

1. Introducing an international perspective on industrial ecology

Pauline Deutz and Donald I. Lyons

The aim of this book is to promote a debate about the relationship between industrial ecology (IE), as a business, community and academic endeavour, and the places in the world where examples of industrial ecology can be found. We present analyses of IE demonstrating its context and variability on a global scale. After 25 years of activity, industrial ecology studies and practices can be found across the globe. The commonalities, associated constraints and opportunities are widely discussed in the burgeoning literature. An additional commonality, seldom explored, is that these examples are all happening *somewhere*. The significance of location for the IE activity attempted, the outcome of that attempt, and the transferability of lessons to other locations are rarely considered. Furthermore, studies are conducted *from* somewhere, not necessarily the same place where the IE activities are rooted.

Originally inspired by a session on IE and geography at the International Sustainable Development Research Society conference in Hong Kong in 2010, we have expanded the range of contributions to the book to provide a genuinely global reach in terms of both case studies and authorship. This book provides contextualised overviews of the current state of IE in specific countries or continents, it explores case studies of different types of IE, in a variety of settings (including developed and developing countries), and provides comparisons between different national contexts. Authors draw on several methodological and theoretical frameworks, offering approaches to comparative work, and contributing to the theoretical understanding of the field.

INDUSTRIAL ECOLOGY TODAY

IE is both an academic field of research and a practice that rests on the assumption that the impact of society on the environment can be reduced by drawing on lessons from natural ecosystems. It concerns the flows of

materials and energy that comprise the industrial ecosystem and the scientific, technical, economic, political, social and cultural issues related to those flows (White, 1994). A quintessentially multidisciplinary discipline, IE incorporates a wide range of methodological approaches. These take a system-scale approach based ultimately on biological ecosystems, in some cases adapted by engineering or business approaches. IE work is often normative, though an emerging theme is investigating systems theory or other social science perspectives (see Deutz and Ioppolo, 2015 for an overview of the field).

A substantial component of IE research concerns analysis of the potential for, and/or empirical examples of, industrial symbiosis (Yu et al., 2014). Part of a series on social science perspectives on IE, this book is also primarily, but not exclusively, concerned with industrial symbiosis (IS). IS refers to the flow of residue material/energy between entities, which can occur in a range of socio-spatial contexts (Lombardi et al., 2012; Deutz, 2014). These may include local to regional networks of interconnected companies, such as those that comprise the industrial ecosystem at Kalundborg, Denmark, or the Styrian recycling network in Austria (Ehrenfeld and Gertler, 1997; Schwarz and Steininger, 1997). IS may also be a component of activities associated with an eco-industrial park (EIP), i.e., a site-specific cluster of companies with a collaborative approach to environmental management (Côté and Cohen-Rosenthal, 1998). Recent studies have applied a range of social science approaches to IS in different forms, building on earlier work (e.g., Boons and Howard-Grenville, 2009) for example, applying social network theory to regional IS networks (e.g., Ashton and Bain, 2012; Schiller et al., 2014), or investigating institutional capacity building with respect to EIPs (Boons and Spekkink, 2012).

Significantly, IE is not just an academic field of enquiry but also an area of business activity and policy application that pre-dates academic interest (see Erkman, 1997). Currently, IE-related ideas, such as the Circular Economy and industrial symbiosis, are receiving high-level policy attention, e.g., from China, the European Union (EU) and the United Nations (UNEP/SETAC, 2009; Tian et al., 2014; European Commission, n.d.), and are enjoying support from both NGOs and industry (e.g., Ellen MacArthur Foundation [n.d.] and partners in the UK); public and private sector-led IS projects have been attempted at locations across the world (Lombardi et al., 2012).

Recent years have seen an increase in academic IE contributions, with case studies and collaboration from beyond the initial developed country focus held in common with other fields of academic enquiry (e.g., Rigg, 2007). The initial geographic expansion of interest in IE from North America to Europe and other industrialised countries brought a disciplinary

expansion to encompass social science perspectives (Vermeulen, 2006) to what had been a predominantly engineering approach to sustainability (e.g., Frosch and Gallopoulos, 1989; Allenby and Richards, 1994).

Over the past decade, IE research has extended to Newly Industrialised Countries (e.g., South Korea, Park et al., 2008) and emerging economies such as China (Yuan et al., 2006;), India (Ashton and Bain, 2012), South Africa (Brent et al., 2008) and developing countries (e.g., Bangladesh, Gregson et al., 2012; Thailand, Manomaivibool and Vassanadumrongdee, 2011; and Liberia, Alfaro and Miller, 2013). This further geographic expansion has been conducted by researchers from those countries and by previously established IE researchers. There is thus a global-scale knowledge transfer network, both within academia and between academics and practitioners. This empirical expansion has not been accompanied by a significant shift in disciplinary focus. IE now needs not just to encompass an awareness of economic development and developed country sustainability issues, but also to appreciate the nuances of developing country contexts.

The need for an appreciation of geographic context in IE is underscored by recent developments in both practice and theory. Within academic IE, there is increasing concern for usability of IE tools by industry, rather than primarily as academic research (Despeisse et al., 2012; Arzoumanidis et al., 2014). Such considerations are likely to be of increasing interest to academics at a time when their work is judged in part on its impact beyond academia (Deutz and Ioppolo, 2015). Attention to implementation has not always been a strong feature of academic work on environmental initiatives, even when ostensibly producing tools for industry (Baumann et al., 2002). Improving the usability of IE tools is partly a case of better understanding practice (in industry and policy circles), but also of recognising geographic variability not just of practice but of the circumstance to which it may be applied.

It is surely appropriate for researchers to develop their theories from the empirical contexts on which their research has been based. Consequently, though, theorisations of IE (largely IS) have thus far been rooted in the developed world context (e.g., Boons et al., 2011; Doménech and Davies, 2011; Chertow and Ehrenfeld, 2012). Greater attention needs to be paid to the cultural and institutional context of the developing world. However, caution is advised on the transferability of practices from developed to developing countries given that seemingly basic terms such as 'waste' may have geographic specificities arising from the intersect of policy and practice (Deutz, 2014).

The extension of IE from developed economies to emerging and developing economies is to be welcomed in as much as those places are in need of resource efficiencies associated with sustainable development (Olayide,

Chapter 3, this volume). However, the particular circumstances in the Global South may impact on the forms that IE takes. Even within the developed country context, limited attention has been paid to geographic context, including potential policy transfers from one country's context to another's (Jiao and Boons, 2014). The remainder of this chapter briefly outlines the contribution of each chapter of the book in the context of current debates.

THE CASE FOR PLACE IN INDUSTRIAL ECOLOGY

IE activities are happening, or are desired to happen, in places. Although IS networks may be related to a place most obviously (be it a town, or region, or nation), even process-oriented IE systems are measuring, modelling or planning flows that start, pass through and stop at places. Place is a deceptively simple term which encompasses more than defining coordinates on the Earth's surface (e.g., Hubbard, 2005). As alluded to above, socially and economically, as well as culturally, places are highly variable. Despite the potentials of modern communications and an increasingly interconnected world (in terms of trade and finance flows), there are still locations that are significantly more attractive to investment than others (e.g., Cumbers and MacKinnon, 2004); IE projects are not immune to the economic realities of their locations (Deutz and Gibbs, 2008).

Perhaps unsurprisingly spatial variability has been under-analysed within the IE literature. The field is after all based on a metaphor with nature, which although geographically variable in outcome has underlying principles which are invariable. IE activity relates to materials, processes and techniques that are in principle the same anywhere. For example, engineers and ecological economists draw on the principles of thermodynamics (Daly, 1977; Layton et al., 2012). If a substance can be used, or reused, in a certain way in one location, then physically it could in another. Nonetheless, economically viable, culturally acceptable and socially/politically achievable options are likely to be just as geographically variable as biological ecosystems. A good example of a contextual requirement is supplied by Wang H. et al.'s chapter (Chapter 13, this volume), which develops a model for calculating greenhouse gas (GHG) emissions from Chinese EIPs. In contrast to the relatively small-scale EIPs of co-located firms in the USA, Chinese EIPs are of a larger scale and incorporate residential neighbourhoods. Modelling therefore must incorporate elements of urban as well as industrial settings. The case study used is Suzhou Industrial Park, which has a developed area of 80 km² and a population of

0.7 million (Wang H. et al., Chapter 13, this volume), and which resembles a medium-sized city rather than an EIP in European or US usage.

The twofold classification of countries into the Global North and Global South (Brandt, 1981) as a summary of development level remains depressingly valid (Arrighi, 2001/2002), albeit that there are overlapping sub-groups of newly industrialising countries, emerging and transition economies. Large and widening gaps of wealth exist between developed and developing countries (e.g., Oxfam, 2014; Dutta, 2015), not to mention within countries (e.g., the north–south divide in the UK, McSmith, 2015). For industrial ecologists, the challenge is both to be aware of the circumstances of a particular place as well as to understand its connections to a global and globalising capitalist economy (e.g., Dicken, 2011). In a highly interconnected world linked by commodity and residue flows on a global scale (e.g., Lyons, 2007), residue flows are as globalised as resource flows and the patterns in the North are firmly linked to those in the South (Massey, 1991; Gregson et al., 2012). The interconnections comprising globalisation can have positive effects for development, but not without creating stresses (both environmental and social) (Martens and Raza, 2010).

Development-related issues for IE are well illustrated by Ashton and Shenoy's chapter (Chapter 2, this volume) and Olayide's chapter (Chapter 3, this volume) on India and Africa respectively. These chapters consider the current status of IE across places where the states of development and future trajectories are very heterogeneous. Extractive industry and agriculture (both traditional and large scale) remain economically prominent in Africa, providing opportunities as well as constraints for IE (Olayide, Chapter 3, this volume). Ashton and Shenoy describe how similar conditions are faced by smaller traditional industries and the agricultural sector in India. Much of the developed world-style practice of IE in India is carried out either by branches of multinational companies or by India's indigenous conglomerates.

Issues surrounding IE in those locations can be contrasted with those explored by Lowitt (Chapter 4, this volume) and Boons et al. (Chapter 5, this volume) with respect to the industrialised and post-industrial landscapes of the USA and Europe respectively. Lowitt explores current EIP and regional IS projects in the USA in a policy context where the drive for economic development is more strongly supported than that for resource efficiency. State-level resource/waste policies in the USA contrast with the supranational scale of environmental regulation overlying national policies in the EU.

Whereas the chapters in this book provide relevant material for comparisons of IE in different contexts, most are not themselves undertaking a comparison. Boons et al.'s chapter (Chapter 5, this volume) is an exception,

comprising a large-scale comparison of IS achieved by a collaboration of 16 researchers in nine different European countries. Explicitly exploring the form and development of IE examples between different locations is entering the realms of comparative research, which brings methodological challenges of its own alongside potential insights (e.g., Kennett, 2013). Three major forms of IS emerge, with significant variation within as well as between countries.

Some of the policy applications of IE, most notably of industrial symbiosis, have been consciously learning from/adopting examples from elsewhere (Geng et al., 2012; Tian et al., 2014). Both the politics and geography literatures have explored the complexities of transferring policies (even within, let alone between, countries), and the manner in which policies influence and are influenced by the places in which they are employed (e.g., Peck, 2011; Stone, 2012). In the case study explored by Wang Q. et al.'s chapter (Chapter 6, this volume) there is a deliberate effort to transfer an approach to IS facilitation between very distinct geographic contexts (the UK and a Chinese EIP). The chapter explores the impact of the differing multi-scalar policy regimes in the two contexts and the implications for the effectiveness of the particular approach for facilitating IS connections.

A weakness in the underpinning of IS research has been the reliance on a small number of successful case studies. Lyons et al.'s chapter (Chapter 7, this volume) and Branson and McManus' chapter (Chapter 8, this volume) expand the empirical foundation of IS with contrasting studies of non-hazardous industrial waste flows from Pennsylvania, USA, and non-park based symbioses in Australia respectively. Thereby, they contribute invaluable insight to debates on the importance of proximity and industrial diversity to IS (Chertow, 2000; Van Beers et al., 2007; Jensen et al., 2011). Contrasting the densely industrialised regions of Pennsylvania with relatively sparsely populated Australia firmly indicates the importance of context to outcome.

Institutions are emerging as an important contextual factor for IS and provide the framework for several chapters in this book. Institutions are the formal and informal rules and structures governing behaviour in society (North, 1990). Spekkink (Chapter 9, this volume) discusses how institutional forms in different locations will impact on the form of IS development. Significantly, the form and function of institutions can have distinctive impacts in the context of developing countries (Braveboy-Wagner, 2008) with issues like corruption, which are not unique to the Global South, nonetheless representing a particular challenge (e.g., Bissessar and Owoye, 2014).

Liu et al. (Chapter 10, this volume) consider the particular institutional context of EIP development that has arisen in conjunction with, and in

response to, the rapid industrialisation of China. National-scale regulations stress resource conservation requirements, with implementation at the local to regional scale via a network of industrial parks undergoing transformation to EIPs. This can be compared with the situation in Japan, which is analysed in Patchell's chapter (Chapter 11, this volume). Japan has taken a distinctive approach to IE, favouring eco-towns over EIPs (Ohnishi et al., 2012). Patchell extends this analysis by examining the interplay of eco-towns designed to eliminate domestic waste and extended producer responsibility regulations giving companies liability for post-consumer electronics.

An important characteristic of institutions with respect to the implementation of IE is their ability to learn and develop, i.e., institutional capacity (Healey, 1998; Boons and Spekkink, 2012). Spekkink's chapter addresses this theoretically, using an Event Sequence Analysis (Boons et al., 2014) to explore the development of the institutional context over time. Van Hoof's chapter (Chapter 12, this volume) extends the application of institutional capacity in IE beyond IS to examine a government programme aiming to foster cleaner production in industry. His study of Caldas, Colombia, also extends the application to an emerging economy context.

In the concluding chapter we briefly explore the themes emerging from the book and propose an agenda for further work.

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