industry	Ammonium thiosulphate (fertiliser)	By-product	New technology became available that produced ammonium thiosulphate which is used directly as a fertiliser, rather than as a precursor. This technology replaced the Klaus Process installed in 1990 because it is economically better.

Year & Proj. #	Supplier	User	Material	Type (from the supplier's perspective)	Comments
2002 21	Asnaes Power Station	The Oil Refinery (Statoil)	De-ionised water	Product	Asnaes de-ionises very large amounts of water for use in its own boilers so it was not a problem for them to supply the relatively small amount required by Statoil. The transaction was probably instigated by Statoil who would have preferred a central supply of high quality product than installing and maintaining their own de-ionising plant.
2004 22	Kalundborg Municipality (Water purification plant)	Novozymes (Originally part of Novo Industri)	De-ionised water	Service	Legislators prefer surface water to be used but will allow the use of ground water if absolutely necessary, which in Novozymes case it was. As a way of reducing its demand for ground water, KM built the water treatment plant specifically to process surface water for Novozymes and so help to preserves supplies of ground water for the future.
2005 23	Kara/Noveren	Gyproc	Plaster board	Waste	Scrap plasterboard recovered by Kara/ Noveren is sent to Gyproc for use.
2006 24	Novo Nordisk (Originally part of Novo Industri)	Kalundborg Municipality (Waste water treatment plant – wwtp)	Alcoholic effluent	Waste	Although harmless, the effluent is classified as hazardous waste and normally sent to a specialised treatment company, which is expensive. The KM wwtp needs carbohydrates to work well so they receive a truck load of the effluent from time to time.
2007 25	Asnaes Power Station	The Oil Refinery (Statoil)	Sea Water	Service	JC thinks this transaction probably came about because Statoil increased its demand (new expansion) and Asnaes had idle capacity due to closing down old units.
2008 26	Aluscan	Nordisk Aluminat	Aluminium hydroxide in waste water	Waste	Transaction instigated by JC Consult to save costs for Aluscan.

Year & Proj. #	Supplier	User	Material	Type (from the supplier's perspective)	Comments
2009 27	Asnaes Power Station	Inbicon	Steam	Product	Energy required by newly established ethanol plant on the power station site.
2009 28	Inbicon	Statoil	Ethanol	Product	Additives to petrol
2009 29	Farmers	Inbicon	Straw	Waste	Straw is used as a raw material for producing ethanol. According to the Dong website (see printout 20/5/11), the straw is waste, left over from harvest.
2009 30	Novo Nordisk /Novozymes	Kalundborg Municipality	Steam condensate	Waste	Some steam condensate is returned to KM via the district heating system.

Bibliography

Abraham, M. A., and N. Nguyen (2003), 'Green engineering: defining the principles': results from the Sandestin Conference, *Environmental Progress 22*(4), 4.

Addriansen, H. K., and L. M. Madsen (2009), Studying the making of geographical knowledge: the implications of insider interviews, *Norwegian Journal of Geography*, *63*, 145–53.

Adriansen, H. K., and L. M. Madsen (2009), Studying the making of geographical knowledge: the implications of insider interviews, *Norsk Geografisk Tidsskrift – Norwegian Journal of Geography*, *63*(3), 145–53.

Allenby, B. R. (2009), The industrial ecology of emerging technologies, *Journal of Industrial Ecology*, *13*(2), 168–83.

Allenby, B. R. (2003), Industrial Ecology Redivivus, *Journal of Industrial Ecology*, *6*(3–4), 4–6.

Allenby, B. R. and D. J. Richards (Eds) (1994), *The greening of industrial ecosystems*, Academy Press, Washington DC.

Altman, J., and R. van Berkel (eds)(2004), Industrial symbiosis for regional sustainability: an update on Australian initiatives, in *11th International Sustainable Development Research Conference*, pp. 1–10, Manchester, UK.

Anastas, P. T., and J. J. Breen (1997), Design for the environment and green chemistry: the heart and soul of industrial ecology, *Journal of Cleaner Production*, *5*(1–2), 97–102.

Anastas, P. T., L. G. Heine, and T. C. Williamson (2000), Green engineering: introduction, in *Green Engineering*, edited, pp. 1–5, American Chemical Society.

Anderson, J. C., H. Hakansson, and J. Johanson (1994), Dynamic business relationships within a business network context, *The Journal of Marketing*, *58*(4), 1–15.

Andrews, C. J. (2001), Building a micro moundation for industrial ecology, *Journal of Industrial Ecology*, *4*(3), 35–51.

Andrews, C. J., and J. Maurer (2001), Materials exchanges: an exploratory US survey, *Local Environment*, *6*(2), 149–68.

Arrow, K., et al. (1995), Economic growth, carrying capacity, and the environment, *Science, New Series*, *268(April)*(5210), 520–21.

Ashton, W. (2008), Understanding the organization of industrial ecosystems: a social network approach, *Journal of Industrial Ecology*, *12*(1), 34–51.

Ausubel, J. H. (1994), Directions for environmental technologies *Technology In Society*, *16*(2), 139–54.

Ayres, R., and J. van den Bergh (2005), A theory of economic growth with material/energy resources and dematerialization: interaction of three growth mechanisms, *Ecological Economics*, *55*(1), 96–118.

Ayres, R. U. (2000), Commentary on the utility of the ecological footprint concept, *Ecological Economics 32*, 347–49.

Ayres, R. U. (2004), On the life cycle metaphor: where ecology and economics diverge, *Ecological Economics*, *48*(4), 425–38.

Baas, L. (2008), Industrial symbiosis in the Rotterdam Harbour and industry complex: reflections on the interconnection of the techno-sphere with the social system, *Business Strategy and the Environment*, *17*(5), 330–40.

Baas, L. W., and D. Huisingh (2008), The synergistic role of embeddedness and capabilities in industrial symbiosis: illustration based upon 12 years of experience in the Rotterdam harbour and industry complex, *Progress in Industrial Ecology – An International Journal*, *5*(5–6), 399–421.

Backhaus, K. B., B. A. Stone, and K. Heiner (2002), Exploring the relationship between corporate social performance and employer attractiveness, *Business & Society*, *41*(3), 292–318.

Bailey, R., B. Bras, and J. K. Allen (2004), Applying ecological input–output flow analysis to material flows in industrial systems, *Journal of Industrial Ecology*, *8*(1–2), 69–91.

Bain, A., M. Shenoy, W. Ashton, and M. Chertow (2010), Industrial symbiosis and waste recovery in an Indian industrial area, *Resources, Conservation and Recycling*, *54*(12), 1278–87.

Baitheiemy, J. (2003), The seven deadly sins of outsourcing, *Academy of Management Executive*, *17*(2), 87–98.

Barnes, H. (1992), Survey on Denmark (11): fertile project exploits recycled wastes – Industrial Symbiosis, *Financial Times*, The Financial Times Limited, London.

Bartelmus, P. (2003), Dematerialization and capital maintenance: two sides of the sustainability coin, *Ecological Economics*, *46*(1), 61–81.

Baruch, Y. (1999), Response rate in academic studies – a comparative analysis, *Human Relations*, *52*(4), 421–38.

Baruch, Y., and B. C. Holtom (2008), Survey response rate levels and trends in organizational research, *Human Relations*, *61*(8), 1139–60.

Beach, E. S., Z. Cui, and P. T. Anastas (2009), Green chemistry: a design framework for sustainability, *Energy & Environmental Science*, *2*(10), 1038.

Beckett, R. C. (2000), Accessing corporate memory: some knowledge structure concepts, in *Global engineering, manufacturing and enterprise networks*, edited by N. L and M. J. P. T, pp. 2–16, Kluwer Academic.

Bernstein, W. J. (2004), *The birth of plenty*, McGraw Hill.

Binder, C. (2007), From material flow analysis to material flow management. Part I: social sciences modeling approaches coupled to MFA, *Journal of Cleaner Production*, *15*(17), 1596–604.

Blengini, G., and M. Busto (2009), The life cycle of rice: LCA of alternative agri-food chain management systems in Vercelli (Italy), *Journal of Environmental Management*, *90*(3), 1512–22.

Boons, F. (1998), Caught in the web: the dual nature of networks and its consequences, *Business Strategy and the Environment*, *7*, 204–12.

Boons, F., and J. Howard-Grenville (Eds) (2009), *The social embeddedness of industrial ecology*, Edward Elgar.

Boons, F. A. A., and L. W. Baas (1997), Types of industrial ecology: the problem of coordination, *Journal of Cleaner Production 5*(1–2), 79–86.

Bourg, D., and S. Erkman (2003), *Perspectives on industrial ecology*, Greenleaf Publishing Limited.

Breaux, D. M., P. L. Perrewe, A. T. Hall, D. D. Frink, and W. A. Hochwater (2008), Time to try a little tenderness? *Journal of Leadership and Organisational Studies*, *15*(2), 111–22.

Brundtland, G. H. (1987), *Our common future.* Oxford: Oxford University Press.

Cardew, R. V., J. V. Langdale, and D. C. Rich (Eds)(1982), *Why cities change: urban development and economic change in Sydney,* George Allen & Unwin Australia Pty. Ltd.

Chapman, C., and S. Ward (1997), *Project risk management processes, techniques and insights*, John Wiley & Sons.

Chertow, M. R. (1999), The eco-industrial park model reconsidered, *Journal of Industrial Ecology*, *2*(3), 8–10.

Chertow, M. R. (2000), Industrial symbiosis: literature and taxonomy, *Annual Review Energy Environment*, *25*, 313–37.

Chertow, M. R. (2007), 'Uncovering' industrial symbiosis, *Journal of Industrial Ecology*, *11*(1), 11–30.

Chertow, M. R., W. S. Ashton, and J. C. Espinosa (2008), Industrial symbiosis in Puerto Rico: environmentally related agglomeration economies, *Regional Studies*, *42*(10), 1299–312.

Chertow, M. R., and R. D. Lombardi (2005), Quantifying economic and environmental benefits of co–located firms, *Environmental Science & Technology*, *39*(17).

Chiu, A. S. F. (2004), Eco-industrial park development: initiatives in Asia Pacific, in *The first international environmental symposium for eco-polis*, pp. 1–15, Ulsan.

Choi, T. Y., K. J. Dooley, and M. Rungtusanatham (2001), Supply networks and complex adaptive systems: control versus emergence, *Journal of Operations Management, 19*, 351–66.

Christensen, J. (2006), The industrial symbiosis at Kalundborg, Denmark: a case study, in *International Conference EMAS 2 Environmental Certification*, Università IULM, Milano.

Clark, T., and C. Rollo (2001), Corporate initiatives in knowledge management, *Education + Training*, *43*(4/5), 206–14.

Cleland, D., I. (1994), *Project management: strategic design and implementation*, McGraw Hill.

Cleveland, C. J., and M. Ruth (1998), Indicators of dematerialization and the materials identity of use, *Journal of Industrial Ecology*, *2*(3), 15–50.

Clifford, N., and G. Valentine (2003), *Key methods in geography*, SAGE Publications.

Cohen, J. E. (1997), Population, economics, environment and culture: an introduction to human carrying capacity, *Journal of Applied Ecology*, *34*(6), 1325–33.

Connell, J. (2000), *Sydney: the emergence of a world city*, Oxford University Press.

Corning, P. A. (1995), Synergy and self-organization in the evolution of complex systems, *Systems Research 12*(2), 89–121.

Costa, I., G. Massard, and A. Agarwal (2010), Waste management policies for industrial symbiosis development: case studies in European countries, *Journal of Cleaner Production*, *18*(8), 815–22.

Crang, M. (2003), Qualitative methods: touchy, feely, look – see? *Progress in Human Geography*, *27*, 494–504.

Culaba, A. B., and M. R. I. Purvis (1999), A methodology for the life cycle and sustainability analysis of manufacturing processes, *Journal of Cleaner Production 7*, 435–45.

Daellenbach, U. S., A. M. McCarthy, and T. S. Schoenecker (1999), Commitment to innovation, *R&D Management*, *29*(3), 199–208.

Davis, C., I. Nikolic, and G. P. J. Dijkema (2010), Industrial ecology 2.0, *Journal of Industrial Ecology*, *14*(5), 707–26.

Dawkins, R. (1989), *The selfish gene*, Oxford University Press.

den Hond, F. (2000), Industrial ecology: a review, *Regional Environmental Change*, *1*(2), 60–69.

Department of Environment and Conservation (2007), Environmental guidelines: assessment, classification & management of liquid and non-liquid wastes.

Department of the Environment, Heritage and the Arts (2010), National waste policy: implementation plan.

Department of Sustainability Environment Water Population and Communities (2011a), National waste policy: less waste, more resources: national television and computer product stewardship scheme consultation paper on proposed regulations.

Department of Sustainability Environment Water Population and Communities (2011b), National Waste Policy Fact Sheet: Product Stewardship Act 2011.

Deschenes, P. J., and M. Chertow (2004), An island approach to industrial ecology: towards sustainability in the island context, *Journal of Environmental Planning and Management*, *47*(2), 201–17.

Desrochers, P. (2001), Cities and industrial symbiosis, *Journal of Industrial Ecology*, *5*(4), 29–44.

Desrochers, P. (2002), Regional development and inter-industry recycling linkages: some historical perspectives, *Entrepreneurship & Regional Development*, *14*(1), 49–65.

Desrochers, P. (2002a), Natural capitalist's indictment of traditional capitalism: a reappraisal, *Business Strategy and the Environment*, *2002*(11), 203–20.

Deutz, P., and D. Gibbs (2008), Industrial ecology and regional development: eco-industrial development as cluster policy, *Regional Studies*, *42*(10), 1313–28.

Deutz, P., and I. Lyons Donald (2008), Industrial symbiosis: an environmental perspective on regional development, *Regional Studies*, *42*(10), 1295–98.

Dewulf, J., and H. Vanlangenhove (2005), Integrating industrial ecology principles into a set of environmental sustainability indicators for technology assessment, *Resources, Conservation and Recycling*, *43*(4), 419–32.

Dijkema, G. P. J., and L. Basson (2009), Complexity and industrial ecology, *Journal of Industrial Ecology*, *13*(2), 157–64.

Diwekar, U. (2005), Green process design, industrial ecology, and sustainability: a systems analysis perspective, *Resources, Conservation and Recycling*, *44*(3), 215–35.

Dobers, P., and R. Wolff (1999), Eco-efficiency and dematerialisation: scenarios for new industrial logics in recycling industries, automobile and household appliances, *Business Strategy and the Environment*, *8*, 31–45.

Domenech, T., and M. Davies (2009), The social aspects of industrial symbiosis: the application of social network analysis and network theory to industrial symbiosis networks, *Progress in Industrial Ecology,* *An international Journal*, *6*(1), 68–99.

Ehrenfeld, J., and N. Gertler (1997), Industrial ecology in practice: the evolution of interdependence at Kalundborg, *Journal of Industrial Ecology*, *1*(1), 67–79.

Ehrenfeld, J. R. (1997), Industrial ecology: a framework for product and process design, *Journal of Cleaner Production 5*(1–2), 87–95.

Ehrenfeld, J. R. (2009), Understanding of complexity expands the reach of industrial ecology, *Journal of Industrial Ecology*, *13*(2), 165–167.

Elenkov, D. S., and I. M. Manev (2005), Top management leadership and influence on innovation: the role of socio-cultural context, *Journal of Management*, *31*(3), 381–402.

Engberg, H. (ed.) (1993), *Industrial symbiosis in Denmark*, pp. 1–27, New York University.

EPA, U. (2001), Beyond compliance: supplemental environmental Projects*Rep.*, US Environmental Protection Agency.

Erkman, S. (1997), Industrial ecology: an historical view, *Journal of Cleaner Production 5*(1–2), 1–10.

Erkman, S. (2001), Industrial ecology: a new perspective on the future of the industrial system, *Swiss Medical Weekly, 131*, 531–38.

Faber, N., R. Jorna, and J. van Engelen (2005), The sustainability of 'sustainability': a study into the conceptual foundations of the notion of 'sustainability', *Journal of Environmental Assessment Policy and Management*, *7*(1), 1–33.

Fagan, Robert (2000), Industrial change in the global city: Sydney's new spaces of production, pp. 144–66 in J. Connell (ed.), *Sydney: the emergence of a world city*, Oxford University Press, Melbourne.

Fischer–Kowalski, M., and C. Amann (2001), Beyond IPAT and Kuznets curves: globalization as a vital factor in analysing the environmental impact of socio-economic metabolism, *Population and Environment*, *23*(1), 7–47.

Flowerdew, R., and D. Martin (Eds) (1997), *Methods in human geography*, Addison Wesley Longman Ltd.

Frosch, R. A., and N. E. Gallopoulos (1989), Strategies for manufacturing, *Scientific American*, 144–52.

Garde, S., C. M. Hullin, R. Chen, T. Schuler, J. Gränz, P. Knaup, and E. J. S. Hovenga (2007), Towards sustainability of health information systems: how can we define, measure and achieve it? *MEDINFO*, 1179–83.

Garner, A., and G. A. Keoleian (1995), Industrial ecology: an introduction, 32 pp, Ann Arbor, MI: National Pollution Prevention Center for Higher Education, University of Michigan.

Gertler, N. (1995), Industrial ecosystems: developing sustainable industrial structures, 141 pp, Massachusetts Institute of Technology.

Gertler, N., and J. R. Ehrenfeld (1996), A down-to-earth approach to clean production, *Technology Review*, *99*(2), 48–54.

Gi, W. Y., and C. W. Trumbo (2000), Comparative response to a survey executed by post, e-mail, & web form, *Journal of Computer Mediated Communication*, *6*(1).

Gibbs, D. (2003), Trust and networking in inter-firm relations: the case of eco-industrial development, *Local Economy*, *18*(3), 222–236.

Gibbs, D., and P. Deutz (2007), Reflections on implementing industrial ecology through eco-industrial park development, *Journal of Cleaner Production*, *15*(17), 1683–95.

Gibbs, D., P. Deutz, and A. Proctor (2005), Industrial ecology and eco-industrial development: a potential paradigm for local and regional development? *Regional Studies*, *39*(2), 171–83.

Greening, D. W., and D. B. Turban (2000), Corporate social performance as a competitive advantage in attracting a quality workforce, *Business & Society*, *39*(3), 254–80.

Harding, R. (2006), Ecologically sustainable development: origins, implementation and challenges, *Desalination*, *187*(1–3), 229–39.

Harner, M. M. (2010), Ignoring the writing on the wall: the role of enterprise risk management in the economic crisis, *Journal of Business & Technology Law*, *5*, 45–58.

Harper, E., and T. E. Graedel (2004), Industrial ecology: a teenager's progress, *Technology in Society*, *26*(2–3), 433–45.

Harvey, M. G., and R. F. Lusch (1999), Balancing the intellectual capital books: intangible liabilities, *European Management Journal 17*(1), 85–92.

Haskins, C. (2006), Multidisciplinary investigation of eco-industrial parks, *Systems Engineering*, *9*(4), 313–30.

Heeres, R., W. Vermeulen, and F. Dewalle (2004), Eco-industrial park initiatives in the USA and the Netherlands: first lessons, *Journal of Cleaner Production*, *12*(8–10), 985–95.

Heikkila, J., and C. Cordon (2002), Outsourcing: a core or non-core strategic management decision? *Strategic Change*, *11*(4), 183–93.

Hemingway, C. A., and P. W. Maclagan (2004), Managers' personal values as drivers of corporate social responsibility, *Journal of Business Ethics*, *50*(1), 33–44.

Hewes, A. K., and D. I. Lyons (2008), The humanistic side of eco-industrial parks: champions and the role of trust, *Regional Studies*, *42*(10), 1329–42.

Hinterberger, F., F. Luks, and F. Schmidt-Bleek (1997), Material flows vs 'natural capital': what makes an economy sustainable? *Ecological Economics 23*, 1–14.

Jackson, T. (2008), The role of industrial symbiosis in promoting bio-fuel feedstock uses for UK food and fibre production, *Progress in Industrial Ecology: An International Journal*, *5*(4), 349–60.

Jacobsen, N. B. (2006), Industrial symbiosis in Kalundborg, Denmark: a quantitative assessment of economic and environmental aspects, *Journal of Industrial Ecology*, *10*(1–2), 239–55.

Jensen, P. D., L. Basson, E. E. Hellawell, M. R. Bailey, and M. Leach (2011), Quantifying 'geographic proximity': experiences from the United Kingdom's National Industrial Symbiosis Programme, *Resources, Conservation and Recycling*, *55*(7), 703–12.

Johnston, J. (2008), The citizen–consumer hybrid: ideological tensions and the case of Whole Foods Market, *Theory and Society*, *37*(3), 229–70.

Kaplowitz, M. D., T. D. Hadlock, and R. Levine (2004), A comparison of web and mail survey response rates, *Public Opinion Quarterly*, *68*(1), 94–101.

Kennedy, J., T. Mitchell, and S. Sefcik (1998), Disclosure of contingent environmental liabilities: some unintended consequences? *Journal of Accounting Research*, *36*(2), 257–77.

Kidd, C. V. (1992), The evolution of sustainability, *Journal of Agricultural and Environmental Ethics* 2–26.

Kincaid, J., and M. Overcash (2001), Industrial ecosystem development at the metropolitan level, *Journal of Industrial Ecology*, *5*(1), 117–24.

Kirchhoff, M. M. (2005), Promoting sustainability through green chemistry, *Resources, Conservation and Recycling*, *44*(3), 237–43.

Kitzes, J., A. Galli, M. Bagliani, J. Barrett, G. Dige, S. Ede, K. Erb, S. Giljum, H. Haberl, and C. Hails (2009), A research agenda for improving national ecological footprint accounts, *Ecological Economics*, *68*(7), 1991–2007.

Knight, L. (2009), What is waste that we should account for it? A look inside Queensland's ecological rucksack, *Geographical Research*, *47*(4), 422–33.

Knight, P. (1990), A rebirth of the pioneering spirit: Peter Knight visits an industrial estate in Denmark which trades waste, water and surplus energy, *Financial Times*, The Financial Times Ltd, London.

Korhonen, J. (2001), Four ecosystem principles for an industrial ecosystem, *Journal of Cleaner Production 9*(3), 253–59.

Korhonen, J., M. Wihersaari, and I. Savolained (1999), Industrial ecology of a regional energy system: the case of the Jyvaskyla region, Finland, *GMI*, *26*(Summer), 57–67.

Kronenberg, J. (2006), Industrial ecology and ecological economics, *Progress in Industrial Ecology: An International Journal*, *3*(1–2), 95–113.

Laverty, K. J. (1996), Economic 'short–termism': the debate, the unresolved issues, and the implications for management practice and research, *The Academy of Management Review*, *21*(3), 825–60.

Laybourn, P., and M. Morissey (2009), *National industrial symbiosis programme the pathway to a low carbon sustainable economy*, International Synergies Ltd, Birmingham UK.

Lenzen, M., D. Christopher, and F. Barney (2004), Energy requirements of Sydney households, *Ecological Economics*, *49*(3), 375–99.

Lenzen, M., C. Dey, and J. Murray (2001), A personal approach for teaching about climate change, in *Showcase of scholarly inquiry in teaching and learning*, University of Sydney, Sydney.

Lenzen, M., and J. Murray (2001), The role of equity and lifestyles in education about climate change: experiences from a large-scale teacher development program, *Canadian Journal of Environmental Education 6*(Spring), 32–51.

Lenzen, M., and S. A. Murray (2003), The ecological footprint: issues and trends. ISA Research Paper 01–03, pp. 1–27, The University of Sydney, Sydney

Lenzen, M., and S. Smith (1999/2000), Teaching responsibility for climate change: three neglected issues, *Australian Journal of Environmental Education*, *15/16*, 65–75.

Lenzen, M., M. Wier, C. Cohen, H. Hayami, S. Pachauri, and R. Schaeffer (2006), A comparative multivariate analysis of household energy requirements in Australia, Brazil, Denmark, India and Japan, *Energy*, *31*(2–3), 181–207.

Lifset, R. (2007), Reaching out but staying connected, *Journal of Industrial Ecology*, *11*(1), 1–3.

Lifset, R. (2009), Industrial ecology and public policy, *Journal of Industrial Ecology*, *9*(3), 1–3.

Lockie, S. (2009), Responsibility and agency within alternative food networks: assembling the 'citizen consumer', *Agriculture and Human Values*, *26*(3), 193–201.

Lombardi, R. D., and P. Laybourn (2011), Redefining industrial symbiosis: crossing academic–practitioner and disciplinary boundaries, *Journal of Industrial Ecology* (September).

Lyons, D. (2005), Integrating waste, manufacturing and industrial symbiosis: an analysis of recycling, remanufacturing and waste treatment firms in Texas, *Local Environment*, *10*(1), 71–86.

Marginson, D., and L. McAulay (2008), Exploring the debate on short-termism: a theoretical and empirical analysis, *Strategic Management Journal*, *29*(3), 273–92.

Margulis, L., and D. Sagan (1997), *Slanted truths: essays on Gaia, symbiosis and evolution*, Springer Verlag, New York.

Maxwell, T. P. (2003), Integrated spirituality, deep science and ecological awareness, *Zygon*, *38*(2), 257ff.

McDonough, W., and M. Braungart (2002), *Cradle to cradle: remaking the way we make things*, North Point Press, New York.

McDonough, W., M. Braungart, P. T. Anastas, and J. B. Zimmerman (2003), Applying the principles of green engineering to cradle-to-cradle design, *Environmental Science & Technology,* 435–41.

McDowell, L. (2001), Linking scales: or how to research about gender and organizations raises new issues for economic geography, *Journal of Economic Geography*, *1*, 227–50.

McIvor, R. (2000), A practical framework for understanding the outsourcing process, *Supply Chain Management: An International Journal*, *5*(1), 22–36.

McManus, P., and D. Gibbs (2008), Industrial ecosystems? The use of tropes in the literature of industrial ecology and eco-industrial parks, *Progress in Human Geography*, *32*(4), 525–40.

Mebratu, D. (1998), Sustainability and sustainable development: historical and conceptual review, *Environment Impact Assessment Review 18*, 493–520.

Mirata, M. (2004), Experiences from early stages of a national industrial symbiosis programme in the UK: determinants and coordination challenges, *Journal of Cleaner Production*, *12*(8–10), 967–83.

Mirata, M., and T. Emtairah (2005), Industrial symbiosis networks and the contribution to environmental innovation: the case of the Landskrona industrial symbiosis programme, *Journal of Cleaner Production,* (13), 993–1002.

Murcott, S. (1997), Appendix A: definitions of sustainable development, paper presented at AAAS Annual Conference. IIASA 'Sustainability Indicators Symposium', Seattle WA, 16 February 1997.

Næss, P., and K. G. Høyer (2009), The emperor's green clothes: growth, decoupling, and capitalism, *Capitalism Nature Socialism*, *20*(3), 74–95.

Nakicenovic, N. (1996), Decarbonization: doing more with less, *Technological Forecasting and Social Change 51*, 1–17.

Nasr, S. H. (2010), *Islamic life and thought*, Islamic Book Trust, Kuala Lumpur.

Nisbet, M. (1996), Role of cement plants in industrial ecosystems, paper presented at Proceedings of the Air and Waste Managements Association's Annual Meeting & Exhibition 1996, Air and Waste Management Association, 23 June 1996.

O'Neill, P., and J. K. Gibson-Graham (1999), Enterprise discourse and executive talk: stories that destabilize the company, *Transactions of the Institute of British Geographers, New Series*, *24*(1), 11–22.

Olesen, M. P. (1999), The industrial symbiosis at Kalundborg, *International Journal of Power Plant Technology,* (10/99), 52–54.

O'Riordan, T. and J. Cameron (eds) (1994), *Interpreting the precautionary principle*, Earthscan Publications Ltd, London.

Park, H.-S., E. R. Rene, S.-M. Choi, and A. S. F. Chiu (2008), Strategies for sustainable development of industrial park in Ulsan, South Korea: from spontaneous evolution to systematic expansion of industrial symbiosis, *Journal of Environmental Management*, *87*(1), 1–13.

Posch, A. (2010), Industrial recycling networks as starting points for broader sustainability-oriented cooperation? *Journal of Industrial Ecology*, *14*(2), 242–57.

Prokopenko, M., F. Boschetti, and A. J. Ryan (2009), An information-theoretic primer on complexity, self-organization, and emergence, *Complexity*, *15*(1), 11–28.

Rapoport, A. (1986), *General systems theory, essential concepts and applications*, Abacus Press.

Rees, W. E. (1996), Revisiting carrying capacity: area-based indicators of sustainability, *Population and Environment: A Journal of Interdisciplinary Studies*, *17*(3), 195–215.

Ristola, P., and M. Mirata (2007), Industrial symbiosis for more sustainable, localised industrial systems, *Progress in Industrial Ecology: An International Journal*, *4*(3–4), 184–204.

Roberts, B. (2004), The application of industrial ecology principles and planning guidelines for the development of eco-industrial parks: an Australian case study, *Journal of Cleaner production*, *12*(8–10), 997–1010.

Rose, G. (1997), Situating knowledges: positionality, reflexivities and other tactics, *Progress in Human Geography*, *21*(3), 305–320.

Rutherford, J., M. I. Logan, and G. J. Missen (1966), *New viewpoints in economic geography*, Martindale Press.

Sarros, J. C., B. K. Cooper, and J. C. Santora (2008), Building a climate of innovation through transformational leadership and organizational culture, *Journal of Leadership and Organisational Studies*, *15*(2), 145–158.

Schwarz, E. J., and K. W. Steininger (1997), Implementing nature's lesson: the industrial recycling network enhancing regional development, *Journal of Cleaner Production*, *5*(1–2), 47–56.

Scott, M.R., and D. Brown (2003), Corporate environmental reporting: what's in a metric? *Business Strategy and the Environment*, *12*(2), 87–106.

Seager, T. P., and T. L. Theis (2002), A uniform definition and quantitative basis for industrial ecology, *Journal of Cleaner Production 10*, 225–35.

Senden, L. (2005), Soft law, self-regulation and co-regulation in European law: where do they meet? *Electronic Journal of Comparative Law*, *9*(1), 1–27.

Seyfang, G. (2006), Ecological citizenship and sustainable consumption: examining local organic food networks, *Journal of Rural Studies*, *22*(4), 383–95.

Shiva, V. (1997), Western science and its destruction of local knowledge, in *The post–development reader*, edited by R. Majid, pp. 161–67, Zed Books; University Press, London UK.

Simsek, Z., M. H. Lubatkin, and S. W. Floyd (2003), Inter-firm networks and entrepreneurial behavior: a structural embeddedness perspective, *Journal of Management*, *29*(3), 427–42.

Sinclair, D. (1997), Self-regulation versus command and control? Beyond false dichotomies, *Law & Policy*, *19*(4), 529–59.

Socolow R., al. (1994), *Industrial ecology and global change*, Cambridge University Press.

Sun, J. W. (2000), Dematerialization and sustainable development *Sustainable Development*, *8*, 142–45.

Tansey, J. (2006), Industrial ecology and planning: assessing and socially embedding green technological systems, *Environment and Planning B: Planning and Design, 33*, 381–92.

Tyagi, R. K., and M. S. Sawhney (2010), High-performance product management: the impact of structure, process, competencies, and role definition, *Journal of Product Innovation and Management*, *27*, 83–96.

Uzzi, B. (1997), Social structure and competition in inter-firm networks: the paradox of embeddedness, *Administrative Science Quarterly*, *42*(1), 35–67.

van Berkel, R. (2005), Industrial symbiosis for sustainable resource processing: the cases of Kwinana and Gladstone (Australia), in *6th Asia Pacific Roundtable on Sustainable Production and Consumption*, Melbourne.

van Berkel, R. (2006), Regional resource synergies for sustainable development in heavy industrial areas: an overview of opportunities and experiences, Curtin University of Technology.

van Berkel, R., T. Fujita, S. Hashimoto, and M. Fujii (2009), Industrial symbiosis in Japan, *Environmental Science and Technology*, *43*(5), 1271–81.

van der Voet, E., L. van Oers, and I. Nikolic (2005), Dematerialization is just a matter of weight, *Journal of Industrial Ecology*, *8*(4), 121–37.

Vesilind, P. A., L. Heine, and S. Hamill (2007), Kermit's lament: it's not easy being green, *Journal of Professional Issues in Engineering Education and Practice*, 285–90.

von Malmborg, F. (2004), Networking for knowledge transfer: towards an understanding of local authority roles in regional industrial ecosystem management, *Business Strategy and the Environment*, *13*(5), 334–46.

von Weizsacker, E., A. B. Lovins, and L. H. Lovins (1997), *Factor 4: doubling wealth – halving resources,* Allen & Unwin.

Watts, B. M., J. Probert, and S. P. Bentley (2001), Developing markets for recyclate: perspectives from south Wales, *Resources, Conservation and Recycling 32*, 293–304.

Wells, P. E. (2006), Re-writing the ecological metaphor: part 1. *Progress in Industrial Ecology: An International Journal*, *3*(1/2), 114–28.

Wilmot, S. (2001), Corporate moral responsibility: what can we infer from our understanding of organisations? *Journal of Business Ethics 30*, 161–69.

Wolf, A., and K. Petersson (2007), Industrial symbiosis in the sweedish forest industry, *Progress in Industrial Ecology: An International Journal*, *4*(5), 348–62.

Wood, R., and M. Lenzen (2009), Aggregate measures of complex economic structure and evolution, *Journal of Industrial Ecology*, *13*(2), 264–83.

Yang, S., and N. Feng (2008), A case study of industrial symbiosis: Nanning Sugar Co., Ltd in China, *Resources, Conservation and Recycling*, *52,* 813–20.

York, R., E. A. Rosa, and T. Diets (2003), Footprints on the earth: the environmental consequences of modernity, *American Sociological Review*, *68*, 279–300.