Ecological modernisation and local economic development: the growth of eco-industrial development initiatives

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Abstract: An increasingly influential approach for policy makers is that of ecological modernisation. This approach advocates substantial changes in patterns of production and consumption, but envisages this taking place within the existing social and economic system. This paper investigates one particular form of ecological modernisation policy response at the local level that is growing in importance – the development of eco-industrial initiatives. These initiatives are based upon concepts derived from industrial ecology, aiming to increase business performance while at the same time reducing pollution and waste. The paper outlines the development of eco-industrial initiatives, particularly those based around diverting wastes into more productive uses, and provides a critique of ecological modernisation as a policy program.

Keywords: ecological modernisation; eco-industrial development; local economy; public policy; waste.

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1 Introduction

A concern for environmental issues continues to play an important role in public and private sector policy making, despite fluctuations over time in the seriousness with which it is addressed. Whilst there remains an important debate around whether the reformist ideas of environmentalism can deliver the types of changes needed to avoid continued environmental degradation, or whether fundamental changes of the type advocated by the more radical ideology of ecologism are needed, few policy initiatives fail to address the need to take account of the environment in some form [1]. An increasingly influential approach for policy makers is that of ecological modernisation that, although advocating

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substantial changes in patterns of production and consumption, argues that it is possible to undertake these within the existing social and economic system. Whilst this also allows a range of responses from 'business-as-usual with a green tinge' to more fundamental reform, ecological modernisation in some form constitutes the dominant means of incorporating environmental issues into public and private policy at the present time [2]. At the local and regional scales, ecological modernisation is increasingly being adopted as one basis for economic development strategies on the premise that environmental protection is beneficial for jobs and the local economy [3]. Indeed, such initiatives are intended to deliver economic, environmental and social benefits – so-called 'win-win-win' or 'triple bottom line' solutions. This paper investigates one particular form of policy response at the local level that is growing in importance – the development of eco-industrial initiatives. These initiatives are based upon concepts derived from industrial ecology, aiming to increase business performance while at the same time reducing pollution and waste. The structure of the paper is as follows. After a consideration of ecological modernisation both as theory and as policy prescription, the paper outlines the concept of industrial ecology as the guiding principle for eco-industrial development. Following this, the paper examines debates over definitions of eco-industrial development and outlines the growth of eco-industrial initiatives, with a particular focus upon schemes based around diverting wastes out of the waste stream into more productive uses. A concluding section considers some of the issues and problems involved in utilising ecological modernisation and eco-industrial development approaches to local economic development.

2 Ecological modernisation

The heart of ecological modernisation is a relatively optimistic view of the potential for technological change to lead to solutions for environmental problems [4]. As Roberts and Colwell [3] observe "ecological modernisation suggests that it is possible to integrate the goals of economic development, social welfare and environmental protection, and that through this reconciliation synergies will be generated which can be harnessed and put to good use". The initial development of the concept occurred in the 1980s in the work of Huber [5] and Jänicke [6]. Huber [5] and [7] argued that industrial society should undergo a transition towards an ecologically rational organisation of production on the basis of a changed relationship between the economy and ecology. This transition he termed an 'ecological switchover' and, using a biological metaphor, believed that through this process "the dirty and ugly industrial caterpillar will transform into a[n] ecological butterfly" [7]. Ecological modernisation envisages a process of the progressive modernisation of the institutions of modern society - the basic argument is that the central institutions of modern society can be transformed in order to avoid ecological crisis [8]. This can be compared to approaches based on deep ecology or ecologism which see the necessity of a thoroughgoing and radical restructuring of society (see, for example, the critique by Blühdorn [9]). An ecological modernisation approach would involve both structural change at the macro-economic level, through broad sectoral shifts in the economy, and at the micro-economic level, for example through the use of new and clean technologies by individual firms [10]. Over time, as Buttel [4] observes there will be a shift to "improvement in the efficiency of conversion of raw materials into finished products and to reduction in the quantity and toxicity of the waste stream from industry".

The concept of ecological modernisation has been developed as both a theory and as a guide to more pragmatic policy action. As a theoretical concept it has been used to analyse those changes to the central institutions in modern society deemed necessary to solve the ecological crisis. In this use of the concept, ecological modernisation represents a major transformation, or Huber's 'ecological switchover', of the process of industrialisation onto a different basis which takes account of the need to maintain the sustenance base. Ecological modernisation indicates the possibility of overcoming environmental crises without leaving the path of modernisation [8]. The processes of production and consumption can be restructured on ecological terms through the institutionalisation of ecological aims [11]. This does not simply mean taking environmental factors into account, "but also ensuring that they are structurally 'anchored' in the reproduction of these institutional clusters of production and consumption" [12]. Unlike deep ecology approaches, proponents of ecological modernisation are not asserting the primacy of ecological over economic rationality, but simply argue that the former should be given equal weighting.

From the initial formulations in the 1980s, a number of approaches have developed in ecological modernisation theory (see Mol and Spaargaren [13] and the collection of papers in Spaargaren, Mol and Buttel [14] and Mol and Sonnenfeld [15] for overviews). Mol [16] identifies three broad phases in the development of the theory. In the first phase developed by Huber and Jänicke there was a heavy emphasis on the role of technological innovation, a critical attitude towards the state and a belief in the power of market forces and actors to deliver change. Huber's perspective was that ecological modernisation offered a way out of ecological crisis through more industrialisation, albeit with changed production and consumption. However, this view has been criticised for overemphasising the industrial and technological aspects and neglecting the social context within which these occur. In Huber's initial work, the 'ecological switchover' is a logical, necessary and inevitable stage in the development of the industrial system. From this perspective, technological developments are largely autonomously determined and engender change in industrial systems and their relations with the social and natural environment. From a policy perspective, the dominant role envisaged for technological change means that in Huber's approach the state has little role in redirecting the processes of production and consumption.

A second phase of work from the late 1980s onwards placed less emphasis on technological determinism as a driving force, had a more balanced perspective on the role of state and market forces in the process of ecological modernisation and emphasised institutional and cultural dynamics [17] and [16]. For example, Hajer's work [18] proposed that there are two interpretations of ecological modernisation. Firstly, the initial 'techno-corporatist' interpretation of Huber which emphasises the 'economisation of nature' and elitist decision-making structures, and a second interpretation which not only stresses changes to production and consumption, but does so through greater democratisation, redistribution and social justice. Hajer [19] further developed this second interpretation of ecological modernisation as reflexive ecological modernisation, whereby political and economic development proceeds on the basis of critical self-awareness involving public scrutiny and democratic control. A third phase of work on ecological modernisation theory has paid more attention to consumption processes and also attempted to deal with criticism that ecological modernisation is a very Eurocentric approach [16]. Fudge and Rowe [2] sum up this third phase as one where:

> "environmental problems are conceptualised as challenges for (preventative) social, technical, and economic reform; market dynamics and economic agents are seen as increasingly important; the nation-state is transformed towards the more decentralised and consensual styles of governance which characterise ecological modernisation; social movements modify their roles so that reform ideologies take preference over confrontation with the state; and intergenerational solidarity towards environmental protection is assumed".

Ecological modernisation is also used to describe a more pragmatic political program to redirect environmental policy making [7]. As a pragmatic political program, ecological modernisation approaches suggest that this will engender support from private sector businesses, given that it can have beneficial outcomes [20,17]. Business can gain advantages in a number of ways: through greater business efficiency due to reduced pollution and waste production; avoiding future financial liabilities, such as the potential cost of contaminated land clean-up; through improved recruitment and retention of the workforce due to the creation of a better work environment; from the potential for increased sales of more 'environmentally-friendly' products and services; and finally through the sale of pollution prevention and abatement technologies [21]. However, one criticism of ecological modernisation as both theory and discourse is that it can help to legitimate an environmental policy-making culture that absolves private sector business and major corporations of their environmental responsibilities [9,4]. Whilst ecological modernisation may be predicated upon the potential transformation of capitalist economies, it is also liable, as a discourse, to be "corrupted into yet another discursive representation of dominant forms of economic power" [20] resulting in greater dominance of global resources by transnational industry, national governments and 'big science' in the name of sustainability.

As a political program, a shift towards ecological modernisation would involve a number of interrelated measures: restructuring of production and consumption towards ecological goals, including the development and diffusion of clean production technologies; decoupling economic development from the relevant resource inputs, resource use and emissions; exploring alternative and innovative approaches to environmental policy, such as 'economising ecology' by placing an economic value on nature and introducing structural tax reform; integrating environmental policy goals into other policy areas; and the invention, adoption and diffusion of new technologies and production processes. Mol [16] suggests that:

> "environmental reforms in environmental policy can be classified as ecological modernisation if they move away from a pure hierarchical, state-dictated model of environmental change; if they increase flexibility and involvement of non-state actors via negotiations, market mechanisms and dynamics, and 'self-regulation' within legal and state-set boundaries; and if the technological dimensions of environmental reform do not remain limited to only technological devices of one product, emission or production process step, but include higher aggregation levels, production-consumption chains and economic networks, and organisational adaptations of socio-technological complexes".

In the next section of this paper attention is focused upon the extent to which ecological modernisation can form the basis of public policy intervention to enact such environmental policy reforms and the role of the state in bringing these forward.

3 Ecological modernisation and policy intervention

The major focus of ecological modernisation in policy terms has been upon the potential for change at the level of the nation-state. Although Huber's [5] and [7] early work envisaged a minimal role for the state in the ecological switchover, work in the second and third phase of ecological modernisation takes a different perspective. Spaargaren [22] in a criticism of Huber's metaphor of the caterpillar developing into a 'green' butterfly, argues that this implies a deterministic and passive approach. In his view, however, "the process of 'adaptation' the industrial system has to go through, cannot be grasped in an adequate way without taking into account the fact that this adaptation or switchover is brought about by knowledgeable and capable agents" [22]. Mol and Spaargaren [8] similarly argue that it is difficult to imagine an ecological switchover without state intervention at various levels. The later work of Jänicke [23,24] deals most directly with the role of the state in ecological modernisation. For Jänicke "without state intervention, the greening of production and consumption is an impossibility. The ecological modernisation process must be actively supported by the state in the form of a green industrial policy" [22]. He suggests that the ability of nation states to undertake such holistic environmental approaches results from the interplay of their economic performance with their capacities for innovation, strategic thinking and consensual government.

This may not involve a role for a strong bureaucratic state in ecological modernisation, "rather the role of the state in environmental policy [will have to] change from curative and reactive to preventive, from 'closed' policy-making to participative policy-making, from centralised to decentralised and from dirigistic to contextually 'steering'" [11]. Rinkevicius [25] argues that this is a process that involves a shift from command and control policy to one based on trust, tolerance and dialogue. In the course of this, the various actors involved (firms, governments, regulatory agencies, NGOs etc.) gradually learn about appropriate doctrines and codes and conduct and adjust their own behaviour and actions accordingly. Rinkevicius [25] argues that this process of institutional learning is a key tenet of ecological modernisation, involving cultural change in firms as opposed to mere technocratic compliance. Ecological modernisation, it is argued, will require political commitment to a longer-term, consensual and more holistic approach to economic development and the environment. It has been argued that those nation-states which conform most closely to the ideas of (albeit weak) ecological modernisation (the Netherlands, Germany, Norway, Sweden, Japan) are those which have consensual forms of government ([21], see also Andersen [26] and Cohen [27] and a critique of this view by Mol [16]). As an explicit foundation for policy, however, relatively few attempts have been made to introduce it on an holistic basis – the Netherlands and Sweden perhaps stand out as the two nation states that have attempted to adopt the key tenets of ecological modernisation. In particular, the government of Göran Persson in Sweden adopted ecological modernisation as a basis for development, arguing that Sweden would benefit ecologically *and* economically from such a program [2,27,28]. Ideas derived from ecological modernisation approaches have also entered into European Union environmental policy making [3]. Whilst the whole concept of ecological modernisation remains open to debate, ideas derived from it have also begun to enter into policy prescriptions for local and regional development, albeit that the term itself is often not used [29,30].

Some authors view the process of transformation associated with ecological modernisation as culminating in a phase of industrialisation based on closed-loop manufacturing systems and advanced environmental technologies in order to repair the 'design flaws' of modern industrial society [31]. In practical terms many of the attempts to reconcile conflicting objectives between the environment and economic development through the application of ecological modernisation concepts have come through an interest in industrial ecology [32]. The next section of this paper outlines the perspective of industrial ecology and the potential environmental and economic gains from such an approach.

4 Industrial ecology

Industrial ecology (IE) utilises an analogy of industrial systems to natural ecological systems in an attempt to understand the potential for environmental improvement in industry (see Frosch and Gallopoulos [33] for the seminal statement on industrial ecosystems and Anonymous [34] for a critical view of the ecological analogy). As opposed to comprising isolated components in a system of linear flows, processes and industries are seen as interacting systems. Burström and Korhonen [35] argue that

> "the environmental benefits of IE are to be found in the reduction of virgin material and energy inputs to the industrial system, and of waste and emission outputs from the system. In a successful *industrial ecosystem* the economic gains lie in the reduction of raw material and energy costs, waste management costs and costs resulting from environmental legislation, as well as the improvement of 'environmental image' and 'green market' potential".

This provides a basis for thinking about ways in which various waste-producing processes, plants, or industries can be connected into a network of interchange in order to minimise the amount of industrial material currently going to disposal sinks or lost in intermediate processes. Rather than focusing upon minimising waste from a particular process or facility (i.e. pollution prevention), the emphasis is upon minimising waste produced by the larger system as a whole [36,37]. Industrial ecology therefore represents a shift away from considering localised environmental impacts in isolation so that the focus is not upon issues such as cleaner production and eco-efficiency, which reduce materials inputs and reduce wastes *at the level of the firm* [38,39]. Instead, industrial ecology is said to offer an holistic conceptual framework for the kind of "significant, systemic industrial change" of the kind needed to eliminate environmental damage [40]. Whilst impacts at the level of the individual firm or process remain important, these must be seen as connected to the wider industrial ecosystem. In industrial ecology studies, these firm or process impacts are dealt with through the parallel concept of industrial metabolism, which is concerned with the efficiency of the metabolic processes within species individuals (in this case firms or processes) [41]. Improved industrial metabolism across the whole spectrum of industrial processes would, it is argued, make the creation of industrial ecosystems easier [40]. "A better understanding of material flows is a first step to increasing the eco-efficiency of society's metabolism by closing material flows into loops of recycling and reuse" [42].

In an industrial ecosystem, effluents and wastes from one process serve as the input materials for other processes or are recycled for further production, mimicking food webs

in natural systems [43]. In another ecological parallel, it is proposed that 'niche species' will emerge to fulfil particular functions, such as transforming wastes into useful inputs. In an 'ideal-type' industrial ecosystem, there would be complete or nearly complete internal recycling of materials, effectively the achievement of 'zero discharges'. In reality, most commentators realise that this is probably unattainable, but nevertheless worth pursuing as a goal [44]. As Korhonen [45] points out "it is obvious that the vision of a perfect industrial ecosystem will never happen. However, it would also seem obvious that the direction presented by the vision is the way to strive at in environmental policy and industrial environmental management". At present though, whilst in natural ecosystems the largest flows in the producer-consumer-recycler system are from producers (plants) to recyclers (micro-organisms, bacteria, decomposers, fungi), in industrial ecosystems flows from both producers and consumers to recyclers are small scale [46].

It is suggested that a number of economic, environmental and social advantages can be gained from adopting an IE approach: waste products from one industry provide the inputs for another, reducing input costs; reduced waste streams mean lower waste disposal costs; waste now has an economic value, increasing profits; the creation of a larger and more varied economic base, as well as more jobs; reduced emissions mean less need to separate industrial and residential land uses and consequently reduced movement between the two [43]. Overall, then, this represents the 'win-win-win' outcome often proposed for ecological modernisation – not only do participating firms benefit financially, but also there are broader societal gains in the form of reduced environmental impacts and improved jobs and working conditions. Industrial ecology is thus an attempt to combine both product competitiveness and environmental improvement by shifting from a linear to a materials cycle approach [47]. A major objective within the industrial ecology agenda is therefore to engender a fundamental paradigm shift in the organisation of industry-ecology relations [42,48]. Tibbs [40] argues that "the result of an industrial ecological approach over time will be a gradual overall transition, taking several decades, to an eco-industrial infrastructure, so that all process systems and equipment, and plant and factory design, will eventually be built to interconnect with industrial ecosystems as a matter of course". This therefore overlaps substantially with the aims of ecological modernisation, both as a theory and as a pragmatic policy program. The paper now turns to an examination of the application of industrial ecology concepts through eco-industrial development as a local policy initiative.

5 Implementing industrial ecology: eco-industrial development

A growing number of local and regional initiatives have attempted to implement industrial ecology in the form of eco-industrial development. The early focus of these was upon a specific type of eco-industrial development – the eco-industrial *park* (EIP). These EIPs are based on industrial ecology concepts, aiming to increase business performance while at the same time reducing pollution and waste [49,50]. An initial definition of an eco-industrial park by leading US practitioners, Lowe and Warren, [51] was:

> "a community of manufacturing and service businesses seeking enhanced environmental and economic performance through collaboration in managing environmental and resource issues including energy, water, and materials…the

> community of businesses seeks a collective benefit that is greater than the sum of the individual benefits each company would realise if it optimised its individual performance".

The eco-industrial literature frequently uses the town of Kalundborg in Denmark as an example of this type of development. Here, a network of waste and energy exchanges occurs between the city, a power plant, a refinery, a fish farm, a pharmaceuticals plant and a wallboard manufacturer. The local power company pipes residual steam to the refinery and, in exchange, receives refinery gas – the latter was previously flared as a waste product. The power plant burns this refinery gas to generate electricity and steam and sends excess steam to a fish farm, the city and the pharmaceuticals plant. Sludge from the fish farm and the pharmaceutical processes become fertilisers for local farms. Finally, a cement company uses fly ash from the power plant, whilst gypsum produced by the power plant's flue gas desulphurisation process is used as a raw material by a company producing gypsum wallboard [37].

Debate has occurred over whether eco-industrial development should be defined by the park element and by firm interaction. A Research Triangle Institute report [52] argued that park development comprises only one possible method of implementing industrial ecology and that this term only applies to those developments that involve member business interactions, both amongst themselves and with the natural environment, by means of by-product exchanges, resource partnerships or symbioses. Conversely, one of the founders of the EIP movement has emphasised that any development should actually *be* an industrial park, as understood by real estate developers [53]. In an addition to his earlier definition [51], Lowe [53] adds

> "an eco-industrial park or estate is a community of manufacturing and service businesses *located together on a common property*…The goal of an EIP is to improve the economic performance of the participating companies while minimising their environmental impacts. Components of this approach include green design of park infrastructure and plants (new or retrofitted); cleaner production, pollution prevention; energy efficiency; and inter-company partnering. An EIP also seeks benefits for neighbouring communities to assure that the net impact of its development is positive" (emphasis added).

However, Schlarb [50] has argued that the substantial difficulties involved in developing and constructing closed-loop industrial parks mean that local or city-wide opportunities for resource exchange comprise a less restrictive form of eco-industrial development. Such a (re)definition would still involve some form of inter-firm networking and interchange, but this could occur over a wider spatial scale and between business and the community, as well as business-to-business links. Schlarb [50] argues further that "eco-industrial parks are still considered a possible format for eco-industrial development; however, such parks are now nestled within a broader regional context in which park tenants not only interact amongst themselves, but also with other firms in the region and with the surrounding community". Moreover, these broader eco-industrial networks can help to integrate private sector-led eco-industrial development with a wider range of participants. In this manner firms and the local community can be brought together for mutually beneficial developments. Such initiatives could encompass incentives for firms to train and hire local staff, introduce better physical working conditions and improve worker health and productivity, as well as providing communities with the power to make their own decisions about the forms of industrial and commercial development desirable in their local area [54,50]. The emphasis in this type of

eco-industrial development is therefore as much upon the *social* benefits of eco-industrial development as it is upon the economic and environmental gains. Whilst waste exchanges and energy cascading may remain important elements of eco-industrial development approaches, Côté and Cohen-Rosenthal [54] observe "if the goal is sustainability of the industrial community and ecosystem, a more comprehensive perspective involving ecological, economic and social aspects is necessary".

Thus a range of possible eco-industrial developments and definitions have subsequently emerged reflecting a movement away from an initial emphasis upon co-located firm interaction with an emphasis upon energy cascading and resource interchanges. For example, Table 1 identifies seven different types of eco-industrial development, of which only the first involves firm interaction [52]. Recent discussion has focused upon whether any of these is sufficient in itself to be considered as an eco-industrial development. For example, Lowe [53] believes that an eco-industrial *park* must comprise *more* than these seven components, even though they may be included within it, and maintains that "the critical elements are the interactions among the park's member businesses and the community's relationship with its community and natural environment". He suggests that developing closed-loop systems may be important, but this is only one of a number of elements in EIP design. Others have a more relaxed view of what constitutes eco-industrial development. North and Giannini-Spohn [55] argue that eco-industrial development can involve a 'palette of strategies' for increasing resource efficiency. Whilst an ideal eco-industrial development would eventually incorporate all of these strategies in the long term, companies participating initially might add strategies incrementally as the business case for each becomes stronger. Table 2 lists some of the strategies that companies could adopt.

Table 1 Types of Eco-Park development

A single by-product exchange pattern or network of exchanges
A recycling business cluster (e.g. resource recovery, recycling companies)
A collection of environmental technology companies
A collection of companies making 'green' products
An industrial park designed around a single environmental theme (e.g. a solar energy-driven park)
A park with environmentally friendly infrastructure or construction
A mixed use development (i.e. industrial, commercial and residential)

Source: Research Triangle Institute [52].

6 Eco-industrial development policy initiatives

Whilst the Kalundborg example developed organically over a long time period and as a result of voluntary cooperation between the companies involved, there are increasing attempts to recreate key features of Kalundborg through policy intervention. Proposals have been developed for an 'eco-fit' park in Styria (Austria), building on existing regional recycling networks [48]. Other forms of eco-industrial and eco-site development can be seen in Emscher Park in Germany and Turin Environment Park in Italy. In the

UK, there are well-advanced plans to develop a Sustainable Growth Park in South Yorkshire [56] and a Business Council for Sustainable Development initiative for a National Industrial Symbiosis Programme with target sites in the Humber subregion, the West Midlands, Merseyside, Southampton, Grangemouth, the North East and Northern Ireland [57]. The example of Kalundborg was also one factor behind the drive to establish EIPs in the USA by the Clinton administration. In 1994 the President's Council on Sustainable Development (PCSD), together with the Environmental Protection Agency and the US Department of Energy, designated four EIP demonstration sites – at Baltimore, Maryland; Cape Charles, Virginia; Brownsville, Texas and Chattanooga, Tennessee [58]. The PCSD used a similar definition to Lowe and Warren [51], with the inclusion of the local community as both a contributor to resource flows and a beneficiary of environmental and economic improvements. The goals for almost all of the US parks include job creation, increasing the tax base, or other economic objectives. Some parks have goals such as becoming the first EIP with an ISO 14000 environmental management system, becoming a zero-emissions EIP, having all major tenants producing sustainable products with sustainable manufacturing practice, and becoming totally energy independent of fossil fuels or outside electricity [49]. Two parks are not places but are 'virtual' EIPs with materials exchanged on a regional network basis. Managing entities for the EIPs encompass government and private sectors, including cities, counties, local economic development corporations, private industry, and other non-government organisations [49].

Table 2 Potential elements of eco-industrial development strategies

Resource recovery, pollution prevention and cleaner production
Integration into natural ecosystems
Industrial clustering
Sustainable/green design
Anchor tenant
Life cycle assessment
Job training
Environmental management systems
Deconstruction and demanufacturing
Technological innovation and continuous environmental improvement
Public participation and collaboration

Source: Schlarb [50].

A number of eco-industrial initiatives have focused upon dealing with waste streams. In the UK for example, this has been driven by the need to comply with EU legislation. The Strategy Unit of the Cabinet Office has recently identified a number of barriers to dealing with existing UK waste streams in compliance with this EU legislation including: insufficient investment in infrastructure and collection and disposal methods; low public awareness and lack of incentives to change household behaviour; negative public perceptions of environmental and health hazards of waste disposal and treatment. There are clear synergies to be gained by the development of a cohesive infrastructure to valorise recovered waste material in local areas and eco-industrial park development

could promote both a local solution to waste disposal and the retention of residual value from recovered waste in the local area. However, such initiatives will require significant investments in infrastructure, technology and awareness by a host of stakeholders including the government, local authorities and the private sector. Several UK local authorities in the North and the Midlands, working in partnership with the private sector and not-for-profit companies such as Urban Mines, are considering the development of waste stream-based eco-industrial parks as part of their strategies to meet recycling targets derived from EU legislation [59,60].

Indeed, there are a number of existing eco-industrial projects in Europe and the USA that are based around the aim of diverting wastes out of the waste stream and, especially, away from landfill. Projects that involve diverting wastes out of the waste stream fall into three main categories (although individual projects can fall into one or more of these categories):

- *Using wastes as a source of energy production*, especially burning waste to produce electricity. The Cabazon Resource Recovery Park in Mecca, California uses biomass (wood, woody wastes and agricultural residues) to produce electricity at a 48 MW power generation plant. The site also incorporates recycling facilities for tyres. A similar waste-to-energy scheme as part of a larger eco-industrial development project is also planned for the RENOVA eco-industrial park in Puerto Rico.
- *Converting wastes into a product that can then be sold to a third party*. Customers may or may not be co-located on the same site. There are several existing and planned initiatives which fall into this category – production of crumb rubber from tyres for use as road and play area surfaces at the Cabazon Resource Recovery Park and the production of soil enhancer from organic wastes through vermicomposting at North West Louisiana Commerce Centre in the USA. London Remade is developing an eco-industrial site within the Thames Gateway to recycle glass into materials for construction purposes including shotblasting, roadstone surfacing and sharp sand. A more complex arrangement can be found at the Ecosite du Pays de Thau in Southern France; here municipal waste water streams from seven towns are dealt with in a lagoon system which protects water quality essential for oyster and shellfish production. Shellfish waste is also processed into animal feed and industrial soil amendment products.
- *Using waste products as input into other firms' production processes*. This is the type of by-product exchange initiative that comes closest to a definition of eco-industrial development involving firm interchanges and co-location. Examples include: the Hartberg Ökopark in Austria where paper recycling provides materials for a company making insulation materials; Styria, also in Austria, where research into a recycling network began by tracing the by-products and outputs of two major firms and uncovered a complex network of exchanges (albeit largely unconscious) among over 50 facilities; and plans for a computer and electronics disposition park in Texas. Several schemes either have, or plan to, develop web-based waste exchange or trading facilities to assist firms in the process of finding appropriate partners. For example, this is planned at the Dagenham Dock Sustainable Industrial Park and has already been carried out at the Industrial Ecosystem Development Project at the Research Triangle Park in North Carolina and the Northern Ontario Waste Materials Exchange database in Canada.

7 Conclusions: ecological modernisation, eco-industrial development and policy implementation

Whilst policy makers may not always utilise the term explicitly, ecological modernisation approaches are increasingly becoming the basis of local economic development policies which attempt to integrate economic development and the environment. The obvious attraction of ecological modernisation, for policy makers at least, is that it seemingly allows the achievement of 'win-win-win' outcomes. Thus not only does it deliver environmental improvement, but it would also appear to do so without seriously challenging existing economic practices. The basis of ecological modernisation in innovative behaviour, applications of technology and improved economic competitiveness, all suggest that its adoption as a policy solution can be complementary to other attempts to modernise developed economies. It is this seeming compatibility with mainstream economic activity, if only we can be forward thinking and 'modern' enough to make the ecological switch, which explains the appearance of ecological modernisation in policy. Perhaps not surprisingly then, seen in the guise of a pragmatic program for business and government ecological modernisation appears to offer a means to solve the environmental problem. One way in which the concept of ecological modernisation is being taken forward in this guise as a pragmatic political program is through its interpretation as industrial ecology. Based around ideas that industrial systems can be remodelled along ecological lines, industrial ecology suggests that wastes can be reduced or reused as inputs into other production processes to 'close the loop' as opposed to linear production systems. One practical application of this has come in the form of eco-industrial developments, some of which are attempting to realise co-located, closed-loop production, whilst others have broader aims. All, however, seek to gain environmental improvements in conjunction with economic and/or social aims. Eco-industrial development would appear to fit in well with the second and third phases of ecological modernisation – in particular the notion that through interaction and coworking, firms and other actors will learn about appropriate behaviour and alter their own behaviour and actions. Eco-industrial development is therefore one potential method of developing the types of institutional learning processes and cultural change associated with ecological modernisation. All this may, then, appear to be an optimistic scenario for future economic development. For specific local economies, ecological modernisation would appear to offer a route towards a better environment and improved economic performance. However, as a basis for policy, it can be argued that there is a particular problem with ecological modernisation (and eco-industrial development) which is directly related to a shortcoming in theoretical development.

One problem is that ecological modernisation lacks a theory of power relations. The assumption often appears to be that the logic of ecological modernisation is so obvious (and profitable for business) that its widespread adoption is simply a matter of time. As Leroy and van Tatenhove [61] comment "as nobody seems to oppose it – and as the theory lacks power relations, there is hardly any room for opposition at all, ecological modernisation is assumed to occur almost automatically". The implementation of policy, however, is about the exercise of political and economic power and, whilst this is rarely made explicit ecological modernisation is a fundamentally *political* concept [62]. Whether it can be introduced depends upon "who is in control, who sets agendas, who allocates resources, who mediates disputes, who sets the rules of the game" [63].

Ecological modernisation is thus as much an ideological and political issue, as it is an ecological and economic one [64]. These same issues are also applicable to eco-industrial development. Although eco-industrial parks and other forms of eco-industrial development are growing in number, they rarely appear to be a central plank of policy, but are rather isolated responses that may allow policy makers to 'tick the environmental box' while getting on with the main business of economic development which may continue to be environmentally destructive. Whilst ecological modernisation and eco-industrial development may appear to offer the opportunity to introduce strong environmental protection measures, as with the equally slippery concept of sustainable development there is the possibility that it can equally serve as a cover for 'business-as-usual with a slight green tinge'. As Christoff [65] comments "there is a danger that the term may serve to legitimise the continuing instrumental domination and destruction of the environment, and the promotion of less democratic forms of government, foregrounding modernity's industrial and technocratic discourses over its more recent, resistant and critical ecological components".

Secondly, ecological modernisation approaches have little to say about the forms of institutional adaptation or change required, despite recognising that these are necessary. From a policy perspective, much work on ecological modernisation still has relatively little to say about barriers to implementation. This is related especially to undertheorisation of the state in ecological modernisation. In early accounts the role of the (central, regional or local) state was seen as minimal [5,7]. In later accounts there is a more sophisticated understanding whereby the state performs an enabling and contextually steering role. However, there is still little detail of the form of institutional adaptation or change required at nation-state level, let alone at the scale of the local economy. Ecological modernisation sublimates the 'enabling state' as the institutional response that will secure the efficient functioning of the market economy within a framework of state regulation [66]. This enabling state will deliver ecological modernisation through corporatist relationships between government and industry, although co-opting environmental movements where necessary, thus ignoring issues of participation and reducing the rest of society to passive consumers to be provided with enough information to make informed (but market-based) choices. This failure adequately to conceptualise the social processes means that the types of embedded cultural transformations that will sustain factors such as environmental improvements, reduced consumption and greater equity are unlikely to be realised [27,67,68]. From the perspective of eco-industrial development institutional adaptation is often also seen in a normative fashion – the example of Kalundborg illustrates that inter-firm networking based on trust and cooperation is possible, hence the argument runs that it can be created through policy. In reality, however, the cultural change associated with networking behaviour and waste interchange has proved much more difficult to implement than perhaps first thought.

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