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Industrial Symbiosis in Action

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Lombardi, D. Rachel and Laybourn, Peter, "Industrial Symbiosis in Action" (2007). *Forestry & Environmental Studies Publications Series*. 32.
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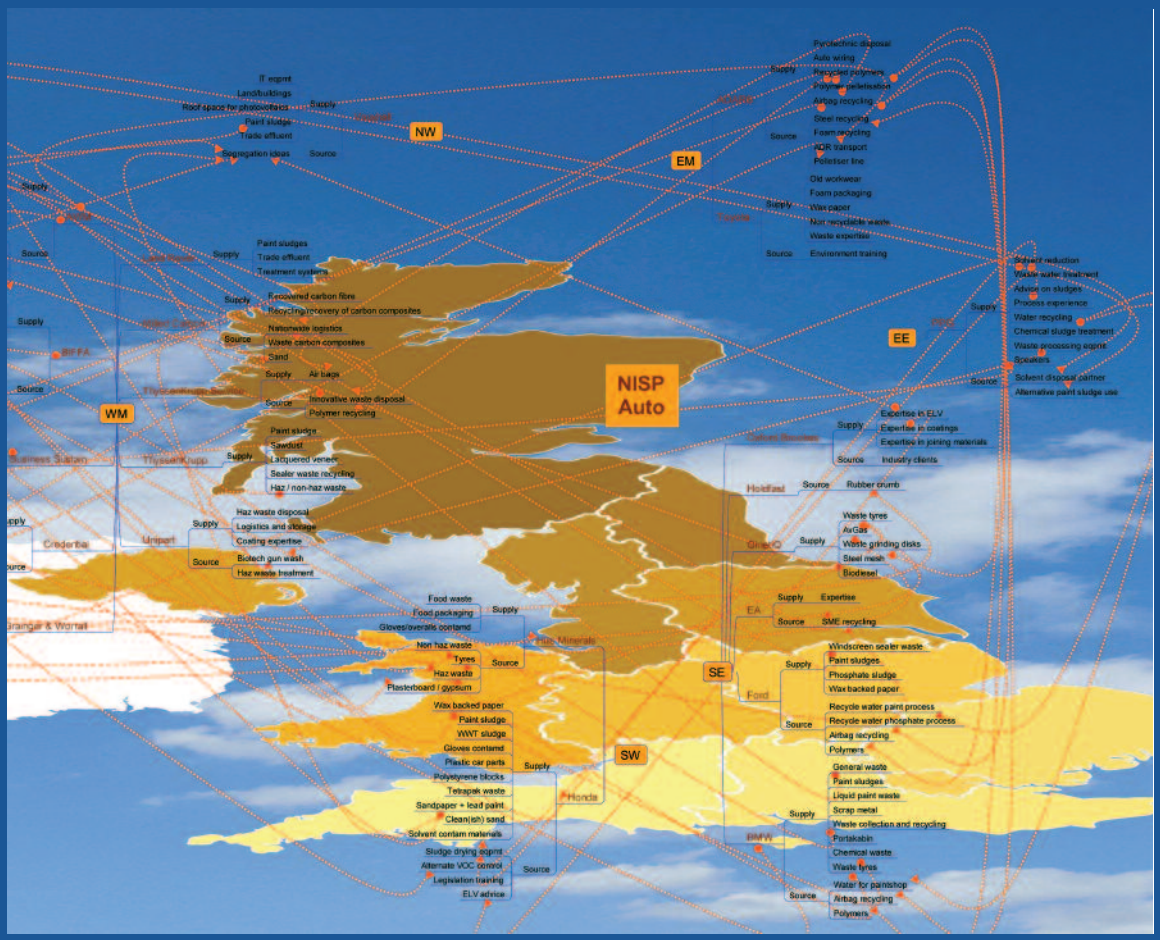
Report Number 12

Industrial Symbiosis in Action

Report on the Third International Industrial Symbiosis Research Symposium Birmingham, England, August 5–6, 2006

D. Rachel Lombardi, School of Engineering, University of Birmingham, UK
Peter Laybourn, National Industrial Symbiosis Programme, UK, EDITORS



YALE SCHOOL OF FORESTRY & ENVIRONMENTAL STUDIES

Yale F&ES Publication Series
Report Number 12

DATE OF REPORT	May 2007
REPORT EDITORS	D. Rachel Lombardi and Peter Laybourn
EDITORIAL ASSISTANCE	Valerie Petersen
SERIES EDITOR	Jane Coppock
COVER IMAGE	The cover image depicts a "mind-map" of resources from a typical workshop of the National Industrial Symbiosis Programme (NISP) in the UK.
COVER DESIGN	Bryan Gillespie, Yale RIS
PAGE LAYOUT	Dorothy Scott, North Branford, CT
PRINTING	Yale RIS
PAPER	100% post consumer, FSC-certified

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Industrial Symbiosis in Action

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With Thanks and Some Envy

Professor Marian Chertow, Center for Industrial Ecology,
Yale School of Forestry & Environmental Studies, USA

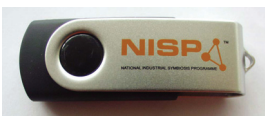
When we initiated the Industrial Symbiosis Research Symposium in 2004, who knew if there would ever be another? The timing must have been right, though, as the Symposia not only have continued, but also seem to improve greatly with age. The August 5-6, 2006, Birmingham Symposium, Industrial Symbiosis in Action, was as fine a meeting as I have ever attended, so with thanks and some envy (green, of course) I applaud the extraordinary role played by our host, Peter Laybourn, fearless leader of the largest industrial symbiosis program(me) in the world. Let me gratefully recognize our sponsor, Ralph Hepworth of Advantage West Midlands, who recognized the potential of bringing an analytic eye to the challenges of regional development.

Chris Rogers, Ramesh Rameswamy, Marian Chertow, Rachel Lombardi and Peter Laybourn

The mark of a great meeting is not only good and useful content, essential, of course, but the exceptional ones do something more: they create and enhance community. In the following pages this report will tell all that any reader may wish to know about the content of the meeting. I want to describe the spirit, the comraderie, and the attention to all of our worldly needs that made us feel proud to be industrial symbiosis researchers on a quest and delighted to be in Birmingham that special weekend.

Delegates are treated to a canal trip.

First, the logistics required us to walk from our conference hotel through the pedestrian walkways and grand city square of Birmingham. This allowed us to see that far from being sentimental about an industrial past, Birmingham was brimming with art, sculpture, and the future. The brand new conference facility was attractive, spacious, and literally let the daylight shine through so we never separated environment from our essential work. Dinner at the magnificent City Hall with Deputy Lord Mayor Mike Nangle made a grand impression on everyone. And how best to see the past and future of Birmingham on a Sunday morning? By canal boat, of course, with a narrated tour not only of the industrial symbiosis projects, but also of the history of Birmingham itself.



As material-generating as it may be, my heart was globally warmed by Peter's placement of the words "Industrial Symbiosis" on various paraphernalia. Move over university sweatshirts and hotel pens: we now have branded carrybags and large

capacity memory sticks that remind us time and again of what we are all about. Also, owing to the perseverance of ex-Yalie and current Birminghamite Dr. Rachel Lombardi and the support of International Synergies Limited, we have this very useful publication. Finally, all year, I have heard about connections that were made during our two days together: a book being outlined, academic programs being supported, jobs being created, and, oh yes, reduced emissions and increased material recovery wherever our band lurks.

Bravissimo. On to Toronto 2007!

Acknowledgements

Mr. Peter Laybourn, Programme Director, NISP, UK

At City Hall

They say that with age comes wisdom – not so in my case – when will I stop volunteering (although these days it usually means volunteering others) to do things! Having said that, offering to host the 2006 Symposium was one of my better commitments for a multitude of reasons. The IS research community is stimulating to work with and the inspiration for much of what we have attempted in the National Industrial Symbiosis Programme. We are quite rightly wrapped up in what we are aiming to achieve for the health of communities and the planet; but, our attempts are often frustrated for a number of reasons, from political to technical. However, for those of us in the privileged position to be applying industrial symbiosis as practitioners it is like being in a 'sweetie shop'. I will explain. To start a working day knowing that one could be working with any number of companies of any size, in any sector, about any resource, in any part of the country and at the end of it having contributed in some way to delivering environmental, economic and social benefits is a rare treat. Motivation personified!

Ralph Hepworth, Marian Chertow, Mike Nangle and Peter Laybourn

Industrial Symbiosis as a term is new to many (my own initiation was 1999, as I discuss in Session 1) and is understood by even fewer. It will not remain that way. Through the efforts of the research community and practitioners, I cannot see the decade ending without industrial symbiosis being a major contributor to sustainability in most parts of the world. There is a sense of urgency like never before that practical solutions are found to address pressing environmental problems that in turn place pressure on social and economic systems (to be honest does it matter what order we place these in?) On that urgent note I would like to thank all delegates for their time and contribution, to thank those that would have dearly loved to make it but for other commitments, and a special thanks to those who made it happen, namely:

Planning Committee: Weslynne Ashton, Marian Chertow, Roland Clift, Noel Jacobsen, Reid Lifset, and Rachel Lombardi

Event sponsor: Advantage West Midlands

Publication sponsor:

International Synergies
industrial ecology solutions

Host:

NISP™
NATIONAL INDUSTRIAL SYMBIOSIS PROGRAMME

Organised through: the University of Birmingham with support from the Engineering and Physical Sciences Research Council (EPSRC) Sustainable Urban Environment Program through a sequence of grants: GR/S 20482, EP/C 513177, and EP/E 021603.

UNIVERSITY OF BIRMINGHAM

EPSRC

Co-chairs: Professor Roland Clift of the University of Surrey, and Professor Chris Rogers of the University of Birmingham

The NISP team: I would especially like to thank the people I volunteered (!) for pulling it together: Marie Reynolds, Liz Quance, Will Clark, Dr. David-Huw Owen and James Woodcock.

Thanks to the Department for Environment, Food and Rural Affairs under their International Sustainable Consumption and Production programme for sponsoring a participant.

Special thanks to Deputy Lord Mayor Mike Nangle of Birmingham City Council for attending evening dinner and arranging an impromptu tour of the historic council chamber.

And thanks to the Yale School of Forestry & Environmental Studies Publication Series and its Editor Jane Coppock for publishing this report.

Industrial Symbiosis: Implementing Sustainable Development

Mr. Ralph Hepworth, Business Development Manager, Environmental Technologies Cluster, Advantage West Midlands, UK

Advantage West Midlands were delighted to sponsor the Third International Industrial Symbiosis Research Symposium held in Birmingham in August 2006. As a Regional Development (government) Agency tasked with the economic well being of the West Midlands region of England, and having a statutory responsibility for sustainable development, industrial symbiosis has been a significant weapon in our armoury in pursuit of both of these objectives.

Our support for industrial symbiosis dates back to 2003 when some early funding led to what is now known as the UK's National Industrial Symbiosis Programme (NISP); we continue to support NISP in the West Midlands. From our regional perspective, NISP has delivered new jobs and business start ups together with reductions in the cost base of industry whilst simultaneously delivering environmental 'goods' such as diverting wastes from landfill and reducing CO_2 emissions. All of these benefits have been achieved for modest investment in the programme, which has shown outstanding value for money.

There is a broader contribution to economic growth as well. The core of capability that has been built up by the National Industrial Symbiosis Programme attracts new business to the region, including inward investing companies that can take advantage of the resources available as a result of the programme. Industrial symbiosis acts as an accelerator in the development of environmental technology companies, the 'solution providers' in the industrial symbiosis network, who are then better able to address export markets.

We supported the Symposium because we recognise that the practical application of industrial symbiosis has been born out of academic research, and we are proud of our small contribution in encouraging this pioneering work at an applied level. We also welcome the increasing international standing in which your work is held. We live in a global economy, with many problems in common, and the exchange of knowledge of this type can play a large part in finding common solutions. It was a particular pleasure to meet like minded people from India, China, Korea and The Philippines, amongst many others, at the symposium.

There was another particular pleasure also that came from the breadth of expertise represented at the Symposium: engineers, material scientists, social scientists and others. This deep interdisciplinary commitment was invigorating to work with and must be very relevant to today's challenges. Industrial symbiosis may be a young research field but, with this quality of interest, must have a major contribution to make, not least to Agencies like my own.

We commend the IS research community for your efforts and would urge you to continue finding the language, tools and techniques that are needed to encourage business and government to move down the paths you identify. For our part, we will continue to champion industrial symbiosis and look forward to much collaboration.

Advantage West Midlands

Introduction and Overview

Mr. Peter Laybourn, Director of NISP, UK, Dr. D. Rachel Lombardi, University of Birmingham, UK, Professor Roland Clift, University of Surrey, UK, and Professor Chris Rogers, University of Birmingham, UK

THE EVOLUTION OF A SYMPOSIUM: WHAT CHANGES . . .

Welcome to this report on the Third Annual Industrial Symbiosis Research Symposium (ISRS), held in Birmingham, UK, on 5-6 August, 2006. The first ISRS was held at Yale University 7-9 January 2004, initiated by Professor Marian Chertow and the Yale Center for Industrial Ecology.[1] Researchers and practitioners from 15 countries were invited to discuss the current state of knowledge in the field of IS. In 2005, the second annual Symposium took place in Stockholm, at the Royal Institute of Technology (see Appendix 3), funded by the Nordic Council of Ministers, targeting primarily the academic and research community to identify and discuss ongoing theoretical and empirical research.

The emphasis of these symposia has been on generating discussion and setting the research agenda for those studying industrial symbiosis (IS). This year's title 'IS in Action' is indicative of our progress, both in understanding and in implementing IS around the world, and perhaps appropriately held outside a university campus for the first time. Three years ago, our agenda focused on WHAT we could do; now we are examining HOW – as evidenced by our host, the UK National Industrial Symbiosis Programme, the first national IS programme in the world, now a European Eco-Innovation exemplar only 3 years in! (We should all have taken him quite seriously when Peter Laybourn introduced himself at the 2004 ISRS with ". . . and I'm here to pinch your ideas!"). Perhaps NISP is a forerunner in terms of practical implementation providing an insight into actual environmental and commercial successes of industrial symbiosis on a large scale. We also have for the first time a presentation from a major company to explain its attraction to industrial symbiosis. From 2004 and 2005 to the present, one notices a reduced focus on barriers and an increasing focus on opportunities for IS. There is an increased emphasis on engagement models to facilitate network development.

[1] Editors' Note: Proceedings of the First Annual Industrial Symbiosis Research Symposium on are available for free download at http://www.environment.yale.edu/2534/current_titles/and http://www.yale.edu/environment/publications

AND WHAT DOESN'T: THE KEY ISSUES CONTINUE

Four key issues identified in 2004 for further research and discussion continued to evolve in 2006:

- **Definition of IS**, while not a session in itself this year, arose a number of times as the group searched for common themes across geographies and economies to inform the definition of IS (see Sessions 2, 3A, 4);
- **Implementation of IS** featured centrally with our host NISP and substantial contribution from many others, academics and non-academics alike, involved in implementation throughout the world; the recurring theme of what structures (institutional, political, legal and economic) were needed to facilitate IS networks and implementation (all sessions);
- **Quantification of benefits** is of critical importance to NISP for securing their government funding, and to others making the business case for exchanges (see Sessions 1, 4) and those interested in benchmarking (see Sessions 1, 2); the distribution of benefits was discussed as well (Session 4); and
- **Role of other disciplines** featured prominently in Session 4 with particularly lively debate and active engagement around the social science contribution to understanding and advancing IS.

Additional recurring themes are addressed further in the Themes and Future Directions section:

- **Two emerging paradigms**: the planned IS paradigm being implemented in Korea and China, for example, versus the voluntary IS paradigm found in Denmark, Austria and the UK.
- **Facilitated networks and working cross sector** as mentioned above were central to every presentation.

INDUSTRIAL SYMBIOSIS FULFILLING THE TRANSLATION ROLE

We are reminded of the adage 'what gets measured, gets managed.' Looking across the stakeholders involved in industrial symbiosis in the UK: the government agencies focus on climate change, economic development, and waste strategy; NISP measures outputs in metrics dictated by its funders (i.e. government) in terms of water, energy, waste, CO_2, and so on; companies focus on their specific resources, be it pumice or sludge, and the regulations and costs associated with them; for IS practitioners, that water isn't water – water is characterised by its contaminants, flow pattern and temperature – characteristics that limit or enhance its usefulness. There are a host of levels of translation going on, and yet everyone is supposed to be working toward the same goal of sustainability: companies are not accustomed (yet) to thinking in terms of climate change, and governments tend not to think about sludge, per se. There is a role for some structure, some facilitation to connect the various parties, to engage them to work toward a more sustainable outcome.

We suggest that IS could provide this facilitative role as it can move easily (with its broad community), if not seamlessly, between agents of economic and environmental policy and across all sectors of production. As was evidenced throughout the Symposium, some of the greatest challenges are around communication and the decision making processes, which requires bringing together the different agendas, finding a common language in which to communicate, agreeing upon common goals and, finally, forging a path forward.

'WHY ME AND HERE'

One of our chairpersons is faced with many of the same challenges identified above, but in a different context. Professor Chris Rogers of the University of Birmingham brings a new voice to the IS community. A geotechnical engineer, the bulk of his work still focuses on underground infrastructure, soils, and tunnelling. A few years ago, he was drawn into a project to bridge the sustainability divide – theory to implementation: understanding a complex decision making process, working toward a common language, facilitating more sustainable actions. The project, part of a national effort to advance Sustainable Urban Environments, is exploring how sustainability is incorporated (or not) into the urban regeneration process in Birmingham's Eastside. The multi-disciplinary team (urban planner, environmental geoscientist, an infrastructure engineer and landscape designer/chartered town planner, joined in March 2006 by an industrial ecologist) works together to produce a holistic, inter-disciplinary approach to the study.

The barriers to sustainability in the field of urban regeneration may ring true to some in the field of IS: practitioners' lack of experience, lack of certainty, lack of willingness to do things differently, lack of understanding what sustainability truly means. The current phase of research highlights path-dependency and lock-in arising from decision points in the development process – again concepts that may resonate with some in IS. Professor Rogers' research seeks to influence the planning process – one of the frontiers of IS discussed this year (see Session 3B).

COMMON CHALLENGES

Co-chair Professor Roland Clift pointed out the further similarities between Professor Rogers' work implementing sustainability in urban regeneration and our own implementing sustainability via IS: what we're doing isn't always well-defined or understood, nor is the decision-making process and its stakeholders. The definition of IS will no doubt continue to be discussed, debated and refined by this community (Mr. Laybourn adds to the fray in Session 1). As for the networks that make IS happen – who are the decision makers, what motivates them – Professor Clift made the following observation. He described our most commonly cited IS example, Kalundborg, Denmark, thusly: "Looking at it as a chemical engineer, there's technologically nothing remarkable about it whatsoever, it's just an integrated chemical complex." What's remarkable is how the relationships built up that enabled different corporations in different industries to behave as if they were a single

integrated complex. The creation, development and role of networks in implementing IS was a challenge all could relate to, regardless of where on the globe they called home.

ROADMAP OF THE CONFERENCE REPORT

As mentioned, the report for the 2004 ISRS are available on the web (http://www.environment.yale.edu/2534/current_titles/ and http://www.yale.edu/environment/publications).

While there were no independent proceedings for 2005, a summary is provided as an appendix in this document. This year, we tried to do something different – as the Symposia have the explicit goal of setting a research agenda, we tried this year to engage with speakers and participants to create more of a group output. All Symposium attendees were invited to submit their impressions, takeaways, and thoughts from the meeting for inclusion in this report. Some speakers provided written summaries – these are presented with a brief introduction in italics preceding the speakers' contribution. For the rest, a summary was written by us based on notes, presentation slides, and the video tapes of the event.

At the end of most sections, the group's discussion and debate is synthesised in the form of research questions. We have strived to represent the contributions in a thought-provoking manner – in most cases, names have been omitted. It goes without saying, but said it must be – the insights are the group's, any mistakes are ours alone.

OUR MISSION, SHOULD WE CHOOSE TO ACCEPT IT

Lest there be any doubt of the challenge we're up against with our mission of Industrial Symbiosis in Action, Professor Clift made explicit the barriers in our path right from the start: "I don't know if anyone else came here on foot this morning, but it reminded me of trying to find partners in IS: you wander around for half an hour in a light rain; there's nobody about to ask; there are no signposts – and when you finally end up, more or less by random, you are then given a map."

Let us hope that the future holds better weather, an enhanced community, and a clearer map!

SESSION 1: INTRODUCTION TO THE NATIONAL INDUSTRIAL SYMBIOSIS PROGRAMME

The Industrial Symbiosis Research Symposium (ISRS) was created in 2004 for the express purpose of giving researchers an opportunity to share their knowledge and experience on the state of the research and to establish research priorities; since that first year, a selection of practitioners have joined a host of academics to assist in grounding the research in applied industrial symbiosis (IS). This year, the Symposium was entitled 'Industrial Symbiosis in Action' to highlight the advances in implementation; our host, the National Industrial Symbiosis Programme (NISP) from the United Kingdom, is featured in this session, with the first commercial company to present at an ISRS.

In this first session, three perspectives on NISP were presented: Mr. Peter Laybourn, founder and programme director, described the origins of NISP, its achievements to date, challenges, and a vision for the future. Mr. Laybourn included specific questions on which he hoped the academic community would shed light and make NISP even more effective. Mr. Richard Heathcote of Scottish and Newcastle PLC, UK discussed the company perspective as a longstanding member of NISP: what benefits it has brought to his company, and some challenges to further work. And Mr. Abhishek Agarwal presented the issues surrounding the quantification of the benefits of IS exchanges, an issue raised by many at the ISRS, using NISP as an example.

NISP: Origins and Overview

Mr. Peter Laybourn, Programme Director of NISP, UK

The aim of this presentation was to update researchers on the inner workings of NISP and chart its rapid development since becoming a national programme in 2005. NISP's rapid growth has delivered a concomitant impressive range of economic, environmental and social benefits.

The origins of NISP date back to 1999 when I became aware of the By-Product Synergy (BPS) work going on in the Gulf of Mexico region by the U.S. Business Council for Sustainable Development (BCSD). The cost model used by the U.S. BCSD in BPS programmes was thought to be inappropriate for the UK business environment; consequently finding sources of public funding appeared to be the way ahead. In 2003, the umbrella idea of NISP was put into place enabled by grant funding from the Veolia Environmental Trust with a contribution from Advantage West Midlands, and was quickly followed by a sub-regional programme and two regional programmes.

There was no 'road map' for how to undertake such a programme on such a scale, so much of the early work was 'learning' on the job and making the type of mistakes that eventually led, through experience, to the development of effective tools and techniques for applied industrial symbiosis. To attract continued funding, the programme had to demonstrate economic benefit. Credibility in the programme was quickly established by exceeding all delivery promises (of outputs e.g. tonnages diverted from landfill, jobs creation, CO_2 reductions, cost reductions to business etc). Additionally, the scale of outputs far exceeded in value for money terms (i.e., tonnes of CO_2 diverted per pound investment) more traditional resource-efficiency programmes, and has continued to do so.

NISP was able to expand from its regional base to go national in April 2005 through funding from a 'hypothecated' landfill tax. Funding for the current year is set at £6M. NISP now has over 70 'practitioners' working on the programme across the 9 regions of England, plus Scotland and Wales and anticipates working in Northern Ireland soon, which would make it a truly national programme.[1] The governance of the programme is very important and in Corporate Social Responsibility terms gives us our 'licence to operate'. At a national level we have an independent board that includes as Chairman, Professor Paul Ekins, a leading academic (environmental

[1] In February 2007, NISP launched its Northern Ireland programme, making NISP truly national.

economist), and representatives from the regulator and government. Crucially, we have strong regional governance via programme advisory groups that are business-led. Being business and business opportunity-led is immensely important for engagement with the business community. This ensures that our regional teams maintain a sharp business focus. 'Membership' of NISP is now approaching 4000 industry members and includes companies from most sectors and of most sizes (from individual entrepreneurs through to multi nationals). The programme is also gaining international attention: trade missions have visited from countries such as China, Korea, Japan, and the USA.

WHERE WE ARE NOW

The principal outputs of the programme (excluding 'attribution' and 'persistence' factors: see Mr. Agarwal's presentation, this session) between April 2005 and June 2006:

- 1,483,646 tonnes diverted from landfill (of which 29% was hazardous wastes).
- 1,827,756 tonnes of virgin material saved.
- 1,272,069 tonnes CO_2 savings.
- 386,775,000 litres potable water savings.
- £36,080,200 additional sales for industry.
- £46,542,129 of cost savings to industry.
- 790 jobs created.
- £32,128,889 private capital investment in reprocessing.

The programme is sustainability in action: environmental, economic and social benefits. What adds to the credibility of the programme is that outputs are audited, underscoring the importance of metrics and measurement in industrial symbiosis programmes.

There have been a number of challenges on the route to success for NISP. There was no job description for an industrial symbiosis 'practitioner' and we have had to develop competency models en route on which to base our recruitment. The IS approach has had to compete for funding with traditional resource efficiency tools and agencies. Even at the governmental and funding levels there has been a lack of understanding as to how industrial symbiosis works and a tendency to 'pigeon-hole' IS as a waste or recycling programme. With a few notable exceptions, the funding institutions do not seem to readily embrace holistic programmes and thinking. At the outset of the programme there was an expectation that the issue of confidentiality would prove to be a major barrier for the IS network; fortunately it has not been a major factor in the UK. The concept of mutual benefit and partnership rather seems to unlock information between the parties and they are prepared to collaborate rather than compete. Having identified potential commercially viable (and low risk)

synergies has not necessarily led to their implementation. Occasionally the management culture of a company will revert to business as usual rather than look beyond their company boundary.

Currently our own practitioner resource is not optimised to achieve maximum outputs: the resources are spread quite evenly across the regions irrespective of the potential for IS in those regions, a result of the nature of the funding. Like the government funders, the press (both trade and nationals) has been slow to see IS as anything other than a 'recycling initiative' or a 'waste programme'. Progress is being made, however, and we hope it is only a matter of time before IS articles will be commonplace in mainstream business press. The benefit to industry, such as massive cost reductions and additional sales, raise pressures for industry to pay for the programme; we can see why this notion is attractive BUT there are several good reasons why we believe that some sort of public funding is necessary:

- **Information** – tends to be less free flowing when a percentage of the benefits is seen to be going elsewhere;
- **Honest broker** – currently as independent facilitators we are in a position of trust;
- **Legal** – a focus on contractual arrangements necessary to secure funding is a distraction to synergy outcomes;
- **Barriers to entry** – charging for participation limits membership and is a real barrier to the participation of smaller firms and potential solution providers;
- **Limiting opportunities** – with limited participants one is automatically limiting the IS opportunities;
- **Social return** – there is evidence that IS programmes return more in tax revenues to the public purse than they receive in grants;

In this case, it can be argued that industry is paying for NISP as the UK government committed to return a portion of the landfill tax escalator back to industry through a range of support programs, of which NISP is one.

Our understanding of IS has evolved since the first ISRS at Yale in 2004. Modifying Marian Chertow's definition distributed in 2003 for our own UK purposes yields the following (additions in italics) [Chertow 2000]:

> "Industrial symbiosis, as part of the emerging field of industrial ecology, requires attention to the flow of materials and energy through local, regional *and national* economies.
>
> Industrial symbiosis engages traditionally separate industries *and other organisations* in a collective approach to competitive advantage involving physical exchanges of materials, energy, water and/or by products *together with collaboration on the shared use of assets, logistics, expertise and knowledge transfer*).

> The keys to industrial symbiosis are collaboration, the synergistic possibilities offered by *relative* geographical proximity *and a demand led approach supported by third party facilitation*."

The principle modifications include: for a small country such as the UK, a national scale can be appropriate for synergy implementation – we're already shipping waste 200+ miles to landfill. The second modification is that where industries are already collaborating around materials, additional synergistic possibilities often arise for asset utilisation, logistics and knowledge transfer. The third is an acknowledgement that independent facilitation is necessary to advance.

FUTURE VISION

The ambition for the programme in the short term (~ 2010) is to attract double the existing funding, against which we anticipate being able to treble the numbers of companies involved in the programme and quadruple the outputs. Our confidence in this is based on an increasingly sophisticated tool called CRISP (Core Resources for Industrial Symbiosis Practitioners) and improving our facilitation model with industry, complemented with elements of sector engagement targeting such as Automotive and Construction.

Looking further to the future, NISP has aspirations in the following areas. To add to our current demand-led model of 'working with the willing' we can do more predictive modelling: identifying theoretical synergies for groups of companies based on our knowledge and database. Currently NISP is consulted on draft policy and has the opportunity to inform the final output based on technical evidence, at which time the framework of the policy is already set. NISP hopes to drive future policy frameworks so that collaborative action is stimulated and rewarded. NISP is keen to see many more IS programmes develop internationally, to be able to learn and benchmark against others. To date NISP has had limited impact on regional resource planning; we hope to build on the work of our NISP Yorkshire and Humber team (discussed by Dr. Bailey in Session 3B) to facilitate the coming together of the principal resource users (e.g. of water and energy) in a region to map out current usage and future demand, and to identify more sustainable systems for the future.

RESEARCH IDEAS

Academic research in the following areas would most help NISP at this point in its development:

- **Measurement of total programme impact:** To some extent NISP is reliant (for continuation of funding) on achieving specific output targets based on metrics around landfill diversion, cost reductions and so on. The programme also contributes, however, in terms of education and training, knowledge transfer, culture change within industry, research and development of new technologies and processes, and material substitution, to name just a few areas of additionality. Finding ways to quantify this

additionality is a challenge when the focus of attention is elsewhere. It may result that the additionality of IS programmes is more important than its initial 'hard' outputs.

- **Social network analysis:** The NISP network has evolved rapidly; understanding this network development could help us improve the network and the outputs realised from it. The work being undertaken by Jennifer Howard Grenville and Ray Paquin from Boston University (see Session 3A) is just the beginning of our learning about networks and could lead to some sort of 'gap analysis' that would enable us to strengthen the network.
- **Metrics:** To give policy makers options as to where to most effectively spend public monies, programmes need to be compared, usually against value for money parameters. We have been working with the independent research company Databuild Ltd to audit the programmes outputs, and with Abhishek Agerwal (Robert Gordon University, this Session) to examine our approach to metrics. Much more could be done in this area.
- **Predictive model:** Eventually we would like to do some predictive work to complement our current demand-led work. We have some experience from the early days of the programme of using a consultative approach (providing 'outside in' solutions) rather than a facilitative approach (where companies are involved in generating solutions from the beginning), the former having little success. Is there a better way to use predictive modelling to approach companies who are not part of a network?
- **Policy framework:** NISP is inherently reactive to background conditions of the market, regulation and policy framework. What within that policy framework could be changed to make the conditions for IS more favourable? We are looking to the policy insights of our chair Professor Paul Ekins from the Policy Studies Institute to help us understand how we can better exert influence.
- **Benchmarking:** We would be delighted to benchmark our approach against other practitioner models, and would like to know how applicable our own model might be to other economies.
- **Scalability:** We have already been asked by our government to give an indication of the scalability of the programme, i.e. how big can the network grow – 10,000 companies, 20,000, 50,000? Based on existing knowledge we have made an 'educated guess' as to what a network of 15,000 or so companies will look like and the outputs that would be forthcoming, but beyond that our current ability to predict is more limited.
- **New applications:** We suspect that IS has more to offer and perhaps other applications. By concentrating on industry we have not explored possibilities of using this approach within government areas such as the Health Service or Ministry of Defence, nor have we explored the relevance of the approach to small scale micro industries or office environments.

We believe close ties with academia will help us answer some of the above questions and indeed may already be contained within the literature BUT how accessible is the literature to practitioners and how user friendly and who will be doing the reviewing to extract the 'gems' that will give practitioners a greater range of tools and give fresh more effective options for the way forward?

REFERENCE

Chertow, M.R. 2000. Industrial Symbiosis: Literature and Taxonomy. *Annual Review of Energy and Environment* 25: 313-337.

NISP: Industry Involvement

Mr. Richard Heathcote, Scottish & Newcastle PLC, UK

Mr. Heathcote began his presentation with an introduction to Scottish & Newcastle (S&N), the UK's largest brewer. Part of the S&N group, Bulmers make cider from apples, 90% of which are grown in Herefordshire, UK, about 10 miles from the factory, to make 75M UK gallons of cider per year, which is exported worldwide.

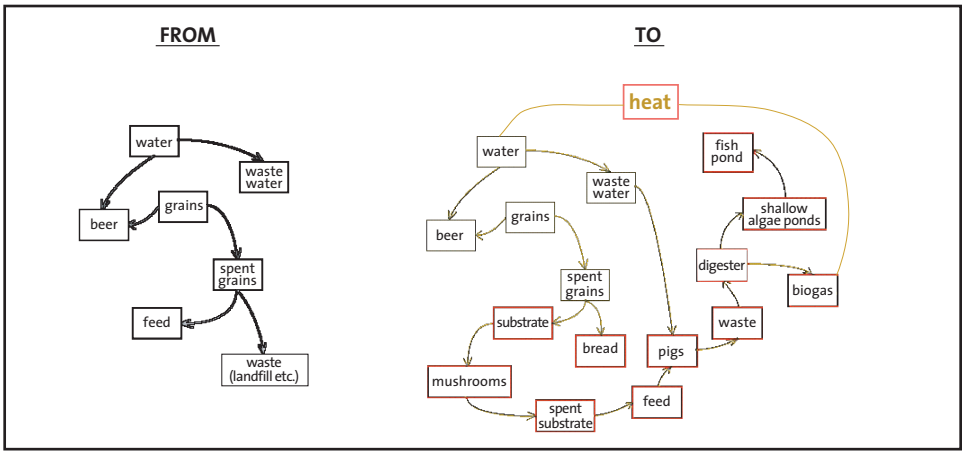
For Bulmers, becoming more sustainable means recognising and balancing their impacts along the three legs of the sustainability stool. As a manufacturer of alcohol, there are tensions on the social side: as Mr. Heathcote aptly observed, some people abuse alcohol and some people die from it. From the environmental side, raw materials are derived from the earth: the apples grow on trees (renewable) but their primary fuel is oil. Bulmers uses 1.5M m3 of water and generates: 34,000 tonnes of CO2 per year from energy use and distribution network; 40,000 tonnes of packaging (mostly discarded by consumer); 30,000 tonnes of organic waste. From the economic perspective, as a publicly owned and traded company, they must make money to survive.

The drivers for improving sustainability are many: gaining political support in recognition of the role (good and bad) that alcohol plays in society; cost reductions; generating commercial benefits; reputational benefits; and employee engagement & recruitment. Bulmers has strategic objectives of zero waste and sustainable development – the Global Zero Emissions Research & Initiatives Network (ZERI) has provided them a platform for thinking about zero waste. One of the earliest members of NISP, Bulmers sees IS as the 'wherewithal' to overcome barriers, and achieve resource efficiency and cost savings en route to achieving zero waste.

The ZERI Network (www.zeri.org) brought to their attention the cyclical flows around a brewery in Namibia; a number of similar ideas have now arisen at Bulmers. In seeking avenues to zero waste, Bulmers has come up against well intended regulation with perverse incentives. The apple pumice is allowed to be called a by-product provided it is used for animal or human consumption. If it leaves the manufacturing site or is used in any other way, it becomes classified as a waste, and something like 47 regulations come into play– a legislative nightmare. But Bulmers want to do other things with it besides feed it to pigs or cows. A mixture based on the apple peel may be suitable as a breeding base for slugs, marketable as fish bait. The

idea originated with a team in North Wales; Bulmers is interested in bringing the idea to scale, although there are logistical concerns that derive from a £1B+ turnover company working with a couple of technical people. The prunings from trees, currently burned, may be suitable for growing exotic mushrooms with a market potential of about £1M/year – an opportunity identified by one of Bulmers' orchard harvesters: through the NISP network, two interested would-be entrepreneurs have been identified. The spent yeast, after use in fermentation, has a high concentration of vitamins and phytochemicals. With NISP's help, funding from the UK Department of Trade and Industry was secured to do proof of concept work to extract vitamins from yeast working with Boots, a large chemist/pharmacist in the UK. One of NISP's case studies is the example of growing tomatoes in greenhouses with waste heat from factory – something Bulmers intend to copy as it is a good fit with a brewery producing a lot of CO_2 and waste/low grade heat. Or rather, grow exotic vegetables, which is a more lucrative market.

Figure 1 ZERI Brewery model, Namibia



Source: www.zeri.org

Participation in NISP has introduced to Bulmers new ways to look at supply chains: up, down, and cross-sector. For example, in the glass supply chain, currently about 70% of recycled glass goes to road-fill or landfill. This is beyond the control of a cider manufacturer – it's up to the retailers and consumers thereafter – but there is a potential a sector savings of £1.2M if the glass could be re-used.

The barriers Bulmers perceived to achieving their sustainability ambitions include the culture of seeing waste as waste – which is where ZERI has helped. There is an increasingly complex and difficult regulatory environment to deal with where new uses arise. Finally, like most companies, investment in non-core business is a difficult 'sell'. Bulmers relies on NISP for brainstorming, access to a network of expertise and implementation partners, innovation and R&D.

NISP: Towards Developing a New and Integrative Methodology to Evaluate Industrial Symbiosis Networks

Mr. Abhishek Agarwal and Dr. Peter Strachan, The Robert Gordon University, UK[2]

In this presentation, Mr. Agarwal and Dr. Strachan highlight the importance for measurement and quantification of results to NISP in order to satisfy NISP's funding bodies, and examine some of the difficulties encountered in capturing overall benefit. The factors of 'attribution' and 'persistence' are found to be particularly important.

[2] This presentation summary is a result of an ongoing research project conducted by the UK National Industrial Symbiosis Programme and Databuild Ltd. in collaboration with the Robert Gordon University.

INTRODUCTION

Following the completion of a comprehensive literature review (Agarwal and Strachan, 2006) in the area of eco-industrial development, the key focus of our current research has been to develop a framework to evaluate the effectiveness (i.e. the benefits and limitations) of industrial symbiosis (IS) networks. Despite a growing interest in eco-industrial development activities in various parts of the world, limited tools and techniques are available that can assist the evaluation of IS networks. It appears that one of the strategic mistakes that developers and/or co-ordinating bodies tend to make is to not quantify the effectiveness of IS networks. The aim of our research is to address this weakness by developing a new and integrative framework to evaluate the effectiveness of IS networks. In doing so, we hope to contribute to both theory development and professional practice in industrial ecology, and in particular eco-industrial development.

BACKGROUND

This research is set in the context of the UK National Industrial Symbiosis Programme (NISP) which is the first IS initiative to be launched on a national scale. Like the emissions trading scheme, the climate change levy and other environmental initiatives, NISP is a visible manifestation of the UK Government's commitment to

an agenda of ecological modernisation (Gibbs, 2003). There is now an emerging literature on evaluating key European Union (EU) and UK Government Programmes including e.g. the EU and UK Emissions Trading Scheme (von Malmborg & Strachan, 2005). Representing an attempt to contribute to broader debates regarding governance, sustainability, policy learning and implementation, this research is set firmly in the context of industrial ecology and eco-industrial development. Having worked in the field of environmental management for a number of years we are concerned that industrial ecology and eco-industrial development have failed to sufficiently influence mainstream policy and management. Having set the research into context, we now turn to the work of NISP.

EVALUATION EFFECTIVENESS: THE NEED FOR AN INTEGRATIVE MEASUREMENT FRAMEWORK

In facilitating our project it is helpful to note that, since the launch of NISP, regional co-ordinators (IS practitioners) have been encouraged to develop case studies of successful IS projects. NISP executives recognised that documenting cases would be an effective way to provide evidence of the economic, social and environmental benefits from member participation and further act as a marketing tool to promote its work. To date, more than forty cases have been developed e.g. an international solution to a UK waste problem, exchange of unused chemicals etc. (NISP 2006). It should be noted that to ensure a degree of rigour the data reported in company cases needed to be confirmed by participant members. However, inconsistencies have arisen in the way data is collected in different regions. Recognising this weakness, a consistent reporting method throughout the programme is being pursued. It is further anticipated that this will facilitate the UK Government's Business Resource Efficiency and Waste (BREW) Programme requirement that NISP produce a comprehensive list of programme outputs. It is also stipulated that NISP must have these outputs verified by an independent body. To satisfy this requirement, the research firm Databuild Ltd was contracted to verify the outputs claimed by NISP.

COMPLEXITY IN MEASURING EFFECTIVENESS

It should be noted that the involvement of various funding bodies in NISP activities and their different requirements adds greatly to the complexity of developing an evaluation framework. For example, the BREW programme partly funds NISP to achieve waste reduction targets whereas regional development agencies collaborate with the programme in order to achieve their economic development targets, that is, the creation of new jobs and business growth. In order to develop evaluation metrics for NISP, measures utilised within the UK BREW Programme metrics were given priority both by NISP and Databuild Ltd, as it takes into account the application of 'attribution' and 'persistence'.

ATTRIBUTION

Attribution is the notion that a particular intervention is responsible for a given outcome. In this case, attribution captures the perception of businesses involved regarding the degree of assistance they have received from NISP. In order to measure attribution, Databuild Ltd collected data from businesses to identify the proportion of benefits that were actually attributed to NISP. In addition, it was difficult to capture change(s) in business thinking/practice and longer term benefits arising from NISP's involvement.While there was some initial concern with this approach to assessing attribution, it has been robust because beneficiaries have tended to respond frankly.

PERSISTENCE

The application of persistence needs to estimate the time scale over which the benefits of a project are expected to last. It should be noted that because of developments in new technologies and processes, and the emergence of new products, the benefits of individual IS projects may decline over time.[3] Further, NISP has only been in existence for a few years and it is unable currently to fully capture persistence. The proportion of projects needs to be followed up after a number of years in order to establish a typical persistence factor and therefore capture persistence of any benefit(s) effectively.

[3] Editors' Note: Practitioners at this Symposium also provided examples where benefits increased over time.

Table 1 Outputs originated from NISP activities for the year 2005/2006

BREW	Reported outputs	Adjusting for attribution	Adjusting for persistence	Output per £1M invested
Materials diverted from landfill (tonnes)	636,852	393,670	1,360,395	388,684
Hazardous waste eliminated (tonnes)	221,625	110,813	289,531	82,723
Virgin materials saved (tonnes)	950,137	598,957	2,129,306	608,373
CO_2 saved (tonnes)	328,964	279,118	1,198,264	342,418
Water saved (tonnes)	264,475	132,238	330,594	94,455
Additional sales for business (£)	16,510,335	14,164,648	64,958,819	18,559,662
Cost savings to business (£)	36,449,707	31,585,723	145,768,655	41,648,185

Source: Adapted from NISP outputs report submitted to BREW Programme

FIRST YEAR NISP ACHIEVEMENTS

NISP's achievements for 2005/2006 are outlined in Table 1, and have been independently verified by Databuild Ltd. It involves all measures that satisfy BREW requirements and takes into account the application of attribution and persistence. Attribution has been measured on three levels: None – 0%, Partial – 50% and Full – 100%. The approach to persistence in measuring the benefits has been flexible as it was found difficult to establish persistence individually for every project until or unless a typical persistence factor had been established. In cases where persistence cannot be estimated, the benefits of the projects were assumed to last for 5 years gradually decreasing by 25% every year.

CONCLUSION

This presentation summary introduced NISP's efforts towards a new approach to evaluating their effectiveness. We would also like to share some further lessons that have arisen from our work with NISP, as they might be of interest to other IS practitioners. These include the need to:

(i) maintain up-to-date information regarding the nature and scope of symbiosis taking place in a programme/project;

(ii) have consistent data collection throughout a programme/project;

(iii) develop typical persistence factors; and

(iv) capture additional benefits e.g. innovation and skills building.

NISP and Databuild Ltd in collaboration with the Robert Gordon University are continuing to develop evaluation models, frameworks and tools, and we look forward to sharing our findings with you in the future.

REFERENCES

Agarwal, A., and P.A. Strachan. 2006. *Evaluation Methodologies to Measure Performance of Eco-industrial Development Initiatives: A Consultancy Report prepared for Databuild Ltd. and the UK National Industrial Symbiosis Programme* Aberdeen: Robert Gordon University.

Gibbs, D. 2003. Ecological Modernisation and Local Economic Development: The Growth of Eco-industrial Development Initiatives. *International Journal of Environment and Sustainable Development* 2 (3): 1-17.

NISP. 2006. *Case Studies: NISP in Action* UK National Industrial Symbiosis Programme, available from http://www.nisp.org.uk/case_study_index.aspx (accessed on 25th July 2006).

von Malmborg, F. and P.A. Strachan. 2005. Climate Policy, Ecological Modernization and the United Kingdom Emissions Trading Scheme. *European Environment* 15(3): 143-160.

SESSION 2:
INDUSTRIAL SYMBIOSIS HOT SPOTS

The goal of Session 2 was to explore how IS is taking shape around the world, models both geographic and technical. Geographically, speakers were invited to address those areas in the world with dynamic programs the group should catch up on: Australia, Korea, China, and North America. The technical 'hotspot' addressed how information models are being used in IS – the topic of the 2007 ISRS in Toronto, Canada.

In the first ISRS in 2004, we grappled with 'what is IS;' certain themes recur across geographies, giving some indication of the nature of IS, however defined. Facilitation is key: what structures (physical and institutional) need to be put in place to facilitate IS exchanges? What is the role of eco-industrial parks in facilitation? What is the role of government and policy?

Industrial Symbiosis Activity in Australia

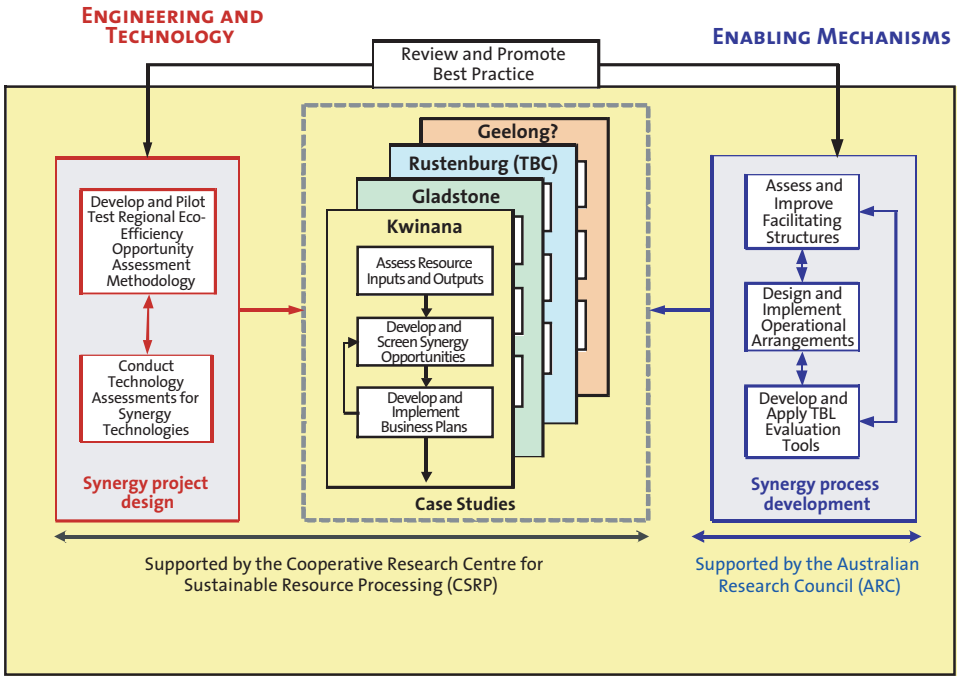
Dr. Steve Harris, Centre of Excellence in Cleaner Production,
Curtin University of Technology, Australia

In the first presentation on IS activity in Australia, Dr. Harris discussed the value of the facilitated approach, and movement towards the creation of customised methodologies and tools for IS development. He also identified the need for consistent and transparent methodology for tracking benefits.

The main industrial symbiosis (IS) activities in Australia occur in the heavy industrial areas of Kwinana (Western Australia, overseen by Curtin University of Technology) and Gladstone (Queensland, overseen by University of Queensland). There are two funded, interlinked research programmes that are supporting the development of further IS exchanges: the first, funded by the Australian Research Council, examines ways to foster the greater uptake of IS through facilitating structures that encourage information sharing and collaboration, guidance for companies on reaching contractual agreements, and evaluation methods to assess the triple bottom line benefits of IS; the second, funded by the Centre for Sustainable Resource Processing (www.csrp.com.au), provides practical support to industries to identify and develop IS at Kwinana and Gladstone, and includes a foundation project to create customised methodologies and tools for IS development. Promising developments have recently occurred that could see IS projects developing in Geelong (Victoria, Australia), Wagga Wagga (NSW, Australia) and Rustenburg (South Africa).

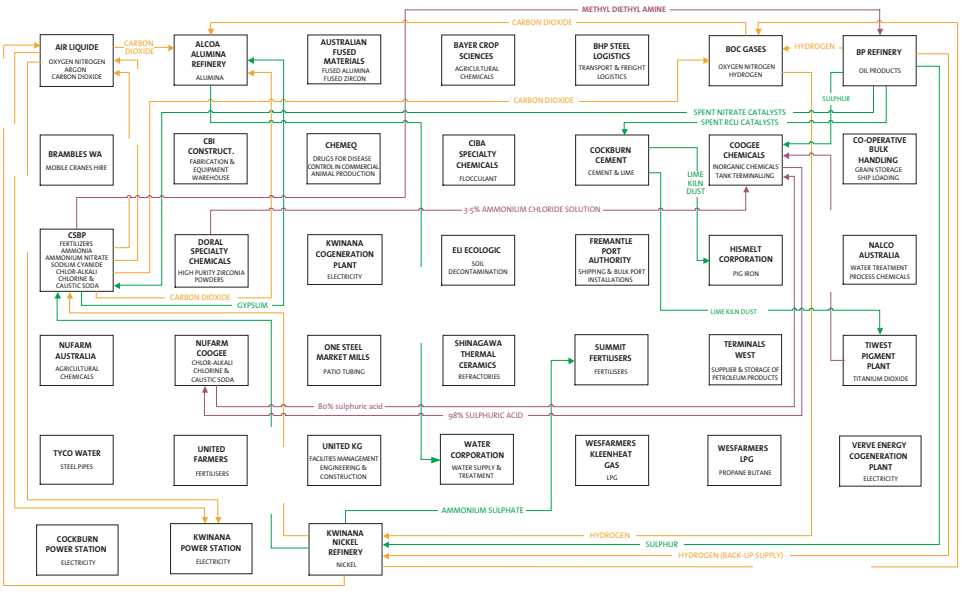
In the Kwinana area, with 48 existing exchanges, the research identified over 90 potential IS exchanges [van Beers et al 2005; see Figure 2]. A screening method was developed that helped select the most promising exchanges to initially target. Current efforts focus on the development of 9 short-listed opportunities: ammonium sulphate, sodium sulphate, electrodes, grain, zirconium waste, treated effluent, oily wastewater, dust suppression water, and demineralised water. Similarly, work in the Gladstone region (currently 7 existing exchanges) is focussing on the following key areas: utilising consolidated waste as alternative fuel, water re-use and monitoring technology developments for large waste streams.

Figure 1 The main industrial symbiosis activities in Australia



Source: van Berkel 2006

Figure 2 Existing By-product Synergies in Kwinana



Source: van Beers et al. 2005

Recently a review of 22 of the world's most notable IS networks [van Berkel 2006] reported 162 exemplary exchanges. The review suggested that three 'success factors' necessary for IS projects to be realised were:

- **Convincing business case:** an opportunity to reduce costs, generate new revenue and/or secure access to vital resources that can be materialised by one or more businesses; and
- **Societal license to operate:** at the minimum all government approvals should be in place, but preferably also endorsement from affected communities, key non-governmental organisations and/or an opportunity to create or improve skills, jobs and/or livelihoods; and
- **Proven technology:** process and equipment are available to make the resource synergy happen, so that the resource is being transferred between the companies involved and converted as and when required.

In the Kwinana area, current barriers to further synergies are community opposition and regulatory issues. This has resulted in recent plans to develop a communication strategy (that will help promote the positive aspect of synergies to the community, government, and other stakeholders) and a regulatory issues paper (to educate the regulators on the positive aspects of synergies and how current regulations and policy are stopping synergies that would have positive sustainability consequences).

REFERENCES

van Beers, D., R. van Berkel and A. Bossilkov. 2005. *Capturing Regional Synergies in the Kwinana Industrial Area: 2005 status report.* Perth (WA), Australia, Centre for Sustainable Resource Processing. Available online at: http://www.csrp.com.au/_media/pdf/3B1StatusReportAugust2005Final.pdf

van Berkel, R. 2006. *Regional Resource Synergies for Sustainable Development in Heavy Industrial Areas: an overview of opportunities and experiences.* Perth (WA), Australia, Curtin University of Technology. Available online at: http://www.c4cs.curtin.edu.au/resources/publications/2006/arc_synergybaselinereport_may06.pdf

Industrial Symbiosis Activity in Korea

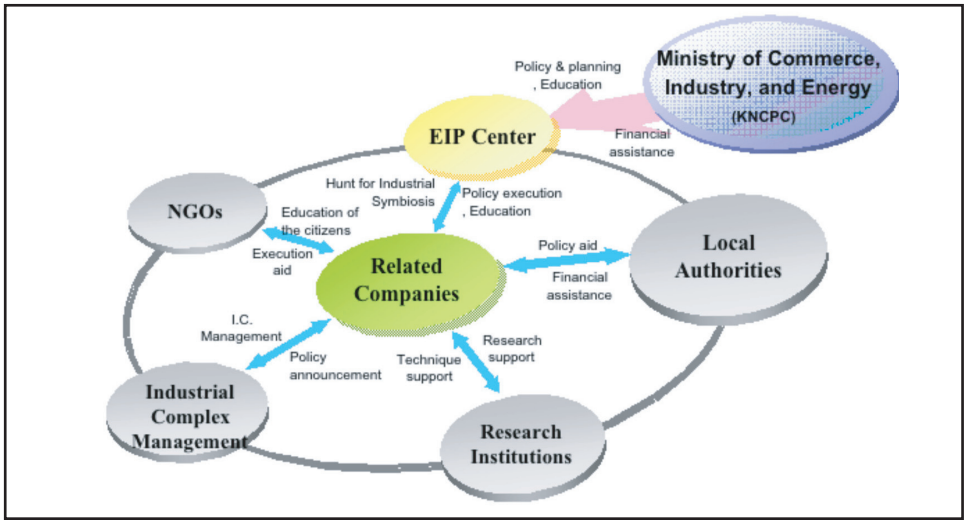
Professor Changwon Kim, Pusan National University, South Korea

In the second presentation of the session, Professor Kim described the top down central government approach to IS in Korea. The presentation raised questions around scale (large numbers of small companies as opposed to fewer numbers of very large companies), and describes the role of dedicated EIP centres to facilitate exchanges.

After a brief introduction to the economy of Korea, Professor Kim described the National Plan for Eco-Industrial Park (EIP) development, run by the Korean National Cleaner Production Centre and the Ministry of Commerce, Industries and Resources. There are 28 national Industrial Parks (IP) and 180 local IPs now. A three-phase national effort to develop EIPs was launched in 2005 with the following objectives: the first 5-year phase (2005-2009) is to evolve 5 demonstration pilot projects; the 2nd phase (2010-2014), to extend the learning from the pilots to 20 IPs; and the 3rd phase to develop their 'own style' of EIP with the objectives of maximizing reuse within each park and achieving zero emissions. Additional objectives of the project include achieving harmony with the community, and sustainability. It is a top-down approach run by central government: the Ministry of Commerce, Industries and Resources has established an EIP centre in each park to organize companies and local authorities to facilitate exchanges, and as a resource for investigators and practitioners (see Figure 1).

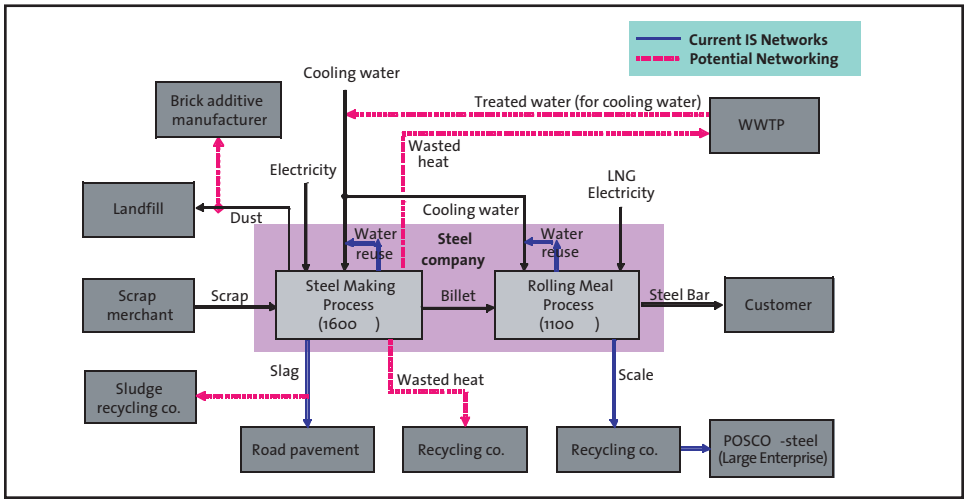
In 2006, three feasibility studies were started, including Busan, Incheon, and Daejeon. In Busan, the 2nd largest city in Korea, there are currently 2 IPs: one national, and one local government funded with a large number of very small companies (averaging 20 employees each). The two IPs are to be joined by a bridge so they are treated as one for the analysis, for a total of 2000 small companies, 10 large companies, and 8 industrial associations (employing over 46,000) that facilitate finding IS exchanges. Waste and by-product information is summarised from the city government: some waste streams (such as metal) are already captured and others not at all (sludge). Professor Kim proposes to establish a centre in the IP to analyse energy, by-product, and water flow networks through a process diagram & management technique, with the goal of making the IP an EIP, and eventually extending to Busan city. The vision was given of a sustainable Busan Eco-city (c 2016-2020) with a circular economy.

Figure 1 Organizations participating in EIP centre



In the Busan region, Professor Kim identified 15 existing networks amongst 30 companies. An example of existing IS networks in Korea is a steel company reusing wastewater on site, and using scrap to make steel bar; the slag currently goes to road pavement, but the dust is disposed of in landfill. Proposed exchanges include using the dust for brick additives manufacturer; using the treated wastewater for cooling; and capturing waste heat (see Figure 2). Professor Kim also demonstrated the potential for growth of industrial symbiotic networks in both the dyeing and leather industries.

Figure 2 Industrial Symbiosis case study of a steel company, Korea. Current networks are in solid lines; potential exchanges are in dashed lines.



Industrial Symbiosis Activity in China

Professor Shi Lei, SEPA Key Laboratory of Eco-Industry, Tsinghua University, China

In this presentation on IS activity in China, Professor Shi Lei described an approach in which the central government is the driver of EIPs and IS to address resource depletion and environmental pollution. He raised a number of questions around planning for IS, both technical and institutional. Professor Shi Lei also raised the issue of targets and benchmarking, as did Mr. Laybourn in Session 1.

In response to rapid economic development, especially of the heavy industrial sectors, China looks to industrial symbiosis to deal with the increasing pressures of resource depletion and environmental pollution. As of September 2006, the Chinese Environmental Protection Agency (SEPA), the first central government agency to promote a circular economy, has established 16 national pilot eco-industrial parks (EIPs), the first in 2001 (see Table 2). Among them, 9 are based on resource-intensive industrial parks, 9 are based on existing Economic & Technical Development Areas (ETDA) or high-tech industrial parks, and one is a recycling-oriented park (see table 2). The National Development & Reform Commission (NDRC), the current leading agency to promote the circular economy, also approved 13 national pilot EIPs (4 ETDAs has been included in the list of SEPA), including 2 agricultural EIPs and Caofeidian industrial park where the Capital Steel company will be moved to due to the Olympic Games in Beijing.

Besides the approved pilot EIPs, it has been announced that many other national-level and provincial-level industrial parks are to be built into EIPs, not to mention the industrial concentration sites at municipal and township levels (after December 2004, only national- and provincial-level industrial parks can be approved and named "industrial parks"; the total number is about 2700 currently). Documents have been issued to guide the planning and construction of EIPs, including the Technical Standards for the 3 types of EIPs by SEPA, which take into effect on September 1, 2006. Furthermore, the Circular Economy Law is in preparation with the support of the World Bank.

However, EIPs are not the whole of industrial symbiosis in China. Industrial clusters are very popular in China, especially in the East China provinces of Zhejiang and Jiangsu. In fact, many products marked "Made in China", such as shoes, ties, pens and toys, are produced from these clusters. Unlike the pilot EIPs mainly based on the

heavy industrial sectors or foreign-invested sectors, these clusters usually focus on textiles and accoutrement, food manufacturing, metal hardware, and other lighter industrial sectors. Generally speaking, these clusters show remarkable differences from pilot EIPs in terms of resource efficiency, environmental performance and economic competitiveness.

Together with the dynamic feature of China's economy, the differences in components, placement, organizational structure and even origins existing in the two main industrial symbiotes make it difficult to understand industrial symbiosis in China. For example, what is the relationship between physical linkages and non-physical linkages in industrial symbiotes? Another example, how does industrial symbiosis create or eliminate the path-dependency and lock-in phenomena? More practical questions, how does one integrate industrial symbiosis into the development of industrial parks?

In simple words, not only natural resources, labour, capital investment and other non-institutional issues should be examined and reviewed carefully, but also policy, political structure and other institutional issues should be included. That is to say, understanding the institutional perspective, and not just the technological, is central to China's industrial symbiosis.

Some specific questions for planning a specific EIP only from technological perspective are:

1. **Targeting.** What are the targets for energy and/or resources usages, or what are goals for waste minimization of EIPs? Pinch analysis technique, a thermodynamics-based tool for analyzing production processes, may contribute to this question.
2. **Topological structure.** What topological structures are required to achieve these targets? Centralization or distribution, this question is central to almost every infrastructure planning problem.
3. **Multi-objectivity and uncertainty.** There are several goals to be traded off, and many uncertainties during the development process.
4. **Ownership diversity.** There are many enterprises in EIPs. How does one seek a balance among them?
5. **Co-evolution.** How does one deal with the co-evolutionary problems existing between land usages, infrastructure construction, and industrial development?

ACKNOWLEDGMENTS

I would like to thank Marian Chertow for her kind invitation and discussion; I also thank Anthony Chiu SF, Edgar Hertwich, and Han Shi for meaningful discussions.

Table 1 The national pilot EIPs approved by SEPA and NDRC (as of September 2006).

No.	Name	Main sectors	Agency
1	Guigang, Guangxi	Cane-Sugar making	SEPA
2	Nanhai, Guangdong	Environment protection industry	SEPA
3	Baotou, Inner Mongolia	Aluminium	SEPA
4	Changsha, Hunan	Economic & Tech Develop. Park	SEPA
5	Lubei, Shandong	Chemicals	SEPA
6	TEDA, Tianjin	Economic & Tech Develop. Park	SEPA/NDRC
7	Fushun, Liaoning	Minerals	SEPA
8	Dalian, Liaoning	Economic & Tech Develop. Park	SEPA/NDRC
9	Suzhou High-tech park, Jiangsu	High-tech park	SEPA/NDRC
10	Suzhou Industrial Park, Jiangsu	Industrial park	SEPA
11	Yantai, Shandong	Economic & Tech Develop. Park	SEPA/NDRC
12	Guiyang, Guizhou	Coal & Phosphorous Chemicals	SEPA
13	Weifang, Shandong	Chemicals	SEPA
14	Zhengzhou, Henan	Aluminium	SEPA
15	Baotou, Inner Mongolia	Iron & steel	SEPA
16	Antai, Shanxi	Economic & Tech Develop. Park	SEPA
17	Mengxi High-tech park, Inner Mongolia	High-tech park	NDRC
18	Wuhan, Hubei	Agriculture	NDRC
19	Yangling, Shaanxi	Agriculture	NDRC
20	Mudanjiang, Heilongjiang	Coals	NDRC
21	Luzhou, Sichuan	Coal, NG	NDRC
22	Shanghai Chemical Zone	Chemicals	NDRC
23	Zhangjiagang, Jiangsu	Metallurgy	NDRC
24	Caofeidian, Hebei	Iron & Steel	NDRC
25	Chaidamu, Qinghai	Salt lake (K/Mg/B)	NDRC

Industrial Symbiosis Activity in North America

Professor Marian Chertow, Yale University, USA

In this report, Professor Chertow highlights the policy issues and advances in North America at four levels: national, state/provincial, regional/local, and corporate/NGO.

NATIONAL LEVEL

Neither the U.S. nor Canada has a great deal of systematic IS activity at the national level. The U.S. Congress saw the reintroduction of HR 1237 "The Brownfield Redevelopment Assistance Act" in which eco-industrial development was highlighted as a preferred reuse for Brownfield sites.

STATE AND PROVINCIAL LEVEL

In 1996, Nova Scotia, Canada, adopted its "Solid Waste as Resources" policy, which encouraged closed loops on paper and cardboard to create a fibre cycle and to create a manufacturing fund. The law is attributed with the creation of over 1000 jobs. In 2006, seeking to align the large number of provincial development strategies in a common direction, Nova Scotia produced a strategy called "Sustainable Prosperity" as a cradle-to-cradle proposal embracing circular economy thinking that is both ecologically positive and business friendly. In the U.S., there was some state interest in water reclamation projects, particularly in Florida and California.

REGIONAL AND LOCAL LEVEL

The former U.S. army base in Devens, Massachusetts, which has been a site for eco-industrial development for many years, is actually becoming a separate town. Officials are updating the Master (Reuse) Plan with Goal 9 being to "support the efficient use of resources;" a regional approach to utilities is being studied.

Three Canadian projects have made progress. Alberta's Industrial Heartland, a global petrochemical and chemical cluster, is using eco-industrial development as a key strategic element. The Greater Sudbury Development Corporation in Ontario

announced plans in July 2006 to create a web-based GIS 'synergy-finder' tool for local businesses to build relationships and increase efficiencies across companies. The industrial park in Hinton, Alberta, received Canada's first eco-industrial zoning designation with flexible development guidelines as well as a combination of $5 million in government grants and loans. This regulation is important from a practical standpoint for determining, for example, the legality of IS exchanges such as redistributing water.

CORPORATE/NGO

Canada's J.D. Irving Company is developing a project in the former Saint John Shipyard in New Brunswick to redevelop the area incorporating symbiosis opportunities into a 'green' industrial park. The U.S. Business Council for Sustainable Development is pursuing a 'facilitated collaboration' model to identify by-product synergies in Kansas City and Chicago USA.

ACKNOWLEDGMENTS

Thanks to many members of the Eco-Industrial Development Council for their updates.

Information Technology for Industrial Symbiosis

Mr. Gabriel Grant, Purdue University, USA

Mr. Grant reviewed the development of IT tools for IS over the past 10 years exploring how best to utilize IT to enable the growth of IS networks. Computers and computer models are good at storing vast amounts of information, and optimizing complex networks; they can also enable social networking. They cannot on their own identify the specific information needed, build the complex model, or leverage the social networks. The challenge thus is how to harness the power of the computer to advance IS.

Starting in 1996, the US-EPA together with Industrial Economics Incorporated and Clark University developed an IS tool with 3 parts: a large materials and energy flows database (FaST); a linear optimization model to identify companies based on FaST output (DIET); and the REaLiTY tool that identifies potential regulatory, economic and logistical conflicts in the proposed linkages. Used in combination, the tools identified potential synergies between existing and potential firms, and checked the synergies against the database of potential barriers. The tool was applied a few times, but was deemed too complex for the general user. [Dubester 2000]

A project started in 1997 by Bechtel to develop a set of tools yielded the Industrial Materials Exchange tool targeted for use by regional planners and industrial participants; two adaptations followed, the Dynamic IME (DIME) and Matchmaker tools. First put together for the Brownsville Economic Development Council, its function was similar to the FaST model. Keyword searches yielded false positives and false negatives; to address this, a group of Yale students developed a taxonomy which would enable multiple users to engage with the tool [Brown et al 2002; Burnham et al. 2001].

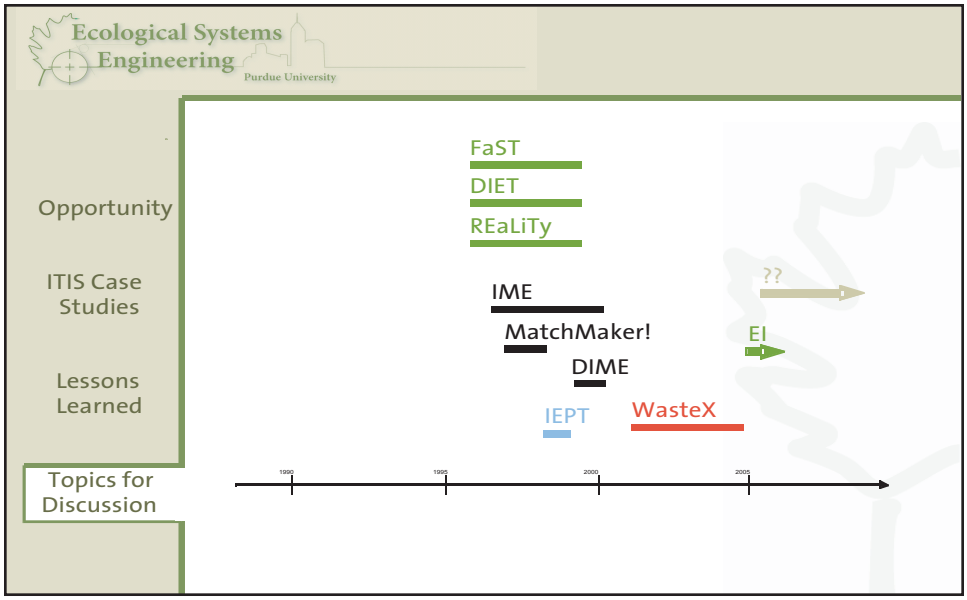
The Industrial Ecology Planning Tool (IEPT), developed by Carolyn Noble as a master's thesis, was the first tool to integrate GIS capability, specifically focusing on water in the Baytown Industrial Complex. The GIS model allows the calculation of costs for transport based on real location data [Nobel 1998].

WasteX was developed by a group of companies in Jamaica to identify partners for waste exchange. The tool, focused on outputs only, was operationally online from

2001 to 2005. One barrier common to waste exchanges is the non-standard classification of wastes limiting usability [Clayton et al 2002].

Finally, Enabling Innovation (EI) is a project started in 2005 by a consortium of academic institutions and development agencies with the goal of enabling the exchange of knowledge and technology between developing communities. Target users include villagers, developmental organizations, and engineering students and instructors.

Figure 1 Timeline of IT model development



Challenges common to IT tools for IS over the time period examined:

- Usability: if the tool is designed for multiple users, a system must be in place to deal with various classifications for the same material
- Training and expertise required: goes to usability
- high start-up costs: who pays for the establishment and maintenance of such systems?

More broadly, the issues raised by these IT tools are:

- What are the root barriers to IS and how might IT address these? It might not be a complex optimization model, it might be social capital – in which case how can IT tools help?
- What is the minimum information required to make useful suggestions for by-product synergies?
- How do we lower the cost of entry?

REFERENCES

Burnham, C., A. Mangan and D. Groberg. 2001. By-Product Synergy: A Tool for Sustainable Greenhouse Gas Emissions. http://web.archive.org/web/20020816083110/www.bcsdgm.org/bps_abstract.htm#reference%22

Brown, J. Gross D, and L Wiggs. 2002. The MatchMaker! System: Creating Virtual Eco-Industrial Parks. *Yale F&ES Bulletin* Number 106, pp. 103-136.

Clayton, A., Muirhead, J., and H. Reichgelt. 2002. Enabling Industrial Symbiosis through a Web-based Waste Exchange. *Greener Management International* 40: 93-106.

Dubester, L. 2000. Materials Flow Through the Community: Creating New Resource Opportunities. August 2000 http://www.chelseacenter.org/pdfs/rbed_cet.pdf

Nobel, C. 1998. A Model for Industrial Water Reuse: A GIS Approach to Industrial Ecology. Bureau of Engineering Research. Austin, University of Texas. M.S. in *Engineering*: 142.

Session 2 – Discussion and Research Questions

- Certain themes recur across geographies, regardless of whether it's a top-down government driven approach, or a voluntary, Nordic/NISP model approach. Do they substantiate those universal success factors to IS that have been identified in the literature? How do such universal factors inform the debate over 'what is IS'?
- What are the barriers and enablers to IS within existing regulatory and legislative frameworks? What characterizes the optimal IS policy framework (legality of exchange; societal license to operate; planning process)? Facilitation of the social networks has been identified as critical to IS; is there a role for legislation or regulation regarding these social networks – for example, requiring government capital tenders to consult with existing local IS or business networks?
- Much has been said about the regulator role in IS, often in connection with barriers. How do we move from informing and educating the regulators about IS to proactive involvement and partnership over time? What, if any, inconsistencies with their remit might exist?
- How much can we rely on IT models to facilitate IS? IT models may be able to identify a number of potential IS exchanges, but their identification does not always lead to their implementation. Perhaps models can be programmed to deal with poor quality data, but if the network and social capital are central, a theme that recurs throughout the symposium, is this an inherent limit to their usefulness? Does this not suggest that further model development should be done in conjunction with engagement models to inform the development of the IT tools?
- In each IS system, it must be determined who collects data, who maintains it, and who owns it. Focusing on collection, three choices have been identified: government mandated surrender of data; facilitators collecting data directly from companies; and companies entering data into a common database themselves. Quality of data is a critical issue, as identified in the modelling work in the 1990s and again recently by NISP. In the past,

distributed input of data led to poor quality information; various companies were entering materials flows using trade names, resulting in taxonomy issues. One difference between compulsory and voluntary provision of data may be that the voluntary set is incomplete – you get what the companies want to give you. In the NISP experience, that is still enough to identify synergies, and over time, as trust develops, companies are more forthcoming with information. What is the most efficient way to handle data collection, and how does it depend on context?

- The cost of entry for companies has been discussed as a barrier to IS, raising the question of who pays? Should support derive from the public sector (as with the UK-based NISP model) or are there ways for the networks to be supported by industry (as with the US-based By-Product Synergy model)? What are the implications for each model? How will the results differ?
- To what extent has IS been explored as a source of innovation? Under what conditions can IS act as an accelerator to research and development? The common assumption that proven technologies are required for IS is contrary to unpublished work by the University of Birmingham which found that of 125 synergies completed under the auspices of NISP, 19% involved new technological development or pure research. IS drives innovation in a certain direction – can we do it more intentionally, for example, through research programs to develop new products and processes to use certain flows? Water shortage as a constraint needs a local solution, as does finding a user for low grade waste heat. From an engineering perspective one asks, are these generic problems with generic solutions?

SESSION 3A: DISCUSSION AT THE LEADING EDGE – MECHANISMS TO ADVANCE INDUSTRIAL SYMBIOSIS

Despite the wry observation of the practitioner-moderator Mr. Christensen that he'd always found it much easier to find mechanisms to stop IS than to advance it, the three speakers spanning the academic to practitioner spectrum identified the same mechanisms central to advancing IS: at least as critical as presenting IS as a business opportunity is developing a robust network.

In discussing the NISP engagement model, Dr. Murphy described using the business case to get the companies' attention, then offering value through facilitating cross sector exchanges, and political and regulatory situations that many companies do not know how to approach. The resulting NISP networks underpin Dr. Jennifer Howard-Granville's work; she and colleague Ray Paquin have been studying the existing networks in 4 of NISP's regions, making explicit the characteristics of the networks and providing possible explanations of how social ties come about and their role in the development of robust IS systems.

In presenting on IS work in Austria, Dr. Hasler further made the point that the network of companies, once established, essentially becomes a structure unto itself – through trust and cooperation, and the companies' self-identification with the network. Professor Hasler sees IS as balancing the longer term perspective of the environment with the short term economic perspective through the shared goal of increased efficiency.

Facilitated Industrial Symbiosis: Network Forms and Evolution in NISP

Professor Jennifer A. Howard-Grenville and Ray Paquin, Boston University School of Management, USA

This presentation looked at the early promise of using social network analysis to examine existing NISP's industrial symbiosis networks. The study includes comparative analysis of two regions and highlights both potential strengths and weaknesses thus opening up possibilities for IS practitioners to make IS networks more robust.

SOCIAL NETWORK ANALYSIS

Social network analysis is a social science technique used for mapping and comparing the structures of social systems, whether they are made up of organizations, groups, individuals, or combinations of these. Social network analysis represents "ties" (affiliations or relationships) between members of a network. Prior work on industrial symbiosis (IS) suggests that pre-existing social ties between organizations or individuals enable the development of IS, as do more broadly shared norms (Ehrenfeld and Gertler, 1997; Baas and Boons, 2004; Chertow and Lombardi, 2005), demonstrating the value of understanding IS as a social, *and* material, economic, ecological, and geographic phenomenon.

Social network theory provides possible explanations for how social ties come about and why. First, the theory suggests that formal ties between organizations often grow out of informal ties between their members, that they are developed through repeated interaction, and that they may be facilitated by a third party (Gulati, 1999; Smith-Doerr and Powell, 2005). Further, the theory suggests a number of benefits to social network ties, including access to information and opportunities, shared norms and trust, sources of motivation, learning and resources, and smoother and more timely interactions (Smith-Doerr and Powell, 2005). However, there are a number of challenges associated with developing such ties in an IS system: new types of interactions, or the development or use of new technologies, by companies who have no prior dealings with each other; or the degree of uncertainty surrounding IS

arrangements. In sum, while there may be significant benefits to establishing social network ties as a way of progressing towards IS, there are also significant obstacles.

PRELIMINARY RESULTS FOR NISP REGIONS

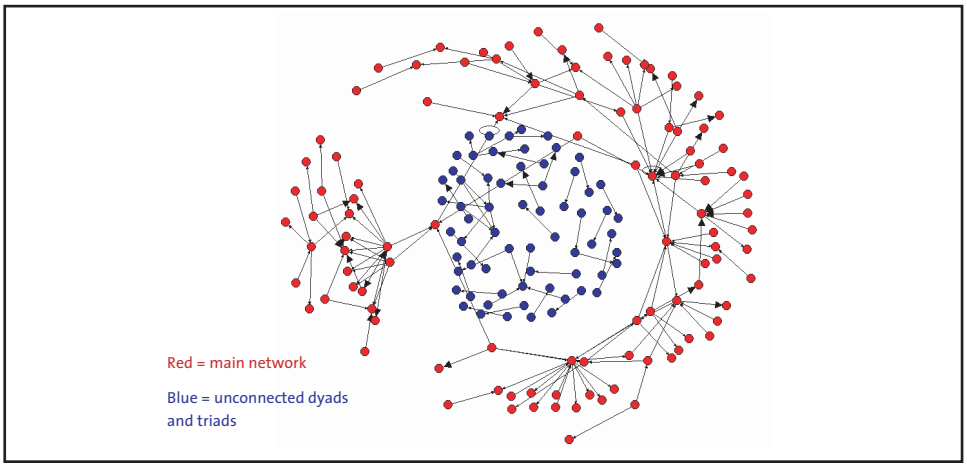
This talk introduced early social network analysis results based on a comparison of two NISP (National Industrial Symbiosis Programme) regions. NISP operates from a unique position as it is facilitating the formation and evolution of IS networks on a large (national and regional) scale. We focus on four of NISP's ten regions, and in this presentation gave early network structure results on only two of the four focal regions. Social network analysis was performed using NISP's synergy grids (documentation of all existing and potential IS relationships, by stage of the relationship) for the West Midlands and the North East, two of the regions in the program with the longest history of engagement.

Results show some interesting commonalities and differences between the network structures of the two regions. The West Midlands network (see Figure 1) is characterized by a core "ring" of industry members who all have at least one exchange with each other and also have a number of exchanges or relationships with others (seen as a number of "sub networks" off the main ring). There are also a large number of one-to-one exchanges between members who are not connected at all to the main ring. The West Midlands networks appear to be anchored around several key industries that are prevalent in the region, but are more highly geographically dispersed and do not have a history of interaction.

The evolution of the core ring is uncertain, but as the main members of this ring are among the most active in the program it is likely that they will see further growth and development of their symbiosis ties. Whether this occurs by the growth of larger and more complex sub networks or by the development of connections "across" the ring between its main members depends in part on the nature of the potential exchanges and the types of opportunities seen by NISP (as facilitator) and/or the members themselves. The latter type of development would lead to greater ties between diverse firms and greater "cross linking" of the network, which could lead to a more robust network in which novel information flows. One potential disadvantage of the growth of sub networks alone is that it could be focused on a certain industry or industrial facility's waste, and therefore limit the opportunities for truly novel, perhaps three-party symbiosis arrangements.

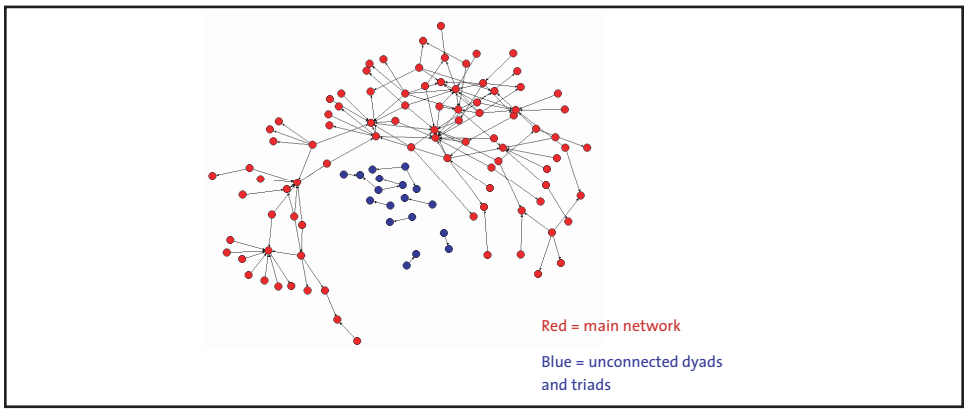
The North East network structure (see Figure 2) also shows a core network with higher density ties and a number of unconnected dyads. However, in the North East the core network does not appear as a ring of main players who are connected to each other through only one or two primary ties. In contrast, it appears as a "multi-connected" system where each main member is connected to a number of other main members. The growth and development of this network could lead it to become even denser among these main members, perhaps limiting the potential for new ideas and opportunities to enter in. However, a dense, multi-connected system is quite robust, at least theoretically, as the removal of one main member would not fundamentally break apart the system.

Figure 1 West Midlands main network and components. Red is the main network, blue is the unconnected dyads and triads.



Source: Howard-Grenville

Figure 2 North East main network and components. Red is the main network, blue is the unconnected dyads and triads.



Source: Howard-Grenville

While the analysis is preliminary and much more must be understood about the nature of the ties, how they came about, their directionality, etc. in order to explain the current structure and predict further development, there is great promise for using social network analysis to map and compare different industrial symbiosis systems. In this case, hints about the current structures can be found in looking at the history and industrial make-up of each region. The North East industrial symbiosis networks may be heavily centred on the petrochemicals industry that has been historically dominant in the region, is geographically co-located, and has processes conducive to resource exchange. The West Midlands industrial symbiosis networks appear to be anchored around several key industries that are prevalent in the region, but are more highly geographically dispersed and do not have a history of interaction.

ROLE OF FACILITATOR

In both cases, a facilitator (NISP) can serve a critical role in introducing companies to each other, helping to build the network either from the main players (by encouraging sub-networks), or across them (by encouraging cross-industry exchanges), or both. Any targeted facilitation approach (e.g. by industry sector, or by geography sector) has potential trade-offs with the diversity and density of the emerging network. For example, growth around sub networks may be a natural course because it tracks materials from one industry but it may reduce the diversity of the network overall, having implications for its capacity to renew itself (through new information flows and new members) over time.

Network analysis can help facilitators to visualize patterns in the network structure, understanding them better through their in-depth knowledge of the individual members, and actively managing their implications. Network analysis is also an important tool for use by scholars seeking to better understand industrial symbiosis emergence and development. Critical to the use of the quantitative modelling techniques is complementary qualitative understanding of the nature of the ties and the conditions surrounding their development. Only through this qualitative analysis can the logics of the structures (how they form and why the look as they do) be understood. Key questions facing scholars interested in this area include:

- How do we adequately measure truly "social" ties in an industrial symbiosis network? Ties of acquaintance or friendship between *individuals* may be important in the development of ties between *companies* in the emergence of industrial symbiosis, so social network analysis ideally needs to capture both. A challenge is that these ties are very hard to measure systematically in a large network, and also must be followed over a long period of time to understand their effect.
- How do we construct and compare to a "base case" industrial symbiosis network? In other words, what might have happened under different conditions, or with different pre-existing social ties? This question relates to understanding just how important each of a number of factors (e.g., social ties, regulatory incentives, environmental impacts, economic factors, etc.) is in influencing the development of industrial symbiosis.

REFERENCES

Baas, L. W. and F. A. Boons. 2004. An industrial ecology project in practice: Exploring the boundaries of decision-making levels in regional industrial systems. *Journal of Cleaner Production* 12: 1073-1085.

Chertow, M. R. and D. R. Lombardi. 2005. Quantifying economic and environmental benefits of co-located firms. *Environmental Science & Technology* 39(17):6535-6541.

Ehrenfeld, J. and N. Gertler. 1997. Industrial ecology in practice: The evolution of interdependence at Kalundborg. 1(1): 67-79.

Gulati, R. 1999. Network location and learning: The influence of network resources and firm capabilities on alliance formation. *Strategic Management Journal* 20(5): 397-420.

Smith-Doerr, L. and W. W. Powell. 2005. Networks and economic life. In N. J. Smelser & R. Swedberg (Eds.), *The Handbook of Economic Sociology* 2 ed. Princeton, NJ: Sage/Princeton University Press.

Focus Engagement Models[1]

Dr. Adrian Murphy, NISP- West Midlands Regional Director, UK

[1] Editors' Note: The case studies discussed by Dr. Murphy are available at www.nisp.org.uk

In his presentation, Dr. Murphy discussed NISP's focus on maintaining a close relationship with businesses and understanding of their issues in order to best facilitate cross-sector IS business opportunities, key to their engagement strategy of "working with the willing." Also central to the facilitation model is a close relationship with the regulator.

FACILITATOR OF BUSINESS OPPORTUNITIES

Dr. Murphy began by describing NISP's philosophy of engagement as "working with the willing:" in his experience, presenting a company with an IS opportunity does not, by and large, get the company engaged; an opportunity to improve environmental performance receives some interest, but engagement is still unlikely. The entry line must be a business opportunity. NISP has demonstrated ability to reduce costs and emissions, increase sales and asset utilization, create jobs and attract inward investment through IS. To assure a strong connection to its local business community, NISP partners with industry associations, and each NISP region has an advisory group composed of local businesses (ranging from multi-nationals to micro-industries and individual entrepreneurs). The majority of NISP regional coordinators (leaders of the regional teams of practitioners) and practitioners have a background in industry that facilitates their understanding the companies' business drivers.

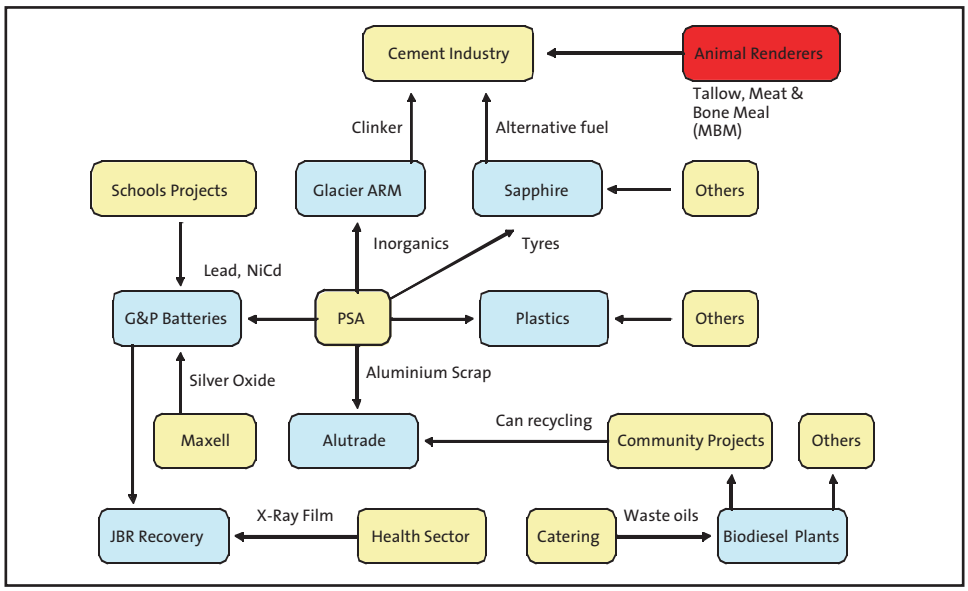
The facilitation role was central to connecting Maxell, electronic component manufacturer, and JBR Recovery, a precious metals recovery facility 5 miles away. Each year, Maxell sells of order 60 million slim-line silver oxide batteries to the automotive industry across Europe. The batteries have a limited shelf life, resulting in 2 tons per year of waste batteries being land-filled as hazardous waste – an avenue closed by a change in legislation in 2005. The neighbouring JBR Recovery had excess capacity, and was looking for anything that contains silver. The batteries contain over 40% silver with a current market value £100k/year – once recovered. The silver recoverer hadn't thought to pursue batteries; the battery seller hadn't thought about the silver. It took someone working cross sector to make the connection, and the introduction.

STRATEGY FOR ENGAGEMENT

NISP-WM is involved with companies of all sizes in a number of industrial sectors: their strategy of engagement is "wide and deep". Many of the current 4000+ members are at the early stages of interaction, engaged in preliminary conversations about IS and its benefits. If NISP can provide them some easy wins, the companies become more engaged. The next step might be to hold a workshop with a number of companies at the same time. At the workshops, NISP gathers data on the companies; simultaneously, the companies make their own connections with other attendees. In the early stages of engagement there are no predefined boundaries or expectations on what kinds of exchanges may be identified. The resulting engagements are with those self-selecting – thus willing – companies (see Figure 1).

One member company, an animal renderer, processes about 300,000 tons each year of food waste from food companies, supermarkets, and abattoirs. Prior to Animal By-Product Regulations, waste food could be sent to landfill; this process is no longer permitted. Through use of what is essentially a giant pressure cooker, the foods are broken down into component parts: solids, liquid, and fats. Working cross-sector, NISP helped the company identify opportunities for the reuse of these outputs. The company has since installed a £1M system to process the solids containing minerals and carbon value; they now displace fossil fuel use for a cement manufacturer. Four hundred thousand (400,000) tons of water each year were purchased by the business, put through effluent treatment after use, then thrown away; the company is now cleaning the water and reusing it in the process. The fats are now going into bio-diesel. This company is not just engaged in the program; they are using IS to shape the future of their business.

Figure 1 NISP-facilitated IS network developing in the West Midlands regions.



Source: Murphy

PARTNERSHIPS WITH GOVERNMENT – REDUCING RISK

Legislation can sometimes be a barrier to IS exchanges, either de facto or through misinterpretation by the regulator or by the companies themselves. Where this misinterpretation occurs, NISP can leverage its relationship with the regulating bodies – the Environment Agency and the Department of Environment, Food and Rural Affairs – to clarify the intent of the policy and occasionally to work with the regulator to chnge the policy. Sometimes NISP's role is to facilitate the companies accessing government agencies and resources which small companies in particular have difficulty doing as they lack the appropriate knowledge. For example, a small recycler needed significant investment to grow its business, and then increased input supply (in this case, cans) to match. The recycler had been pursuing alternative sources of funding, but had not thought to approach the regional development agency, which, facilitated by NISP personnel, awarded them a capital grant; NISP also identified through its network additional sources of cans as input.

In conclusion, the NISP early network growth has been predominantly self selecting i.e. those willing companies who have gone beyond initial engagement. The presentation of a business opportunity brings them in: being open minded and reactive to the challenges faced by industry effectively engages them in IS, leading to the facilitation of many IS exchanges across all resource types and all sectors.

Inter-Firm Coordination

Dr. Arnulf Hasler, EU Regional Management of Upper Styria West, Austria

Reiterating the centrality of the business case – that IS is always driving the business competitiveness of the economy – Dr. Hasler emphasized the need for people to work together to create the win-win situation. Creating a long-lasting sustainable situation for companies requires balancing the short-term economic perspective and the long-term ecological perspective; the common aim is increased efficiency.

Dr. Hasler identified three stages to the growth of the company networks, resulting in the creation of something larger than the sum of its parts; that is, the network created takes on a life of its own. The process is iterative. In stage 1, companies meet to explore the potential for working together: information exchange is central. In stage 2, they are forming the network, that is there is the consciousness of being part of the total structure: identity with the network and confidence in it are central. In the final stage, the strategic management of the central structure is key to the network becoming self-sustained. As the companies interact more and more frequently, they find out more about one another, creating mutual understanding and strengthening the network, and the companies' own self-definition as part of the network.

Trust between companies and confidence in the system are the basis for new cooperation. Few people (if any?) ask to see the captain's pilot's license when boarding an airplane; the stewardess in her uniform is the public face of that system, and passengers trust in that system. Similarly, for IS, the networking managers are the face of the IS system. As part of the network, one trusts the whole system; it is not necessary to meet everyone and question their trustworthiness; the only commitment is to work together with the system. Short mental distance helps to build trust and cooperation.

The IS work in Styria, Austria, is part of a regional development package of programs that focus on economic growth. The regional structure supporting the IS network was not created by the government, but rather supported and financed by the 72 communities in the region through a regional association. Its focus is primarily on information exchange, building up transparency in the region. Feeding local data into a benchmarking system enables the creation of benchmarks for regional policy, supporting programs for regional planning.

By creating ecological competence, the companies of Styria are becoming more competitive. Innovation is promoted by creating centres, building networks and

clusters. For example, the wood cluster is working toward creating a sustainable business based on regional resources; when the raw materials are sourced regionally, more of the value generated remains in the region.

Session 3A – Discussion and Research Questions

- Initial discussion centred around the relative merits of mechanistic approaches (more complex/sophisticated data driven modelling) and humanistic/social approaches (use what we know about humans and relationships). Mr. Christensen observed that there are various ways to proceed, depending on culture, all related to human interactions, and that even if we strengthen the modelling tools, people have to talk to each other. Picking up on the phrase 'working with the willing,' can a theoretical model be used to identify 'willing' and then bring them together thus shortening the 'dating' period?
- Dr. Hasler described IS as unifying the short term economic perspective with the longer term environmental perspective through increased efficiency; one participant asked 'what if economic [benefit] comes at cost of the environment?' Although this is a possibility (see e.g. Chertow and Lombardi 2005) it was suggested that to date most of the evidence pointed towards dual economic and environmental gain, and that the rigorous application of measurement and metrics can identify any negative environmental costs at an early stage. Under what conditions does economic gain outweigh environmental benefits? Is it a systemic problem such that the IS approach should be re-examined?
- Engagement precedes facilitation: engagement is the entry into the network – once engaged, specific exchanges can be facilitated. Regarding engagement, what are the tradeoffs between a targeted industry sector approach versus a targeted geographic approach? Under what conditions, and to what extent are they mutually supportive?
- The ecological metaphor was raised regarding the social network analysis, in that more diverse connections (may) make for a more robust system. The remodelled industrial system has been likened to a more complex natural system with increasing number of interactions. How robust is the metaphor? At the strategic level, do we want particular connections? Regarding facilitation, one might do some targeted exchanges for significant outputs – at what cost to the wider system/network? Are more connections always better? Is there such a thing as 'too big' a network?

- Society acts to discourage certain flows (e.g. toxins) in part through economic and regulatory burdens. IS allows companies to lessen these burdens, for example, through avoiding disposal. Would a more sustainable outcome result if the burdens were left intact to incentivize innovation? For example, does being able to recapture the silver from batteries prolong the reliance on a system that uses disposable batteries? Or as one participant put it, 'is there such a thing as a bad connection?' Does it hinder or prevent the system from evolving to a more sustainable form? IS interventions have resulted in culture change within companies that may accelerate more sustainable forms – is that as effective a path to a more sustainable outcome?
- The ultimate impact of IS on consumption has not been disaggregated. Do economic savings accrue to investors, or propagate through to consumers in the form of lower prices, or both? Is the net impact of IS to make industry more efficient at producing more throwaway goods?

SESSION 3B: DISCUSSION AT THE LEADING EDGE – INDUSTRIAL SYMBIOSIS AND REGIONAL DEVELOPMENT

The first year of the ISRS (2004) included a session on urban & regional planning; its aim was to describe the role of regional IS systems and examine institutional initiatives for their implementation. This year, we push the conceptual framework beyond the regional planning of IS to a system greater than IS: the impact of IS on regional planning more generally. What does an IS approach offer the general planning process? As our first speaker aptly put it, this analysis takes IS beyond industry: we have to think of society and the world.

Both speakers addressed water use and economic development, albeit in differing contexts: Mr. Ramesh Ramaswamy in India; and Dr. Malcolm Bailey in the Yorkshire-Humber region of England. Both used an IS approach to examine the (primarily but not exclusively industrial) flows of water in the region, and fed their results into the respective larger regional planning process. Central to NISP-YH's contribution to regional economic development was its ability to engage with companies and to take a regional view of resource flows. The regional analysis of resource flows in India, when combined with the more traditional socioeconomic drivers of planning decisions, elucidated tradeoffs and alternative solutions to development that neither approach could have done alone.

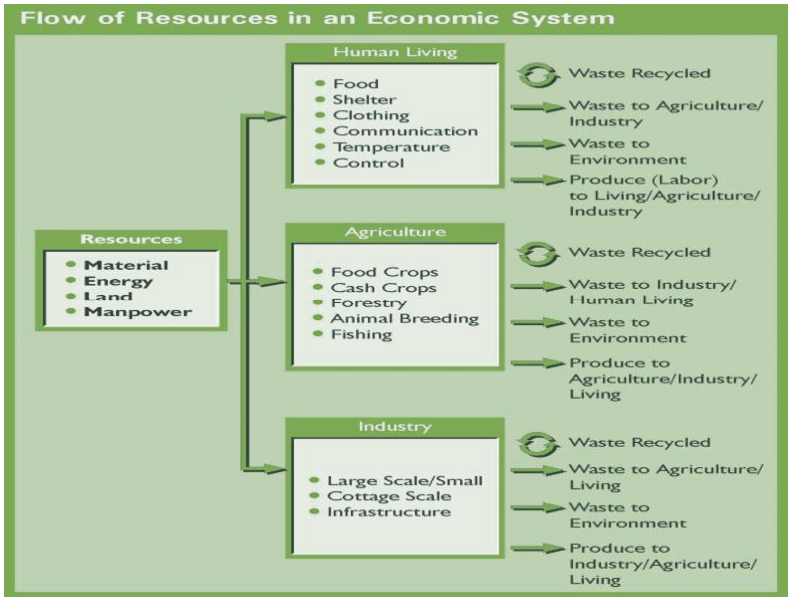
Industrial Symbiosis and Regional Planning[1]

Mr. Ramesh Ramaswamy, Resource Optimization Initiative, India

[1] Editors' Note: Case studies presented by Mr. Ramaswamy are available at www.roionline.org

Mr. Ramaswamy started by making explicit three basic concepts: First, in most planning processes, the current basis for decision-making is monetary. Second, environmental issues in the developing world have great significance for the survival of the current generation, not just future ones. Third, the speaker's definition of industrial ecology is that it "involves analysis of socio-economic systems based on a study of flows of material and energy resources and aims to optimize their use." Not just economics, not just material flows – but a whole range of social issues. When one is looking at regional development, one can't look at individual exchanges with millions of small actors; one must aggregate the flows to look across the sector, and across the region.

Figure 1 The scope of Industrial Ecology.



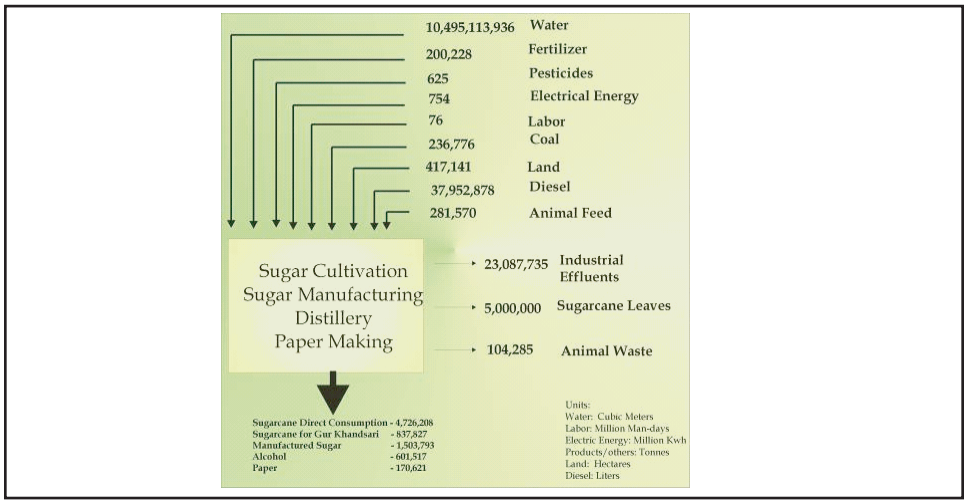
Source: Erkman and Ramaswamy 2003

INDUSTRIAL SYMBIOSIS: APPLICATIONS IN AGRICULTURE

In India, 50% of the energy used and 90% of the water are inputs to the agricultural industry – a situation representative of many developing countries. An analysis of the resource flows through 3 selected agro-industrial systems (rice, sugarcane, cotton) was performed and a set of metrics were created to address the question: what kind of yield does society receive from each crop? Sugarcane was expected to be the most pernicious due to large amounts of waste generated.

The system boundary was defined as the state of Karnataka where the average land holding is 1.5 acres; aggregating flows for the multitude of actors was necessary for a regional perspective. Along the value chain, only the immediate product was included in the analysis (e.g., sugar as product of sugarcane, not the cakes in which the sugar was later used). The result was that sugarcane generates greater yield per hectare for employment, water and power use than either rice or cotton because it is a highly symbiotic crop: the molasses by-product goes into the distilleries; bagasse is used to make paper. This analysis contradicts the popular belief that sugarcane shouldn't be grown in such a dry area, and clearly illustrates the need to think beyond just economics.

Figure 2 The sugar cane system consists of the cultivation of sugarcane, the manufacture of sugar, ethyl alcohol production from the by-product molasses, and paper making from the by-product bagasse.



Source: Ramaswamy 2006

IDENTIFYING PLANNING PRIORITIES – DODDABALLAPUR INDUSTRIAL AREA

This area suffers a local water shortage: ground water is the only source, and it has been contaminated by the textile dyes and pesticides released by the local industries. A new airport planned for the area may be expected to bring a substantial increase in

local population; water requirements are anticipated at 100 million litres per day, which the area does not have. This case demonstrates the need to consider more than just industry when identifying planning options.

PLANNING THE DEVELOPMENT OF THE LEATHER INDUSTRY

In the 1970s the export of raw hides and skins was banned in India in an effort to capture the added value from tanning in-country. The tanning industry requires a lot of water and releases contaminated water to the rivers; rivers are drying up and water is already being trucked in, an unsustainable solution. The leather industry will need a new solution. It is proposed to move the leather industry next to the sea in a symbiotic system with an incinerator (to burn the high-energy organic matter contained within tannery sludge) and a desalination power plant (to provide the clean water). One of the barriers to advancing this solution has been the many governmental departments involved: Power Ministry, Environment Ministry, and Ministry of Commerce representing the leather industry.

The issues arising when using an IS approach to inform the planning process include:

- System definition: relevant to administrative, data collection and development. A more systematic approach is needed for determining the system boundary.
- Data collection and analysis: it is very difficult to gather data at regional levels to be able to map flows. Many things can change in the time it takes to map the flows.
- Dissemination and implementation: The system in India is very traditional and compartmentalized. To address the system, it is imperative that people work together. Relevant legal issues, sometimes a low priority, include movement of hazardous material and shifting liabilities.

REFERENCES

Erkman, S and R. Ramaswamy. 2003. Applied Industrial Ecology – *A New Platform for Planing Sustainable Societies* AICRA Publishers, Bangalore, India.

Ramaswamy, R. 2006. "Industrial Ecology and Agro Industrial Policy", Resource Optimization Initiative, Bangalore. January

Industrial Symbosis as a Regional Development Tool

Dr. Malcolm Bailey, NISP-Yorkshire & Humber Regional Director, UK

The Yorkshire Humber (YH) region is a largely industrial area in the north east of the UK. The south of the region traditionally hosts coal mining, and chemical and engineering activity; the north is mainly agricultural. About 20% of the UK's power is generated in this region, and thus the region is very conscious of its carbon footprint: the regional economic strategy (owned by the regional development agency) identifies as priorities moving the region toward a low-carbon economy (e.g. through resource efficiency), and proving sustainable development as an engine of economic development and regeneration (through new partnerships and new ways of working). The NISP-YH program, active in the region for 3 years, was expected by the regional development agency, one of its funders, to deliver flagship projects demonstrating dual benefits for economic and sustainable development. In delivery terms, it has been demand-led by industry – a 'bottom up' approach emphasising improved business performance for participating companies.

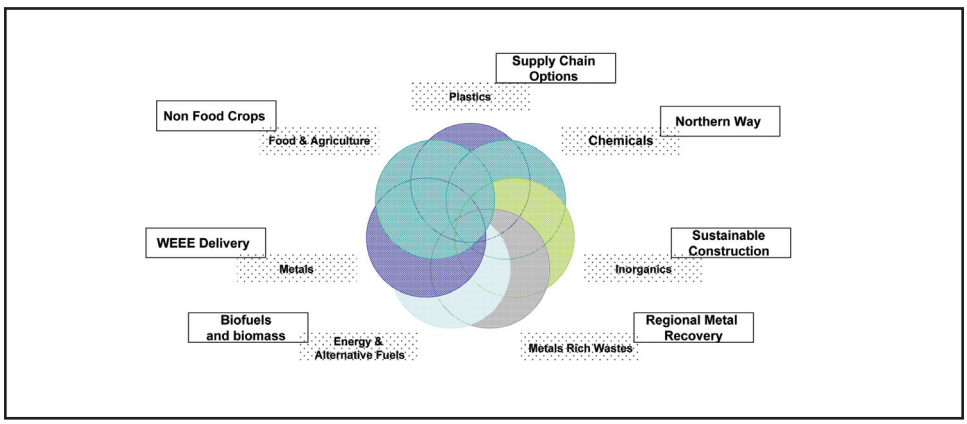
The south bank of the Humber River is seen as prime for industrial development: the industrial mix comprises 3 power stations, 2 refineries, chemical and food processing plants, and agricultural land just inland. However, there is a shortage of non-potable water for cooling and other industrial processes, in part arising from the installation of a new 750MW CHP plant, and limited capacity at the existing water treatment works. Having put forward the idea of examining the water scarcity and development issue to the regional development agency, NISP-YH was charged with the full analysis – not for its expertise in water networks, but for its skill in engaging companies and promoting dialogue with the parties involved: local and regional government, and private industry. In all, NISP coordinated and reported on discussions with 12 public and private sector organisations. Through talking to industry users, NISP-YH learned about their water supplies (borehole, water companies, seawater), regulatory constraints, and utility issues. The option for a combined effluent treatment plant for the large industry water users was explored; the variability of the feeds into the system precluded that solution. Finally, the reuse of water from the existing municipal water treatment plant yielded 3 million tonnes

per annum of non-potable water, unlocking additional capacity for further development in the strategically important area.

The NISP-YH team takes a pragmatic approach: working with the willing where business opportunities arise, rather than targeting specific companies or sectors. Through engaging with many companies, a map of the economic make-up of the region developed and synergistic patterns emerged; with them, opportunities for synergistic economic development. For example, the nature of the industries in the region yield substantial flows of inorganic materials which naturally lend themselves to the sustainable construction industry – not a consciously targeted sector, but one that's resulted from the material flows data and analysis. Metals-rich waste presents very diverse challenges, and often scale is the issue: the economics of the business case for an individual company to recover metal from sludge may be poor due to scale, but the business case for regional delivery (i.e. larger scale) may be stronger.

This 'natural mapping' of the local resource flows, developed through business interaction, enables the programme to move from the tactical to the strategic view of resource optimization, considering not only matching company A's resource with that of company B, but also multi-company and multi-component synergies, to engage in both short-radius synergies involving utilities and longer-radius synergies that tend to be dominated by materials. In reviewing these naturally emerging groupings (minerals, metals, metal rich wastes, plastics, food and agriculture, alternative fuels and energy, chemicals, etc.) at the aggregate level, the programme now naturally finds itself delivering strategic objectives in relation to sustainable construction, WEEE directives, the implementation of national and regional energy policy initiatives, implementation of the non-food crop agenda.

Figure 1 Strategic opportunities (in boxes) deriving from existing resource flows (dotted).



The presentation concluded that 'Industrial Symbiosis' through NISP demonstrably promotes economic development and regeneration, and is a showcase in the delivery of greenhouse gas reduction (and other) targets of strategic importance to the region without deviating from the imperative to deliver business results in the present.

Session 3B – Discussion and Research Questions

- The preponderance of government policy and planners consider an industry sector (or clusters) approach when planning for economic development, although doing so limits the IS solution space: for example, most (all?) chemical companies identify waste heat as an issue, but since they share the surplus, the demand side is missing for an exchange within the sector. Whereas food companies generally need refrigeration, most often powered by electricity, low grade heat (e.g. from the chemicals sector) could meet that demand. IS should be looking toward engagement strategies for sectors that more closely align to regional economic strategies but the facilitation should be cross-sector. The regional mapping of resource flows was undertaken by both speakers in the context of planning economic development. How can the IS community best contribute to the planning discussion?
- NISP does not absolutely define an approach for their practitioners so that they are allowed the freedom to react to background market conditions, regulation and policy frameworks, all of which are constantly changing. If IS is always reactive to background conditions, can it ever be integrated into policy and regulatory framework? How can it be integrated without losing its efficacy, and responsiveness?
- Three distinct approaches to IS have been discussed: geographic focus – as Mr. Ramaswamy demonstrated for the Doddaballapur Industrial Area; resource focus – as Dr. Bailey demonstrated for water; and industry sector focus – as mentioned by Mr. Ramaswamy, e.g. requiring all distilleries to co-generate. What is the most effective way to integrate an IS approach into policy and planning? What is most effective approach to interact with regional economic development agencies – is it geography, resource, sector? All three, or some combination (i.e., a resource approach to a particular sector as placed within the context of a particular geographic region)? Under what conditions is each most effective? How does the local context (cultural, political, and so on – see Session 4) dictate the most effective IS approach for that context?

SESSION 4: INDUSTRIAL SYMBIOSIS IN THEORY AND PRACTICE

In this session, speakers and participants were tasked with rather ambitiously connecting IS to some very big ideas: exploring the IS relationship with or role within sustainability, social science, and business.

IS has been termed 'sustainability in action' and 'a tool for achieving sustainability' without dissent, so there is implicit consensus that our goal is indeed sustainability. What is the evidence that IS is a useful tool for sustainability? In the first presentation, Professor Roland Clift was asked to address the connection between IS and sustainability; a mandate, he pointed out, that was either too broad or too obvious. Professor Clift reminded us of the role IS plays in resource efficiency – critical to sustainability; he then went on to explore the non-typical IS situation of post-consumer waste goods. Focusing on the economic and environmental impacts along the supply chain, he asked whether understanding the supply chain could translate to a tool for aligning business competitiveness and economic imperatives with environmental performance.

If the first speaker addressed the 'Are We' as in 'Are we advancing sustainability?', the second set of speakers were given the equally daunting task of providing the social science context for approaching the normative 'Should We, and if so, How Do We.' Professors Boons and Baas presented a framework for accessing the scope of the social science contribution to IS and its linkage to other fields. Academic analysis of IS often takes on a technological orientation: what material flows should be addressed, and which match with which. But the practitioners' primary concern, as evidenced at this Symposium, is more often: communication (the 3 enablers of IS: communication, communication, communication), networks, and company engagement. The concept of embeddedness as a tool to access the social science perspective led to much lively discussion and debate.

Finally, as discussed throughout this Symposium, the business case for IS can be central to companies' engagement with it. Two practitioners and one academic led the discussion with their perceptions of what drives businesses to participate in IS. The economic case is by no means sufficient as companies do not tend to act as

purely rational economic actors. As with any other business endeavour, many other dimensions are relevant to business, such as the potential for innovation and new business opportunities. And as with any other supplier/buyer relationship, the distribution of costs and benefits is settled through negotiation.

Industrial Symbiosis and Its Relationship to Sustainability

Professor Roland Clift, University of Surrey, England

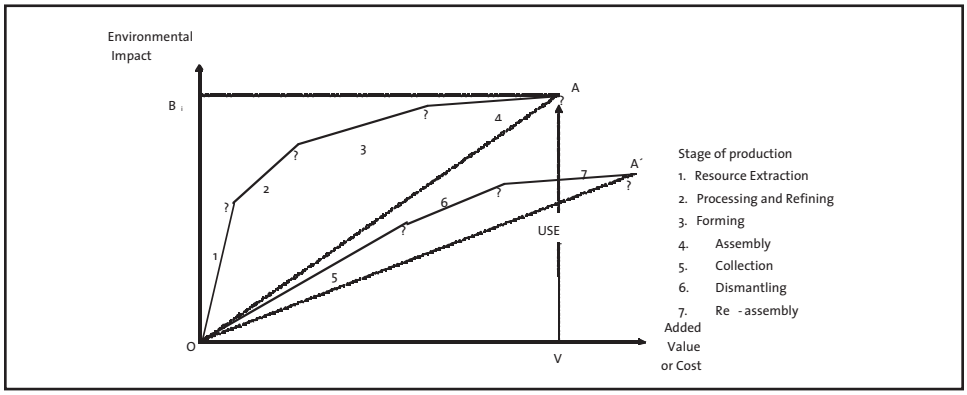
In this presentation, Professor Clift examines the environmental burden and economic value along the supply chain, and what this relationship indicates about when recycling appears attractive and when not. While this analysis is for post-consumer recovery, the characteristics of the supply chain may be indicative of where industrial symbiosis is inhibited, and take-back legislation is necessary.

Traditionally, industrial symbiosis focuses on industrial process or product waste from industry; the overarching goal of sustainability is to organize the economy into closed loops and IS is a useful tool for achieving this goal as it addresses resources efficiency. The cases discussed by Professor Clift took a non-traditional IS approach to examine the incentive for post-consumer recovery of products, i.e. closing loops for waste from used goods. How can understanding the supply chain translate to tools for aligning business competitiveness and economic imperatives with environmental performance? Under what conditions are take-back directives necessary? Specifically, work with Nokia sought to address why it is uneconomic to recycle used telephones: a mobile phone passes out of use usually because of fashion; why is it seen as waste and not a valuable resource to be used? Drawing on an early eco-metrics analysis developed with Unilever, the environmental burden for the manufacturing supply chain for mobile phones was plotted versus economic value captured. As one might anticipate, the parts of the supply chain associated with larger environmental burden (mining and extraction, making components) were not matched by a comparable gain in economic value. The extractive industries do not capture substantial value from mining and extractive activities; most economic value is captured closer to the end product in assembly, where there is considerably less environmental burden.

The manufacturing supply chain was then compared to the curve for recovery and remanufacturing. Both reverse logistics and dismantling entailed quite high costs. Put together, the remanufactured phone had lower environmental impacts in all categories but cost many times more – part of the reason economic drivers alone don't work, and why take-back is sometimes necessary. If there were a more proportional relationship between the economic value and the environmental

burden at the early stages of the manufacturing chain, economic and environmental imperatives might align. A sustainable supply chain would be less convex and preferably straight; recovery and reuse would then be more attractive.

Figure 1 Environmental Impact versus Added Value (or Cost) for the manufacture of a mobile phone (top) versus its later remanufacture (lower curve).



Source: Clift and Wright 2000

Is there a system where the curve is linear? Legal cannabis in Canada has a tightly controlled supply chain, line of sight between the primary producer and user, thus a much more sustainable supply chain. [Clift 2001] Marks & Spencer's, a large UK retailer has been interested in developing food supply chain management techniques. The analysis entailed plotting the environmental burden (CO_2-equivalents) versus economic benefit for 3 distinct suppliers of watercress. The watercress grown in Hampshire, UK, (Marks and Spencer's preferred supplier) had a concave plot. The plot for that grown in Portugal and transported by road to the UK was still concave although with higher environmental burden from transport. The third choice supplier, primarily used during winter months, was Florida, USA; the impact of the air freight produced a convex plot.

Value chain analysis looks at the influence of material flows along the supplier chain. One normally expects a large retailer to dominate its supply chain, but the case for watercress at M&S shows stronger but fairly equal relationships between supplier and buyer; the watercress suppliers do not supply only M&S. This balanced relationship has competitive advantages for both. In the case of mobile phones, the retailer dominates the supply chain. (This is also true in some cases of food retailing, e.g. grapes in South Africa.) Although this is a small number of examples on which to base conclusions, it seems that the economic and environmental imperatives have a chance of going in the same direction when the supply chain is balanced, i.e., when externalities of environmental burden are internalized, or through (rather unlikely) international agreements such as OPEC where suppliers cooperate to increase value capture for primary materials.

Where the price of primary goods is higher, there is more economic incentive for recovery, and thus the potential to reduce the demand for the primary goods. In the

buyer-driven supply chain, the buyer forces down the price of the primary goods, thus making recovery of used goods for recycling uneconomic; unlike IS situations, the demand for the primary material is maintained. Such convex supply chains characterize situations where take-back policy such as the Waste Electronic and Electrical Equipment (WEEE) Directive in the EU is needed to encourage companies to take back used goods at the end of their life. Unfortunately, the existing WEEE systems have no material loops going back to the producers, as would be desired to reduce demands for primary goods.

REFERENCES

Clift, R. 2001. Think Global; Shop Local; Roll Your Own. *Journal of Industrial Ecology* 5(1): 7-9.

Clift, R. 2003. Metrics for Supply Chain Sustainability. *Clean Technology and Environmental Policy* 5: 240-247.

Clift, R. and L. Wright. 2000. Relationships between Environmental Impacts and Added Value along the Supply Chain. *Technological Forecasting and Social Change* 65 (3): 281-295.

DISCUSSION AND RESEARCH QUESTIONS

What does a sustainable supply chain look like? Is flat the ideal, or as concave as possible? For steel and aluminium, both situations with large environmental burden from extraction, the economics of post-consumer recovery has led the market to institute the closed loops itself. What does this analysis yield for the supply chains for steel and aluminium?

The example of a branded good such as mobile phones is one where there is a large increase in the economic value at the end of the supply chain. The materials that IS addresses are, by and large, not final products and thus do not have the large economic value-add (for expired batteries, for example). Is this large increase in economic value at the buyer end of the supply chain a barrier to post-consumer recovery? What lessons can be transferred to the IS system?

Industrial Symbiosis in a Social Science Perspective

Professsor Leo Baas and Professor Frank Boons, Erasmus University, the Netherlands

Professors Baas and Boons took this opportunity to discuss current and potential contributions of social science research to the field of Industrial Ecology/ Symbiosis. It is acknowledged that this field consists of scientists from beta (natural and technical) as well as gamma sciences, and includes academic researchers as well as practitioners, consultants, and engineers. For this reason, the authors proposed to explore: (1) the scope of the social science contribution, and (2) the linkage of this contribution to other parts of the field.

THE SCOPE OF SOCIAL SCIENCE CONTRIBUTION

The field of social sciences includes a diversity of disciplines including: history, sociology, psychology and geography. In order to discuss the contribution of these disciplines, each with their own focus and theoretical strands, we suggest the concept of embeddedness to survey the social science perspective. Industrial ecology/ symbiosis addresses, from a systemic perspective, material and energy streams as they result from human activities. These activities do not occur in a vacuum; they are embedded, that is, they are shaped by the context in which they occur. Building on Zukin and DiMaggio (1991) we propose the following five dimensions:

Cognitive embeddedness refers to the way in which individuals and organisations collect and use information, the cognitive maps they employ in making sense of their environment, and the mental disposition of individuals. Themes that can be derived from this are:

- *Bounded rationality*. Following economic approaches, we often assume individuals and organisations to behave according to a rational actor model. A more realistic view is that action is that rationality is bounded, in the sense that individuals and organisations have limited capacities for information processing and decision-making. It has consequences for our ability to deal with complex, multi value problems such as sustainable development.

- *Systems thinking*. Individuals have different strategies for problem solving. Some of these are more suited to systemic problems than others (Sweet et al., 2003). To what extent can such strategies be identified in the activities of participants in Industrial Ecology initiatives?
- *Characteristics of 'change agents'*. Industrial Ecology deals with social change processes. Individuals that act as change agents within or between organisations have special backgrounds and capabilities. We know little about the ways in which these characteristics emerge, and how they can be successfully employed within IE-networks.

Cultural embeddedness addresses the influence of collective norms and values in guiding economic behaviour, such as the shaping of preferences, and the influence of ideologies in shaping future visions. We believe that within the field there is a tendency to externalize normative issues, or to take normative positions for granted, both in our scientific activities and in our subject matter. Referring to the latter, some interesting topics are:

- *Collective cognitive maps*. Actors within organizational fields (industrial sectors, regions, national societies, product chains) tend to develop a collective view on the world and ways in which problems should be addressed (IE itself is such a map). This narrows the search for innovations and solutions for social and ecological problems. How do such maps develop, and how do they restrain or enhance the development of IE initiatives?
- *Development of consumer preferences*. Industrial systems fulfil and help define consumer preferences. These preferences are to a great extent culturally determined. How have preferences developed over time, and in what ways has industry influenced them to increase material consumption?
- *Defining what is legitimate*. The definition of what is acceptable industrial behaviour is a social construction, as is the definition of what constitutes acceptable government intervention in industrial activities. This helps to explain why legitimate behaviour differs from country to country. Consequently, it is difficult to copy successful practices of IE from one country (or even region) to another.
- *Defining what is sustainable*. Cultural embeddedness directly implies that sustainability cannot be defined objectively. The major consequence of this is that it needs to be defined in local contexts. What are processes to do so, and what mechanisms make existing definitions difficult to change?

Structural embeddedness emphasizes the way in which relationships between actors influence their actions. This dimension has received most attention as a social science contribution to the field of Industrial Ecology. Industrial networks have been analysed (see Session 3A), and coordination mechanisms have been discussed. However, linking these structural features to other dimensions of embeddedness remains a relatively unexplored territory.

Political embeddedness acknowledges the fact that processes of power influence economic actions. This includes the role of the state in the economic process. The role of power is rarely discussed systematically in our field. This may have to do with the fact that it is one of the more difficult concepts of sociology in terms of empirical analysis. Nevertheless, actors are not equally able to influence each other's actions and system outcomes, and this central fact of social life must be taken into account.

- *State promotion of IE.* Although research indicates the importance of spontaneity and emergence in successful examples of IE, many governmental actors have sought to promote IE. Can the traditional power base of the state be used to initiate such developments?
- *Market power.* Relationships between firms are asymmetrical. This has effects in terms of their abilities to start or raise barriers to changes in product chains.
- *Exit, voice and loyalty.* How can employees, citizens and consumers participate in IE efforts, given their disadvantage in terms of power in relation to governments and firms? Are stakeholder dialogues the answer, or do these serve mainly to capture these interests?

Spatial and temporal embeddedness focuses on the way in which geographical proximity and time influence economic action. The dimensions of space and time are implicit in many accounts of Industrial Ecology, yet we believe they deserve explicit treatment. Physical proximity has been identified as a crucial catalyzing factor in, for instance, the occurrence of complex forms of learning and the building of trust. Time is important as the evolution of industrial systems typically involves long time periods. Some interesting themes are:

- What is the relationship between regional and other forms of industrial ecology? Should regional systems be a focus because of the consequences of physical proximity?
- How can effects of physical proximity be capitalized in global production and consumption chains? Can these be viewed as interconnected regional systems?
- What are the consequences of considering life cycles of industries, regions and product chains?
- Industrial systems develop over time, displaying inherent dynamics of institutionalisation. One perspective of intended change is to counteract such inherent developments of social systems.

POINTS FOR DISCUSSION

Above, we have listed dimensions that for us capture the social science contribution to the field of industrial ecology, and listed themes that we feel are worthy of exploration.

- **Question 1:** Do these dimensions cover the scope of the social science perspective?
- **Question 2:** Which of these dimensions/themes have up till now been addressed in our field?
- **Question 3:** What are further possibilities (themes) for research?

LINKING SOCIAL SCIENCE CONTRIBUTION TO MANAGEMENT APPROACHES AND BETA SCIENCES

We feel that there is an urgent need to link the social science contribution to other parts of the IE-field. We see two challenges:

1. Linking social science to beta-science approaches. This is a major promise of the field, yet up till now we fail to provide this linkage in research efforts. It requires research projects in which there is true collaboration between researchers from both sub-fields, with the time to establish a common framework of understanding for making a synergetic contribution.
2. Making a thoughtful step from social science research to management and policy contributions. The majority of social science informed contributions to the field are in fact management-oriented. While valuable, these need to take into account more explicitly the consequences of embeddedness as discussed below. This implies:
    - Change of social practices is successful only if context is taken into account
    - Lasting changes are only possible if context changes as well
    - Leverages: look for local changes that change the system

We feel that there is an urgent need to link the social science contribution to other parts of the IE-field. How can these links be established, fortified, and synergized? We see two challenges.

REFERENCES

Sweet, S., N. Roome and P. Sweet. 2003. Corporate Environmental Management and Sustainable Enterprise: the Influence of Information Processing and Decision Styles. *Businesss Strategy and the Environment* 12(4): 265-277

Zukin, S. and P. DiMaggio (Eds.). 1990. Structures of Capital: The Social Organization of the Economy. Cambridge University Press.

DISCUSSION AND RESEARCH QUESTIONS

Discussion linked each dimension of embeddedness to work presented at the symposium or in the field:

Cognitive embeddedness: NISP hiring is a selection process for individuals to perform a brokerage function – a particular way of processing information. NISP workshops also address cognitive embeddedness, getting individuals thinking in a new way. Mr. Grant's work (see Session 2) also relates to how individuals process information via an IT function.

Cultural embeddedness: this context reminds us that one cannot assume a common language or understanding of terms such as waste. These cultural norms may explain why something technically possible is not practicable culturally. The normative aspects of industrial ecology and sustainability are still the unnamed elephant in the field: as a community, we value neutrality, objectivity, and universal truths – but do we largely ignore the normative aspects of what we're doing? Is it a normative judgment to think 'more exchanges are necessarily better'?

Structural embeddedness: Professor Howard-Grenville's work (Session 3A) on social network analysis provides a better understanding of the patterns of existing NISP networks, with important implications for the robustness of networks and how they can be strengthened.

Political embeddedness: The state promotion of IS was discussed for Korea and China in Session 2, emphasizing the role of IS in environmental protection and resource efficiency over economic benefits. Professor Clift's work (Session 4) explores the influence of the power relationships within a supply chain on its sustainability. Power relationships are central to information gathering: in a top-down situation, practitioners can demand information; in the networking paradigm, the practitioner has to elicit information, requiring a different skill base (linking back to cognitive embeddedness). Understanding power relationships are relevant when examining how to influence government policy.

Spatial and temporal dimensions run throughout the other 5 dimensions. Mr. Laybourn raised the issue of temporal evolution in Sessions 1 and 4. The distinction was made between an inherent dynamic (things naturally changing with time) and an intended dynamic (dynamics introduced on purpose), and the timescale: norms change over decades, not years. The need to make explicit the spatial dimension was also discussed – as one participant pointed out, there are regions in the Netherlands that are smaller than some cities – and this spatial scale is also relevant for development of social networks.

After linking each dimension to other work, the question was raised: which was most important for future research? Discussion was lively. The validity of disaggregating the five was questioned, highlighting the complex interrelationships between them (cause and effect, e.g., are prices determining behaviour or the resultant of said behaviour). The usefulness of the construct in disaggregating social impacts was also highlighted; for example, giving a structure or framework for practitioners to approach the issue of why a technically feasible trade has not gone

ahead. A few practitioners united in the opinion that structural embeddedness was the most important to advance their work. Returning to the lack of clarity around 'what is IS,' it was suggested that further research into understanding what's unique about IS, and common across contexts, will point us to the right dimension. The group agreed it was useful for organizing what social scientists can contribute to IS.

Further reading on integrating social sciences with industrial ecology was suggested by the session moderator, Reid Lifset:

Cote, R. Tansey, J. and A. Dale. 2006. *Linking Industry and Ecology: A Question of Design*. UBC Press.

Green, K. and S. Randles (Eds). 2006. *Industrial Ecology and Spaces of Innovation*. Edward Elgar Publishing.

The Business Management Case for Industrial Symbiosis

Session 4 closed with a panel discussion on the business case for IS. Panelists were: Mr. Peter Laybourn, NISP, UK; Mr. Jørgen Christensen, The Symbiosis Institute, Denmark; Professor Marian Chertow, Yale University, USA.

Mr. Laybourn:

To engage companies, one must recognize their culture and context. Companies are accustomed to being regulated by government, and berated by non-governmental organizations. Where government programmes try to support them, they are often single issue (be it energy or waste, etc.) and directive, dictating what solution should be applied and how it should be implemented. Externally generated solutions often lack company buy-in and ownership – most companies do not appreciate having some outsider come in and imply they're not running their business correctly. It doesn't match their management culture of self-sufficiency, solving one's own problems.

What changes with NISP? We engage with companies, listen to them, and aim to get to the right solution; if we can't help them, we usually know someone who can. Our interaction is to find out problems, and offer solutions – there is no 'should' associated with the interaction. And I find it very interesting that we usually engage based on something completely different than what they contacted us about in the first place.

Mr. Christensen:

Mr. Christensen reminded us that the story of Kalundborg has been told many times. The exchanges initially developed spontaneously, and later on purpose, but always on a voluntary basis. All bilateral relationships were initiated and carried out by the actors themselves. Forty-six years in, it is a non-project done by a non-organization; there is no supreme chief. Most of the projects are still active and making money every day. The low hanging fruits have been picked; the current aspiration is to have a bio-ethanol plant as a good idea in principle, and Kalundborg is well suited in having appropriate users (Statoil, agriculture). Such a large project takes time and effort from every actor. One lesson he's learned over the course of this symposium is that they're not the only ones with challenges selling IS ideas.

Professor Chertow:

Our understanding of the business benefits for IS has changed over the years. Initially considered are the conventional benefits of reducing cost and increasing revenues through resource exchanges that decrease disposal and add new by-product sales: if the business doesn't see the advantages, they don't do it. The next tier recognizes that with the first level alone there are still several unrecognized or undervalued benefits such as productivity increases resulting from labour pooling and resource efficiencies. There are also soft benefits of collaboration that can yield opportunities not related to material flows but through other cooperative efforts both in the present and in the future. IS can also become a catalyst for new innovation driven by a desire to add value to by-products as was demonstrated by Professor Rene van Berkel in Australia.

Emerging business rationales for IS exchanges include:

1) Resource availability is a large factor all over the world, especially where resources such as water or electricity are constrained.

2) Minimizing the risk of supply interruption is another large factor. The need to stay on schedule can even surpass the drive for low costs in some instances. Where transport or timing is an issue, local suppliers may be more reliable.

3) A few studies are showing that collective action has the potential under some circumstances to increase both tangible and intangible benefits to firms. It may also provide regional benefit that exceeds the benefit to any one company.

PANEL DISCUSSION AND RESEARCH QUESTIONS

Business Benefits of IS

Many participants shared experiences around IS as source of innovation, value creation, and competitive advantage. An IS approach is being used to improve the economics of energy utilization through improving resource efficiency and value creation at a refinery; also creating synergistic new industrial activity in the area. In China, IS is first a strategy to cut costs and address poor environmental quality and limited resources, but it is also looked to for new business development opportunities. As discussed in Session 3B, the link was made again here to the potential for IS to contribute to regional development by engaging companies, governments, and researchers on a regional basis working together to enable regions to be proactive.

In the Nordic/NISP model, all exchanges are bilateral (some multi-lateral) and voluntary and the distribution of economic benefits is negotiated as with any other supplier/buyer relationship: price including any necessary infrastructure, guarantee of quality, exit strategy, and so on; in the experience of practitioners at the Symposium, it is the same for IS exchanges. Both parties try to make the best deal

they can. As a relationship matures, the companies may be more and more open with each other, and negotiate more honestly. In the experience of one practitioner, many companies are willing to be a little more flexible in their requirements (e.g., payback time of an investment) when the benefits accrue to the environment.

Economic Case Not Enough

Viewing companies as purely rational economic entities is a naïve view from a number of perspectives. Historically, companies were perceived as social arrangements to achieve collective goals. Currently, the sustainability agenda has gained in profile (as evidenced by Mr. Heathcote's presentation in Session 1) bringing with it a balance of economic, social and environmental objectives. We have also heard about situations where commercially viable synergies have not been implemented due to barriers such as company's management culture, risk aversion, or focus on core business (see Session 3A). This multi-objective decision-making presents a challenge to traditional thinking, and a challenge to the IS community to understand why the economic case is not always enough. It is also where the social science perspective is useful in providing a framework for analysing the non-technical, non-economic contextual barriers to IS exchanges.

Themes and Future Directions

Dr. D. Rachel Lombardi, University of Birmingham
Mr. Peter Laybourn, NISP

In this third annual Industrial Symbiosis Research Symposium (ISRS) focusing on Industrial Symbiosis (IS) in Action, the UK National Industrial Symbiosis Programme (NISP) featured prominently, and the company perspective was included for the first time at an ISRS. Further marking the focus on implementation, a matrix of possible approaches to implementing IS emerged. In the geographic review of Session 2, two fundamentally different approaches to IS were discussed: the planning paradigm in 'developing' economies such as Korea and China where central governments are using IS as a planning tool to foster regional development and resource efficiency; and the voluntary paradigm in 'mature' economies where IS is being applied as an eco-efficiency tool to achieve 'triple bottom line' benefits, and as a basis for regional economic development. Other discussion focused on the juxtaposition of a prescriptive approach (where solutions are provided 'outside-in' in a consultant model) versus a demand-led approach (where programs like NISP respond to requests by business). In addition, approaches were disaggregated by resource focus, industry sector focus, or geography focus (Session 3B). Further research is needed to determine which approach (or combination thereof) is best suited for each set of conditions.

Notwithstanding the differing conditions and approaches, researchers and practitioners were in agreement over the importance of establishing robust networks, effectively facilitating the networks, the usefulness of a social science analysis for understanding and advancing IS, and quantifying benefits. Debate continues around the optimal role of government and policy instruments, the importance of size and scale for IS, and the relevance of business issues such as innovation and supply chains. And when we as a community can pick our heads up from the details of implementation, the larger question remains for substantive debate: where does IS fit in the sustainability agenda?

AREAS OF BROAD AGREEMENT

The Importance of the Network

The academic definition of IS includes connecting a network of companies across sectors in a collective approach. The need for working cross-sector was made explicit

by a number of delegates for both understanding problems and providing solutions: Dr. Bailey (Session 3B) made the point that certain waste flows are characteristic of an industry sector (e.g., waste heat in petrochemical industry) thus necessitating looking to another sector for a solution (in this case, food); Mr. Ramaswamy (Session 3B) demonstrated that without considering all sectors, one cannot fully characterise resource flows and potential conflicts in their use. Professor Howard-Grenville's work (Session 3A) introduced methods to characterise the evolution and structure of existing IS networks, with implications for how to strengthen them. The facilitated approach becomes necessary to address the challenges of cross-sector working: businesses lack the awareness of opportunities outside their own sector; they lack information on potential partners outside their own sector; and they lack the time to find the information (Sessions 1 and 3A).

The Importance of Facilitation

In the voluntary approach, new network opportunities are created, for example, through workshops, outreach events, and tapping into existing networks where possible to accelerate the process (Sessions 1 and 3A). This facilitation was likened to supporting companies through the initial phase of dating. The importance of this skill was highlighted in Dr. Bailey's experience (Session 3B) of NISP-YH being sanctioned to do a regional water study for their networking and facilitation expertise, rather than any particular expertise in water networks. Mr. Heathcote (Session 1) also highlighted opportunities that could not have moved forward without the cross-sector connections made through NISP to other companies and entrepreneurs.

The Social Science Perspective

Linking all approaches was concern for the intangibles of the networks and facilitation: the role of trust and of human interaction (Session 3A), and the business decision-making process (throughout). The social science perspective presented by Professors Boons and Baas (Session 4) provided a structure within which to analyse the non-technical, non-economic contextual barriers to potential exchanges, such as management culture, and risk aversion. Social network analysis may advance understanding on the benefits of social ties networks, such as shared norms and trust (Session 3A).

Quantifying Benefits

Following on from ISRS 2004, the importance of quantification arose a number of times. For the practitioner, quantification of IS benefits was vital to substantiate the business case necessary to secure engagement with industry (Sessions 2 and 3A), and to secure credibility and hence funding from government (Session 1). For policy applications, a valid and complete comparison of options requires all flows to be identified and quantified (Session 3B).

Due to its breadth, the basket of benefits from an IS approach may be substantially undervalued, perhaps contributing to policy makers underestimating or not understanding the potential of an IS approach: resource efficiency programs are not

often measured, for example, on jobs created or private investment attracted – both documented benefits of engagement in NISP. To value fully the benefits generated by IS programs requires leveraging the tools from a host of different fields: environmental impact of tonnes diverted from landfill; economic impact of innovation and additional sales; social impact of learning opportunities and jobs protected and created (Sessions 1 and 4). One asks whether such diverse benefits could be converted to a single currency (e.g., carbon) for comparative purposes. From a program standpoint, tradeoffs must be made on a regular basis: which is "better", a ton of water savings or a ton of landfill diversion, be it waste paper or expired batteries?

AREAS OF DEBATE

Debate: Is IS Business as Usual?

One arena where the academic-led research agenda and the practitioner-led research agenda diverged was around the difference for business between non-IS and IS relationships, if any. Concerns about confidentiality, lock-in, price, and contracts have not borne out through the NISP or Kalundborg experience, but the research evidence to substantiate that experience is lacking. Participants identified literature addressing changes in supply chain evolution that can be used to benchmark supply chains for companies engaged in IS exchanges. Further research and quantification is necessary to clarify whether there are differences in the supply chains and supplier relations for companies engaged in and integrating IS:

- Are there differences, if any, between a non-IS supplier/buyer contract and an IS-supplier/buyer contract for exit strategy, lock-in, distribution of economic benefits, price, other?
- What characteristics, if any, are distinctive for the supply chains of companies that have adopted many characteristics of an IS approach: do they have fewer suppliers than their competitors? Do they have suppliers from more diverse sectors (reflecting increased cross-sector engagement) than their competitors?

Debate: Innovation versus Proven Technology

In the discussion of universal success factors (Session 2), additional assumptions about IS arose: IS as an end-of-pipe technique, not influencing up-stream processes; and proven technology as necessary to counter 'risk' of IS exchanges. These generalizations run counter to the experience of NISP (Session 3) that engaging in IS can foster innovation, namely, new applications for proven technologies from other sectors; processes changed to increase efficiency and reduce or eliminate wastes; and new product development opportunities that, once identified through IS, stimulate new research to bring them to fruition. Without acknowledgement by policy makers (supported by an evidence base) that IS can be an instigator of innovation, IS may continue to be viewed as an 'end of pipe' solution and thus low in policy priorities.

Debate: The Role of Government

Appropriate policies to foster further IS implementation were discussed briefly. When is it appropriate to use part of an 'environmental tax' to support IS networks, and what evidence would be required to do so? Can networks themselves be effectively 'mandated,' or could a resource be targeted and exchanges mandated for that resource [see, for example, Chertow and Lombardi 2005]? Before an assessment of appropriate policy instruments can be conducted, the most effective home for IS within the policy framework must be identified: is it a waste program, as most assume? Or is it a resource efficiency program? Or economic development? Should the program reside at the national level, or should it be regional?

The most common association of IS is with waste programs. The legal definition of waste is often found to be unclear, and as such poses a potential barrier to IS implementation (Session 3A). Delegates from Korea, Canada, the USA, the UK, and others, shared the perception that amending the framework surrounding such legal definitions can take years. In the UK, 'waste protocols' are being developed through a stakeholder process with the regulators to clarify the intent of the legislation, in many cases removing perceived legislative barrier to IS. The future vision for NISP recognizes the potential for a greater role in informing and shaping policy and regulations. En route is a daunting educational task: to change the perception on the part of government, the media, and companies, that IS is a 'waste' or 'recycling' programme. This perception hinders the programme's ability to fully realize its potential to transform the way industry views its material and other resources.

Size Matters: SMEs, Aggregation, and Economies of Scale

Size of Resource Flow

The economies of scale were raised repeatedly throughout the symposium and across geographies. Small flows were associated with small companies (although not exclusively), and the role of aggregation was discussed. Aggregation was central to the analysis done in India (Session 3B). When dealing with many generators of small quantities of waste and other resources, what determines whether these flows can be aggregated? What factors determine the appropriate geographic scale for aggregation?

Network of Networks

NISP started as a number of regional IS programs, each defined by a political-administrative region or sub-region. When NISP rolled out nationally, it maintained the regional delivery structure and the personal contacts important for facilitation. The regional work, in NISP's experience, has been greatly enhanced by knowledge transfer and linkages between networks coordinated at the national level. The issues facing multiple linked networks and the relationship between regions were not addressed at the 2006 ISRS.

Size of Network

The future vision for NISP recognizes the great potential for growth in membership:

as mentioned previously, NISP has already been approached by the UK government for an indication of the scalability of the programme, that is, how big the network can grow. Research is needed to understand the implications of the scale of the network for effective facilitation, the role of personal contact in building the network and facilitating exchanges, and the necessary tools.

SOME FINAL THOUGHTS

The practitioner-led research agenda alternately converges and diverges with the academic-led research agenda in ways that were interesting to the academic, but obvious to the practitioner. Many of the areas of agreement addressed here were identified in Session 1 as central to NISP's wide acceptance by business: being business-led; its reputation as a trusted and independent facilitator and networker; and the audited quantification of benefits to substantiate the business opportunities from IS exchanges. The greatest areas of divergence fall under the rubric of 'business as usual', where academic concerns have not been borne out in the experience of the practitioners present. Other areas of the practitioners' concerns point to the need to engage other disciplines in the practical implementation of IS: engaging with large multinational corporations; engaging with small companies and entrepreneurs and connecting them with the large corporations where appropriate; identifying and engaging with solution providers (including universities and entrepreneurs); engaging at a national level with multiple regional programs; and efficient and effective knowledge transfer amongst linked regional delivery networks.

Debate: IS and Sustainability – When is More Better?

Industrial ecology, and within it industrial symbiosis, have been positioned many times as contributors to the broader sustainability agenda in the academic literature and throughout this Report [for a review and discussion of industrial ecology and sustainability, see Ehrenfeld 2007; for a review of the conceptualization of sustainability, see Hopwood et al. 2006]. Achieving sustainable development is based on equity in its various forms (inter-generational, intra-generational, geographic, procedural, and inter-species) and, it is generally postulated, will require transformation of existing socio-economic systems. The larger question facing this community is whether and how IS can contribute to that transformation.

The current contribution of IS to sustainability may be primarily through eco-efficiency gains: finding "win-win-win" situations with economic gains for the companies involved and resource-related environmental gains. We have also seen the case for IS as a driver of innovation and business culture change, clearly advantageous for sustainability relative to business as usual – but is it innovation in the right direction? It may be the case that certain regulated materials continue to circulate through the economy, avoiding the 'waste' label through IS exchanges, thus mitigating the impact of environmental policies. Looking to the example of lead in society, yes, we can manage the flows but do we as a society want them mobilized at all? [for a debate on the use of lead, see Lave et al. 1997; Socolow and Thomas 1997a & b] As

more regional programs develop and benchmark one against another, what role the implicit assumption of 'more is better'?

It falls to the research community to explore the system boundaries for IS: what is its potential contribution to advancing the sustainability agenda? What policy and structures are necessary to fully leverage that potential? Under what circumstances (if any) does pursuing IS create a misaligned incentive by mitigating a necessary and proper policy burden? If one accepts that industry has the capacity to contribute toward sustainability, then perhaps the potential of IS has as much to do with its ability to engage industry in change as it does with improving eco-efficiency: opening further dialogue and opportunities on a broad range of issues contributing to sustainability, acting as a necessary bridge in the immediate term to a reformed, if not transformed, business model.

REFERENCES

Chertow, M. R. and D. R. Lombardi. 2005. Quantifying economic and environmental benefits of co-located firms. *Environmental Science & Technology* 39(17):6535-6541.

Ehrenfeld, J.R. 2007. Would Industrial Ecology Exist without Sustainability in the Background? *Journal of Industrial Ecology* 11(1): 73-84.

Hopwood, B. Mellor, M, and G. O'Brien. 2005. Sustainable Development: Mapping Different Approaches. *Sustainable Development* 13: 38-52.

Lave, L.B., Hendrickson, C.T. and F.C. Michael. 1997a. Clean Recycling of Lead-Acid Batteries for Electric Vehicles. *Journal of Industrial Ecology* 1(2): 33-38.

Socolow, R. and V. Thomas. 1997a. The Industrial Ecology of Lead and Electric Vehicles. *Journal of Industrial Ecology* 1(1): 13-36.

Socolow, R. and V. Thomas. 1997b. Rejoinder to Lave, Hendrickson and Michael. *Journal of Industrial Ecology* 1(2): 39-40.

Industrial Symbiosis Research Symposium 2006
Industrial Symbiosis in Action
5-6 August 2006

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NISP
NATIONAL INDUSTRIAL SYMBIOSIS PROGRAMME

AGENDA

Industrial Symbiosis Research Symposium 2006
Industrial Symbiosis in Action
Austin Court, Birmingham, England
August 5-6, 2006

Sponsored by Advantage West Midlands and the National Industrial Symbiosis Programme (NISP)
Hosted by NISP West Midlands
Organised through the University of Birmingham and Yale University

Saturday, August 5

Registration and Welcome
9:30 – 10:00am *Registration, coffee & biscuits*
10:00 – 10:30am *Co-Chairs welcome, opening remarks*
- Prof. Roland Clift, University of Surrey, England
- Prof. Chris Rogers, University of Birmingham, England

Session 1 – Introduction to the National Industrial Symbiosis Programme
10:30 – 11:30am *NISP Origins and Overview*
- Peter Laybourn, Director: Introduction to NISP
- Richard Heathcote, Scottish & Newcastle, PLC: Industry Involvement
- Abhishek Agerwal, Robert Gordon University, Scotland: Approaches to Metrics

Session 2 – Industrial Symbiosis Hot Spots
11:30am – 1:00pm Moderator: Prof. Marian Chertow, Yale University, USA
Geographic review
- *Australia*: Dr. Steve Harris, Curtin University of Technology, Australia
- *Korea*: Prof. Changwon Kim, Pusan University, S. Korea
- *China*: Prof. Shi Lei, Tsinghua University, China
- *North America*: Prof. Marian Chertow, Yale University, USA

Update on IS modeling
- Gabriel Grant, Purdue University, USA

LUNCH BREAK

Session 3 – Two Discussions at the Leading Edge

2:00 – 3:30pm Moderator: Jórgen Christensen, Symbiosis Institute, Kalundborg, Denmark

Mechanisms to Advance IS

- Prof. Jennifer Howard-Grenville, Boston University School of Management, USA: Evaluation of brokerage/network models
- Dr. Adrian Murphy, NISP: Focus engagement models
- Dr. Arnulf Hasler, EU-Regional Management of Upper Styria West, Austria: Inter-firm coordination

4:00 – 5:30pm Moderator: Dr. Rachel Lombardi, University of Birmingham, England.

Industrial Symbiosis and Regional Development

- Ramesh Rameswamy, Resource Optimization Initiative, India: IS and regional planning
- Dr. Malcolm Bailey, NISP: IS as a regional development tool

DINNER 7pm **Birmingham City Council Banqueting Suite**

- Councillor Mike Nangle
- Ralph Hepworth of Advantage West Midlands

Sunday, August 6

8:00am – 9:15am – NISP Showcase Canal Tour (Optional - but please come!)

Session 4 – Industrial Symbiosis in Theory and Practice

9:30am – 12:30pm Moderator, Reid Lifset, Yale University, USA

IS and its Relationship to Sustainability

- Prof. Roland Clift, University of Surrey, England

IS in a Social Science Perspective

- Profs. Leo Baas and Frank Boons, Erasmus University, The Netherlands

The Business/Management Case for IS

- Jórgen Christensen, Symbiosis Institute, Kalundborg, Denmark
- Peter Laybourn, NISP
- Prof. Marian Chertow, Yale University, USA

LUNCH BREAK

Session 5 – Wrap-up

1:30pm – 2:30pm Group Discussion: Future Directions and Research Gaps

Moderators: Profs. Roland Clift & Chris Rogers

Summary of Second International Industrial Symbiosis Research Symposium: Stockholm, Sweden, June 11, 2005

Sixty-two researchers from seventeen countries convened in Stockholm in June 2005 to discuss the state of research in the field of industrial symbiosis. Industrial symbiosis is principally concerned with the cooperative management of resource flows through a network of businesses as a means of approaching ecologically sustainable industrial activity. The event was sponsored by the Nordic Council of Ministers and organized through IIIEE at Lund University, Roskilde University and the Norwegian University of Science and Technology, in collaboration with Øresund Environment Academy.

The objective of the symposium was to identify and discuss on-going theoretical and empirical research, as well as current trends, and to continue the dialogue in light of the agenda from the first symposium held at Yale University in 2004. Key issues for discussion included the definition of symbiosis, the most effective means of implementing symbiotic relationships, the quantification of benefits, and the role of other disciplines in research and practice.

INTRODUCTION

Introductory remarks by Dr. John Ehrenfeld, Executive Director of the International Society of Industrial Ecology, challenged his colleagues to address many of the questions surrounding industrial symbiosis. He described a new framework that envisions industrial ecosystems as SOHO systems: self-organizing holarchic open complex systems, based on research by Canadian ecologist James Kay. Properties emerge from the system, and sustainable development is a measure of the health of the system. Key questions include: How do eco-industrial networks evolve? What are the barriers to and key characteristics of effective development? Which models work? What role should the market or government play in this evolution? How does local culture effect development of networks? What is unique about IS/EIN compared to industrial development in general? To the industrial supply chain? Given that managing a complex system over time is very difficult, how best should IS/EIN be considered? Who shares risk and how should it be allocated?

Professor Stefan Anderberg followed these remarks by making a case for increasing the breadth and depth of IS research in Nordic countries. In general, IS is still not a well-known concept in the region except in Denmark. The use of the IE concept is primarily confined to academic circles; however, IS-like activities under various names have been carried out by both municipalities and some industries. There are an increasing number of initiatives to adopt IS in local community development. Forest and metal industries have traditionally undertaken IS activities and remain at the vanguard of implementing IS within industry.

FRONTIES WITHIN CONTEMPORARY INDUSTRIAL SYMBIOSIS RESEARCH

A two-part panel discussion gave presenters the opportunity to talk about cutting-edge research being done in industrial symbiosis at universities. Ramesh Ramaswamy moderated Part I, and the first speaker was Professor Marian Chertow, who discussed the frontiers of industrial symbiosis research thematically (what frontiers are being explored), methodologically (how are we examining questions), and geographically (where are significant efforts underway). She stressed the importance of exploring multiple temporal, spatial and organizational scales in analyzing industrial ecosystems, especially as we come to understand them more as complex adaptive systems. She noted the first sketch of a collective action model proposed by Boons and Janssen, the "natural history" approach her team is using in Puerto Rico to investigate industrial and social networks, and techniques for adapting industrial ecology tools to study IS in developing countries (e.g. Erkman and Rameswamy). Professor Pierre Desrochers offered a perspective on the economic and geographic factors that have led, historically, to by-product linkages. He discussed earlier related concepts including joint production, agglomeration economies, and long distance trade.

Professor Leo Baas provided an historical view of the process by which the industrial ecosystem has evolved in Rotterdam. Development of the project occurred in multiple phases and was directed by a decision-making group consisting of stakeholders from industry, government, academia, and environmental advocacy groups. The phased implementation took into consideration sociologically relevant elements of community, including the existence of informal and formal networks and eventually the adaptation of networks as contexts for learning. The project has been successful in capturing waste heat: the district expects to increase the number of homes being heated from the project to increase from 3,000 in 2006 to 52,000 in 2020. The key factors for the success of IS efforts as observed over the last ten years in Rotterdam include: mutual understanding and recognition between government and industry; good communications and strategic dialogues among major stakeholders; incremental development of complex social networks as the platform of IS, and a sufficiently long time horizon to make it happen.

Discussion covered the importance of coordination, including how much and how little could be coordinated in a market setting. Also, confidence building was discussed as key to reducing transaction costs in network formation. Common

instruments for comparing and assessing data are also important in exchange networks and may help to reduce defections from those who are satisfactorily receiving services but may not wish to continue the obligations of a network.

Professor Matthias Ruth moderated Part II of the panel discussion. First, Professor Rene van Berkel discussed the great progress that has been made in Australia in developing IS in mining and other resource processing sectors. Analytical and diagnostic tools that allow for more systematic understanding of the inter-industry, inter-sectoral material and energy flows have been further developed in Australia, which has been helpful in recognizing benefits which are usually undervalued and underestimated. Successful projects have been found to be a mix of technology, license to operate, and a compelling business case; but if any of these are missing, there is likely to be a failure. IS has been increasingly adopted as industrial development and as a key platform for technological innovation rather than narrowly as an environmental and recycling strategy.

Prof. Yong Geng discussed the increasing resource and environmental pressures that have impeded China's efforts to rapidly improve the quality of life of its population, while protecting its environment from being degraded. Industrial ecology has been promoted as a potential means of breaking the impediment. He stressed that China has to explore its own way of implementing IE, by planning eco-industrial parks, developing appropriate technologies, and, eventually, through the development of a circular economy – a national strategy for future economic development.

Professor Allan Johansson focused on the need for large-scale change, and how most of the efforts to focus on sustainability have focused too much on material and energy issues and not enough on social and soft sciences. He described an alternative strategy to drive sustainable industrial development – that of distributed economies, a strategy to combine sustainable development with knowledge of innovation and entrepreneurial behavior, with a focus on small and medium sized enterprises and communities.

Discussion centered on the role of self-organization in industrial symbiosis and the relative importance of exchange in driving the types of environmental changes needed. In addition to environment, industrial symbiosis should also be seen as a means of achieving competitive advantage. Professor Ruth stressed the importance of studying failures in addition to successes as a means of increasing knowledge

PH.D THESIS RESEARCH: CASE STUDIES AND THEORETICAL IMPLICATIONS

Three Ph.D. students presented their thesis research, giving participants the opportunity to hear from the next generation of leaders in the field of industrial ecology. Weslynne Ashton from Yale described her IS research on industrial clusters in Puerto Rico over a timeframe of about fifty years. This enables the use of tools and criteria from different fields to characterize succession patterns and how the systems adapt to change, and to examine the role of social networks of the actors in the systems more carefully. Murat Mirata from Lund University discussed the action

research he has been conducting that increases flexibility in addressing a complex system from different dimensions. His research has focused on Landskrona, Sweden, where it is necessary to confront the extent to which IS might be helping some firms stay in business that will not be there in the long run when more radical changes must occur. Olli Salmi from Helsinki University of Technology has been researching different views of eco-efficiency and eco-effectiveness in relation to a study of the industrial Kola Peninsula region in Russia. This has led to a comparison between market socialism and market liberalism in understanding what has happened and what should happen in the future.

GROUP DISCUSSION SESSIONS

In the afternoon, conference participants broke out into groups to discuss one of three topics.

The first group, moderated by Professor Jun Bi, conducted a comparative analysis of the ways in which policy and planning effect industrial development in the East vs. the West. The group compared central planning, prominent in Asia, with more self-organized or market-based approaches to development as experienced in Europe and North America. The group agreed that the role of planning was important, but how it is done is a key part of the outcome and can differ widely.

Professor Stefan Anderberg moderated the second group on the role of social systems in industrial symbiosis. Discussion stressed that beyond a tool or physical relationship, industrial symbiosis is also a social network of people so must also focus on organization, processes, and governance.

The third group, moderated by Peter Lowitt, looked at the complexity of developing metrics to evaluate the success of IS projects in light of the different needs of different stakeholder groups. Several efforts to develop indicators were noted at the State Environmental Protection Administration in China, Curtin University in Australia, and Waterloo University in Canada.

PLENARY DISCUSSION ON RESEARCH DIRECTIONS

To wrap up the conference, there was a plenary session on research directions for the future, moderated by Suren Erkman, and a discussion of next steps, led by Mikael Backman, Marian Chertow, Peter Laybourn, and Noel Brings Jacobsen. Dr. Erkman stressed that industrial ecology is a hybrid – not a science but a transdisciplinary concept. Since industrial symbiosis is embedded in other ecosystems, it raises the questions of the limits and relevance of industrial symbiosis and what it can contribute to sustainability.

While the participants stressed the multidisciplinary approach inherent in industrial ecology (and the increasing trend in this direction), there was also some concern that perhaps the field was getting too broad and needed to retain a narrower focus. There were also discussions of the need to broaden the scale of research (spatially, temporally, and organizationally) and to address social sustainability issues in addition to the current focus on technology.

A challenge for industrial symbiosis research is the volatility of companies – internal and external – and the challenges that poses to managing industrial ecosystems. Some expressed the idea that there is still a large opportunity to develop the engineering part of industrial symbiosis and that perhaps research in this area had been neglected.

The potential clash of self-organization and modeling systems theory was raised. Perhaps an iterative approach could be developed as a more fundamental view of these issues is taken. It is important not only to look at the output side (the waste that is a problem that needs to be solved) but also on the input side.

The view that many IE/IS principles go against traditional business school logic was raised. IS even has some enemies, such as those favoring simulation or those in the camp that "we can't bring all the stakeholders together all the time." Finding ways to identify people who will trigger change is key.

Looking ahead to the future of research in the field, symposium participants noted that better tools are needed to evaluate the economic and environmental performance of IS. In addition, participants stressed the importance of drawing on the knowledge and tools of other academic disciplines, while maintaining a distinct identity for the field. Some participants were interested in finding more ways to apply IS knowledge to real world business scenarios—essentially bringing IS out of the classroom and into the corner office. All participants agreed that research is changing to incorporate new tools and approaches, as new discoveries and insights continue to emerge.

Special thanks to Noel Brings Jacobsen for organizing the initial note-taking on which this summary is based.

Stockholm Industrial Symbiosis Research Symposium Schedule
June 11, 2005

09.30 - 09.45: Coffee and registration
Welcome by *Noel Brings Jacobsen*, Roskilde University, *Mikael Backman*, IIIEE at Lund University and *Marian Chertow*, Yale University

09.45-10.15: Introduction
Industrial Symbiosis in Industrial Ecology – Introductory remarks by *Dr. John Ehrenfeld*, Executive Director, International Society of Industrial Ecology (ISIE) **Industrial Symbiosis in a Nordic Perspective** by Prof. Stefan Anderberg, University of Copenhagen

10.15-12.10: Frontiers within contemporary Industrial Symbiosis research
Part I

Systems thinking and industrial symbiosis by *Prof. Marian Chertow*, Yale University, US;

System boundaries and industrial symbiosis by *Leo Bass*, Erasmus University, Netherlands;

From industrial waste to wealth: Past economic and geographical perspectives on the development of by-product linkages by *Prof. Pierre Desrochers*, University of Toronto, CA;.

Questions and plenary discussion
Moderator: Mr. Ramesh Ramaswamy, Resource Optimization Initiative, India

Part II

From industrial symbiosis to distributed economies by *Prof. Allan Johansson*, IIIEE, Lund University, Sweden;

Industrial symbiosis in Australian heavy industrial areas: issues and opportunities by *Prof. Rene van Berkel*, Curtin University, Australia

Potentials and barriers in Chinese eco-industrial development by *Prof. Geng Yong*, Dalian University, China

Questions and plenary discussion
Moderator: Dr. Matthias Ruth, University of Maryland, USA

12.10-13.10: Lunch

13.10-14.10: PhD thesis research – case studies and theoretical implications
Industrial symbiosis in Puerto Rico: preliminary results by *Weslynne Ashton*, Yale University;

Industrial symbiosis in Landskrona, Sweden by *Murat Mirata*, IIIEE, Lund University;

Efficiency and effectiveness in industrial symbiosis by *Olli Salmi*, Helsinki University of Technology;

Questions and plenary discussion
Moderator: Mikael Backman, IIIEE at Lund University

14.10-14.40: Coffee break

14.40-15.40: Group discussions
Focusing industrial symbiosis agenda in:

Group A **Policy and planning: East and West**
Moderated by *Prof. Jun Bi*, Nanjing University, China.

Group B **Social systems and Industrial Symbiosis**
Moderated by *Prof. Stefan Anderberg*, University of Copenhagen

Group C **Performance evaluation**
Moderated by *Peter Lowitt*, Devens Enterprise Commission, Massachusetts

15.40 - 16.55: Plenary discussion on research directions
Interactive session facilitated by: *Suren Erkman*, ICAST, Switzerland

16.55-17.15: Symposium Wrap-Up and Next Steps
Mikael Backman, IIIEE at Lund University, *Marian Chertow*, Yale University, *Peter Laybourn*, NISP and *Noel Brings Jacobsen*, Roskilde University

About the Editors

Dr. D. Rachel Lombardi did her undergraduate work in physics and mathematics at the State University of New York at Stony Brook, followed by a brief stint as an engineer at the IBM T.J. Watson Research Center, NY. She completed her doctoral degree at Yale University in molecular electronics, and started her work in industrial ecology at the Yale School of Forestry & Environmental Studies looking at extended producer responsibility, landfill mining, and industrial symbiosis, interspersed with time at McKinsey & Company and as assistant editor for the Journal of Industrial Ecology. In 2006, she relocated to the University of Birmingham, England where her research continues to examine the business case for more sustainable business models, now in the subject of sustainable urban regeneration. Currently, her work draws on innovation, entrepreneurship, and sustainable development literature to explore the various models of and incentives for business incorporating the longer-term perspective necessary to achieve more sustainable outcomes in property development and urban regeneration.

Mr. Peter Laybourn is the managing director of International Synergies Ltd, and the creator and program director of the UK National Industrial Symbiosis Programme, the first industrial symbiosis initiative in the world to be launched on a national scale. After graduating from university in 1977 with a degree in Economics and Ecology, he spent 18 years in the aerospace manufacturing industry as contracts and commercial manager at GEC Marconi, Smiths Industries and Meggitt Aviation & Marine. After completing a second degree in environmental management, he went on to work as environmental co-ordinator for a local authority, where he helped to set up an Eco-Management and Audit Scheme and an energy efficiency charity. Whilst working as a sustainability consultant with Shell Exploration and Production, he was inspired to create NISP after first hearing from Andy Mangan at the U.S. BCSD about by-product synergy programmes operating in the Gulf of Mexico.

Advantage West Midlands is the regional development agency tasked with the economic well-being of the West Midlands region of England, and having a statutory responsibility for sustainable development. www.advantagewm.co.uk

International Synergies Ltd. is a private company that, amongst other projects, manages NISP. Its vision is to bring about long-term business culture change through profitable actions that result in measurable environmental and social benefits, making a significant contribution to international sustainability.
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NISP is a free business opportunity program that delivers bottom-line environmental and social benefits, and is the first industrial symbiosis initiative in the world to be launched on a national scale. NISP is part-funded by DEFRA's Business Resource Efficiency and Waste (BREW) Programme.
www.nisp.org.uk

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