Interrogating the Circular Economy: the Moral Economy of Resource Recovery in the EU.

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Abstract

The concept of the circular economy has gained increasing prominence in academic, practitioner and policy circles and is linked to greening economies and sustainable development. However, the idea is more often celebrated than critically interrogated. Analysis shows the concept circulates as an idea and ideal, exemplified by industrial symbiosis and extended product life. Yet, its actual enactment is limited and fragile. Instead, circular economies are achieved mostly through global recycling networks which are the primary means by which wastes are recovered as resources. European policies eschew these circuits. Resource recovery through global recycling networks is regarded as a dirty and illegal trade. In its place, EU circular economies attempt to transform wastes to resources within the boundaries of the EU. Through an analysis of two case studies of resource recovery in the UK, we highlight the challenges that confront making circular economies within the EU, showing that these are borne of a conjuncture of politically created markets, material properties and morally defined materials circuits. We show resource recovery in the EU to be framed by moral economies, driven by discourses of ecological modernisation, environmental justice and resource (in)security, the last of which connects to China's resource-intensive development.

Key words:

Circular economies; recycling; resource recovery; anaerobic digestion; waste.

1: Introduction

The concept of the circular economy has emerged recently as a policy goal in the context of rising resource prices and climate change. The aim is to move away from the linear economic model, summarised as 'take-make-dispose' with raw materials in at one end and externalised wastes at the other. Instead, in a circular economic model, wastes become resources to be recovered and revalorised, through recycling and reuse. Through the Roadmap to a Resource Efficient Europe, the EU has committed to becoming a recycling and recovery society by 2020 (EC 2005, 2011a). This vision is underpinned by the promotion of a circular economy *within* its member states and the territorial boundaries of the EU (EC, 2014). Organisations such as the Ellen MacArthur Foundation, working in partnership with the consultants McKinsey, have also championed the potential of the circular economy for EU economies, through a series of reports (2012, 2013, 2014) and through the medium of the Circular Economy Platform, a knowledge exchange network which seeks to bring together leading companies, innovators and regions. In academia the concept of the circular economy has gained purchase in a number of fields including sustainability science, environmental studies and a wide swathe of development studies shaped by low carbon imperatives. It is not hard to see its appeal. The concept appears to decouple economic growth from increasing resource use as well as promoting waste reduction or minimisation. Hence, its use in both practitioner and academic literatures tends to be approbatory, uncritical, descriptive and deeply normative. Given its prominence it is important that the circular economy be subjected to critique.

As a concept, the circular economy has a longer history. This is located in the allied but distinctive fields of ecological and environmental economics. A concern with limits to growth and resource scarcity in economic thought goes back at least as far as Malthus and Ricardo, resurfacing as ecological economics in the 1960s, first in response to Rachel Carson's *Silent Spring* and then in Ken Boulding's 1966 essay on *Spaceship Earth*. In the latter, the planet's finite supply of energy, water and materials is used to argue that sustainable futures rest on materials reuse and recycling, an argument later taken up by Georgescu-Roegen (1971), who argued that economic systems must therefore involve the maximum use of recycling and renewables. These arguments are the basis of ecological economics, a field in which circular metaphors continue to hold sway. This can be seen in the two veins of thought which exemplify current circular economy thinking: industrial ecology and extended product life.

The industrial ecology field has its origins in work by Frosch and Gallopoulos (1989), drawing analogies with material and energy flows in natural ecosystems to argue that the means to sustainable development is to close material loops through the exchange of by-products and wastes. In such a way, so they argued, economies would shift from being linear to circular. Roughly parallel to this, other work began to apply the concept of the life cycle to manufactured objects. Ideas about extending product life, through repairing and reconditioning goods through remanufacturing, were first rehearsed by Robert Lund in the late 1970s and early 1980s (Bras & McIntosh, 1999),and in a 1982 paper by Walter Stahel, who now features prominently in the Ellen MacArthur Foundation's work on the circular economy. Extending product life was seen as a means to waste prevention and as key to a transition to sustainable modes of production and consumption (Cooper, 2005, 2010). Subsequently dubbed 'cradle-to-cradle', to distinguish from 'cradle-to-grave' approaches to product life cycle thinking, this set of arguments focuses on the design of manufactured objects, in which disassembly, adaption and reuse are considered from the outset. It envisages an economy based around reconditioning, remanufacturing and recycling.

Within the EU, circular economies have been justified through environmental economics that applies largely neo-classical economic theory to the environment (Pearce, 2002). The key move is to view nature not as an uncosted externality but as a set of stocks, potential resources, flows and services that can be measured and assigned a value. Various methods and tools to account for materials and energy flows have been developed, including life-cycle analysis, materials flow analysis and triple bottom line accounting (Alexander & Reno, 2012). Related areas of activity have urged the development of carbon accounting, through for example, carbon foot-printing (Minx et al. 2009) and the potential pricing of the environment through ecosystem services (Costanza et al. 1997).

The circular economy then is a diverse bundle of ideas which have collectively taken hold. This constitutes the starting point for our analysis, which aligns with Alexander & Reno (2012), when they state that "the key [...] to contemporary recycling discourse is the extent to which the *idea* (their emphasis) of a perfect circle is taken for reality" (p 5). Critical engagement means more than just reciting the idea as a challenge to orthodox economics but that its instantiation be interrogated. This necessitates examining not just the idea of the circular economy but also the messy world of circular econom*ies*, and examining which wastes are being recovered as resources, and where. Taking account of recovery activities also challenges heterodox accounts to take note of the importance of materials and materiality within contemporary economies. One part of this, as Alexander & Reno (2012) and their contributors demonstrate, is the emergence of Global Recycling Networks (Gregson et al. 2010; Crang et al. 2013). The global trade in wastes, and their recovery, is a key means by which materials are recovered for reuse and recycling. It defines in part what is new about contemporary recycling, and reconfigures conventional accounts of the relationship between Global North and Global South. As Alexander & Reno state: "familiar economic geographies and understandings of how the global economy works are upturned as the developed North becomes a source for scrap/raw materials; marginal regions add value before (re)finished goods are sold, sometimes back to where they came from" (p 4). But, such recovery via global flows is also the result of the inability to transform wastes to resources within the Global North. And yet such an internalised transformation is to what a range of European policy instruments, constructed following the precepts of environmental economics, aspire. This paper focuses on attempts at fostering transformations of waste to resource within the EU, in so doing showing that whilst the circular economy continues to be recited as an ideal, the actuality of forging circular economies within the EU entails challenges borne of a conjuncture of politically created markets, material properties and morally defined material circuits

We begin in Section 2 by examining the two lines of thought which define the idea of a circular economy: industrial symbiosis and extended product life. These traditions are both producer led but they perform different and often idealised visions of the circular economy. They are also notable for a key absence: both write out global recovery and recycling, the primary means by which wastes are recovered and materials keep circulating through economies. This absence signals that the idea of the circular economy is also a moral economy: there are right and wrong ways of constituting the economic circulation of materials and, within the EU, the revalorisation of wastes through global recycling networks increasingly counts as the wrong way to do this. To see how the economies of the EU are being reshaped in ways which attempt to turn wastes into a resource, but within the boundaries of the EU, section 3 considers two categories of materials identified by the World Economic Forum as 'demonstrating the viability of the circular economy' (WEF 2014, p11). The first is what they call a 'golden oldie' of recycling, consumer-generated, or municipal, waste, representing 'well-established, high-volume recyclates with a remaining purity challenge'; the second is food and organic waste, described by the WEF as exemplifying 'rough diamonds' comprising large-volume by-products with new technologies of valorisation. Through a focus on UK municipal waste recovery, as 'dry recyclables' (section 3.1), and organic waste 'markets' (section 3.2), we show that EU circular economies are also moral economies, where judgements on the merits of different circuits of materials drive attempts to create new markets. We conclude the paper in Section 4 by reflecting more widely on the politics that underpin EU circular economies as moral economy.

2: The idea of the producer-led circular economy: industrial symbiosis, extended product life and the moral economy of resource recovery

Industrial ecology, and particularly industrial symbiosis, is often taken as synonymous with a circular economy. The focus is mostly on three scales of closed loop initiatives: within single firms; clusters, or groups, of co-located firms, and city, or municipality-based, activities (Matthews & Tan, 2011). Comparing interventions at all three scales forms the basis for a number of case studies in the industrial symbiosis literature in China (e.g. Zhu et al. 2007; Xu et al. 2008; Geng et al. 2009; Yuan & Shi, 2009; Shi et al. 2010). In the EU the focus of the Roadmap for a Resource Efficient Europe is on clusters, highlighting as best practice the UK's National Industrial Symbiosis Programme, which looks to localised open loop exchanges between industries, and the eco-industrial park at Kalundborg, Denmark (Lombardi & Laybourn, 2012).

Lombardi & Laybourn (2012, p 33) describe Kalundborg as industrial symbiosis' 'poster child'. It figures as the must-cite case in paper after paper in the industrial symbiosis literature. We have reviewed this body of work elsewhere (Gregson et al. 2012), but to recap, Kalundborg, first described by Ehrenfeld & Gertler (1997), is a complex emerging over some 25 years featuring four core plants: a coal-fired power station, an oil refinery, a pharmaceutical plant and a plasterboard manufacturing plant. Waste heat is exchanged from the power station to the other plants and to a CHP (combined heat and power) district heating system. Cascading exchanges of ground water, surface water and waste water, link the plants and there are other residue exchanges, of ash, scrubber sludge and sulphur, which circulate both within Kalundborg and which are traded out of the municipality (Deschenes & Chertow, 2004). Each of the symbiotic links is a separately negotiated business deal. However, amidst the papers that describe Kalundborg only one (Brings Jacobsen, 2006) goes into analytical, financial depth. Brings Jacobsen focuses on the water and steam exchanges at the core of the complex and shows that the motivations for low value exchanges, such as water, are grounded in indirect economic returns on longer term operational performance whereas higher value exchanges, such as steam, are more likely to be related to the direct value of the by-product.

Brings Jacobsen's work remains a rare example in the industrial symbiosis literature where the focus shifts from describing material flows to examining the business economics which make symbiotic exchanges possible. By contrast, other work has focused on case studies of what has turned out to be a very small number of localised symbiotic clusters (Korhonen, 2001, 2002; Geng & Côte, 2002;

Mirata & Emtairah, 2005; Chertow, 2007; van Beers et al. 2007; Deutz & Lyons, 2008). Given the paucity of other cases, Kalundborg has become not just an exemplar case of industrial symbiosis but the paradigmatic case, from which a number of principles have been distilled and then assembled into the policy concept of the eco-industrial park (EIP). EIPs figure across the industrial symbiosis literature, emphasising shared infrastructure and joint provision of services to promote the creation of exchanges of by-products, wastes and energy between firms co-located in the park. However, in North America and Europe they remain largely promotional devices (Hewes & Lyons, 2008) and struggle to get beyond aesthetics, landscaping and waste/energy services, or, at best, reuse surplus heat or power from an energy intensive anchor firm (Gibbs & Deutz, 2005). In response, the industrial symbiosis field has gone back to another lesson from Kalundborg; the short mental distance between its firms which suggests that intangible business and local mores are as important as technical possibilities in deciding what actually gets reused.

The industrial symbiosis field is thus moving from analogies with natural ecosystems and turning to economic sociology and geography accounts of embeddedness for explanatory purchase (Chertow & Ehrenfeld, 2012). The analysis of Kalundborg also signals that the circular economy of industrial symbiosis is grounded in business-to-business transactions in which environmental benefits (and circles) are effects not causes (Brings Jacobsen 2006). At the same time, the case clearly shows open loops outnumber closed ones. Most residues leave the Kalundborg system to be re-valorised elsewhere. Recognising this, along with the conspicuous failure of spatial policies such as EIPs, is to cast doubt on the veracity of an approach which continues to see planned co-location and territorial agglomerations as the basis for the circular economy (Chertow, 2000; Chertow & Ehrenfeld, 2012). It is a point acknowledged in the UK's National industrial Symbiosis Programme, in which a network model of knowledge exchange and innovation prevails, where very few of the nearly 1000 resource exchanges it identifies are bound to contiguous parks, but are framed by serendipitous geographical proximity (Jensen et al. 2011, p 705).

In focusing attention on exchanges of by-products and wastes in planned complexes of co-located manufacturing plants, industrial symbiosis' approach to the circular economy is to increase the intensity of localised resource use; literally squeezing more value from the same initial inputs through co-located manufacturing processes. This contrasts with the extended product life approach. Here the circular economy seeks to stretch the economic life of goods and materials by retrieving them from post-production consumer phases. This approach too valorises closing loops, but does so by imagining object ends in their design and by seeing ends as beginnings for new objects. Unlike industrial symbiosis, the aim is to reuse or repurpose products at a later date after their consumption.

Notwithstanding that the idea has been around for over three decades, extended product life is an approach which, as with industrial symbiosis, continues to recite the aspiration as an endlessly deferred, but attainable, future (Bras & McIntosh, 1999; Guitini & Gaudette, 2003; Imojah et al. 2007; Imojah, 2010; Hatcher et al. 2011). And again, as with industrial symbiosis, the idea of the perfect circle is recited so much that it becomes tantamount to being taken for a real trend. Nonetheless, the evidence for extended product life in manufacturing is demonstrably lacking: a 2008 survey among 36 of China's larger electrical and electronic manufacturers, for example, found little evidence of eco-design in their products (Su et al. 2013: 217), whilst the Circular Economy Platform, hosted by the Ellen MacArthur Foundation, showcases just a few instances of product life thinking in action (and see too: Russell et al. 2010; Chen et al. 2014). At the Resource 2014 Conference in London, the WRAP[1] Chief Executive stated: "I am quite disappointed at how much progress we have made because it has been pitifully slow. We need some real examples of businesses getting a circular economy working and that will help" (http://www.letsrecycle.com – [21]).

[1] Until 2014, W(aste) R(esources) A(ction) P(rogamme) was a UK-based not-for-profit company supported by funding from Defra (the Department of Environment, Food and Rural Affairs) and charged with promoting sustainable waste management by creating stable, efficient markets for recycled materials and products. Defra is the lead government department for waste policy in England and Wales.

Disappointments aside, the issue here is that to effect this vision of a circular economy would require not just producers (that is retailers, manufacturers and their component suppliers) to widely adopt 'take-back' schemes for used goods and either incorporate reconditioning and remanufacturing within their business operations, or create onward linkages with firms specialising in such activities, but also a recasting of goods as stocks and consumption as an activity grounded in the leasing, rather than ownership and possession, of goods. The whole basis of the 'economy shifts from selling and buying products to (…) the utilization of (…) products' (Su et al. 2013: 217). Ease of disassembly and repurposing also runs against trends to secure proprietary technologies through hardening objects against hacking and repurposing. To argue for extended product life, therefore, is to propose nothing short of a wholesale transformation of the basis of contemporary capitalism and consumption.

Critical scrutiny shows that the approaches that define the circular economy exemplify how the idea of a perfect circle comes to be taken for reality. These visions of a circular economy are just that: ideals which, at best, describe a few instances where reordering the activity of the firm on these lines makes business sense. As striking is the obvious omission in these accounts. Notwithstanding that the founding texts of ecological economics valorised the planetary circulation of materials, one scale of materials circulation is absent from these representations. This is global recycling networks; the major means by which loops are closed and materials do indeed keep circulating around the planet and through the world's economies. In this way, the circular economy emerges as a form of moral economy. There are right and wrong ways of keeping materials circulating. Global recycling also figures as the antithesis in EU documentation to 'high quality recycling'; here publications around the EU Roadmap to a Resource Efficient Europe speak of a 'Dirty trade' challenging the EU vision of recycling society (http://www.euractiv.com/), whilst EC documentation refers to the shipments of wastes outside the EU as an 'illegal trade' resulting in 'significant loss of resources for the EU' and links this to key areas of resource insecurity, particularly rare earth metals (EC, 2011b p

19) most of which are supplied by China, and phosphate fertilizer, 90% of which comes from Moroccan-occupied Western Sahara.

In the following section we turn away from the circular economy as an idealised producer-led model. Instead, we focus on how circular economies are being enacted within the EU, using as examples two case studies drawn from the UK. The EU is more than an economic area in which the idea of the circular economy is at the forefront of thinking, debate and policy formation on sustainable economies. The EU is that for sure, but it is also the arena where the circular economy, as moral economy and political economy, meets. To create an EU circular economy requires closing the EU to outflows of materials and capturing materials currently destined for global recycling networks. Circular economies linked to a vision of clean green ecological modernisation are predicated upon enacting the EU as a bounded material system. At the same time, interventions in the EU highlight the challenges of implementing circular economy thinking in real world economies. Given the limited uptake of producer-led models in the EU, circular economies have instead been enacted here by measures and policy instruments drawn from environmental economics, addressing wastes as they are currently generated, in open, still predominantly 'linear' economies, and then attempting to turn these to recovered resources, or tradable goods for EU processors. The focus therefore has been on consumer-generated, or municipal, waste, its recovery, and attempts to reconfigure this as a resource for multiple manufacturing sectors, and on interventions with organic or bio-wastes, including food waste, which also seek to reformat such materials as a resource for diverse sectors. The UK provides an illuminating EU member state through which to examine the challenges facing both sets of interventions, and for two reasons. First, an historic reliance on landfill as the primary 'dispose' option for the UK's linear economy has meant that resource recovery has been closely allied to meeting policy targets for diversion from landfill, rather than focused on producing materials suitable for processors. WRAP's Chief Executive states: "we have actually made fantastic progress over the last few years and we are increasing recycling rates. That is something that we should all be very proud of" (http://www.letsrecycle.com – [21]). But, in emphasising diversion, the

UK case highlights the legacy effects of linear economies and their importance in any transition to circular economies. Second, a political commitment on the part of successive governments to the primacy of the market and to market-making, and increasing tendencies to see the green economy as a site for new business opportunities and innovation, mean that the impetus to develop markets in recovered resources has here been strong. Yet, as we show, collisions of morality, materiality and market logics indicate that the transition to an EU circular economy will be politically contested . Indeed, the matching of material properties and standards with specific market mechanisms looks increasingly certain to pit member state against member state, as across the EU differing waste regimes (Gille 2010) have created different legacies and issues of transition. For the EU to foster a circular economy will mean choosing specific configurations of materiality and market, with differing moral values, and not just physical or technical mechanisms, to rekindle value in recalcitrant waste materials – in ways that compete with global resource and recycling markets.

3: Post-consumption circular economies: turning waste to resource in the EU

To attempt to turn waste from the classic uncosted or negative externality of economics to a resource is a considerable task. This is not just a matter of adding externalities to a spreadsheet, though as we shall see such devices play a key practical role. In the real world economies of the EU turning wastes to resources also requires the wholesale transformation of the waste management sector to a secondary resource recovery sector and its integration with a manufacturing sector which continues to rely on virgin resources.

Within the UK waste management business the source of revenue has been receiving waste, not reselling it or its products. Waste management facilities, be that a landfill, an incinerator or a recycling plant, charge the customer/client to deposit wastes. Charges relate primarily to weight and materials characterisation; a broad rule of thumb is the greater the weight and the more problematic the material, the higher the charge, and these “gate fees” have long been the main revenue stream in the waste management sector.

To turn waste to a resource, however, requires going beyond gate fees and tonnage. It necessitates that wastes are turned to commodities bought and sold in markets. Discarded goods, objects or materials, require separation and segregation, sorting, and sometimes treatment, to render them tradable commodities suitable for purchasing by manufacturers. The challenge facing the drive to create circular economies from wastes in Europe, then, is three-fold. First, to process discarded goods and materials in such a way that they become tradable as goods within EU markets (EEA, 2011); secondly, to do this in the face of well-established global recycling markets which turn wastes to resources but where the demand for recyclates is international (Alexander & Reno, 2012; Gregson et al. 2012; Crang et al, 2013); and thirdly, to do this in conditions of strong environmental regulation, clean production and high labour costs. EU plans correctly point out the need for high quality, that is, pure recyclates. They therefore look to 'high quality' recycling as defined by being located in the EU, where high costs will, it is implied, lead to high quality output. It is this elision we show to be problematic.

A set of policy instruments seeks to aid the transition to circular economies in the EU, including the Waste Hierarchy (Hultman & Corvellec, 2012) and the Waste Framework Directive (WFD). The Waste Hierarchy is a preferential ranking which prioritises ways of managing wastes on the basis of their environmental benefit. At the top of the hierarchy is waste prevention. Below this is recovery for reuse, followed by recycling in which waste materials are reprocessed into products, materials or substances which may be for their original or other purposes, be that either 'up-cycled' or 'down-cycled'. Recovery for energy, and for heat, (incineration) are less favoured than recycling, whilst landfill is the least favoured option and is regarded as 'disposal'. This thinking has informed EU waste policy since the late 1990s.

The Waste Framework Directive (WFD) emerged in response to environmental justice concerns over the dumping of wastes on the people and environments of the Global South. It prohibits the shipment of materials designated as hazardous waste beyond the OECD area, and sets a target that individual EU states should move towards self-sufficiency in waste disposal and recovery. It is the chief means for promoting the proximity principle, which emphasises that wastes should be dealt with close to their point of generation. Waste prevention, minimisation and reduction are key imperatives within the WFD, as is the diversion of waste from landfill which is also allied to actions on climate change, since methane (generated by landfill) is a key greenhouse gas.

The primary means by which environmental values regarding waste have been turned to economic value in the EU is via a form of 'cap and trade' scheme, enacted in the Landfill Tax. Since 1999, a progressively increasing tax on tonnage sent to landfill is meant to provide a strong incentive for municipal authorities to divert waste from landfill to 'beneficial reuse'. And indeed it does but the incentive is about the diversion rather than enabling reuse. Concurrently, infrastructure oriented to the collection and recovery of waste materials has been developed across EU member states, focused in the first instance primarily on household or consumer-derived wastes (Municipal Solid Waste), of which the most recent data shows ~246 million tonnes was collected across the EU-27 with 23 million tonnes in England (Eurostat, 2012). The details of how these recovered materials are to be turned to resources are left to individual member states but, as we show through a focus on the UK, for the most part England, EU circular economies are distinctly moral economies in which there are right and wrong ways to achieve resource recovery, even within the EU's boundaries. We use two case studies to highlight the challenges confronting the shift from linear to circular economies in the EU. Through a focus on the municipal waste sector in England we show how the confluence of politically created markets and the material properties of wastes can all too easily result in the production of low value products reliant on global markets. Increasingly, at EU-level this is seen as doing resource recovery the wrong way. Then, through a focus on anaerobic digestion[2], again in England, we show how the same confluence of politically-induced markets and material

[2] Anaerobic digestion is 'a process of controlled decomposition of biodegradable materials under managed conditions where free oxygen is absent ... that convert[s] the inputs to biogas and whole digestate' (BSI, 2010: 3.2).

properties poses difficulties in attempting to turn organic wastes into energy and fertiliser.[3] Again, the issue of doing recovery the wrong way raises its head.

3.1: UK municipal waste: materials recovery facilities and the weighty legacy of political accounting

In the UK the need to achieve the EU statutory target of 50% of municipal waste diverted from landfill has posed a major challenge. This is because the waste regime (Gille 2010) of the UK historically relied on landfill, unlike for instance Scandinavia that was geared to incinerate most waste. The task of transforming the waste regime fell to local authorities, which subsequently have been centrally involved in the development of a recycling infrastructure for the UK, chiefly through tendering contracts for municipal materials recovery facilities (MRFs). Both the number and capacity of MRFs have increased rapidly in England and Wales. In 2006, WRAP data listed 55 plants, of which roughly half had been commissioned post 2000. By 2007, numbers had risen to 82, with an annual processing capacity of 2.5 million tonnes and by 2010 94 plants with capacity to handle ~ 3.1 million tonnes. Statutory requirements to reach a 50% recycling rate by 2020 have underpinned a turn to large capacity, capital intensive MRFs, whose capital costs are supported by Private Finance Initiative funding (http://www.letsrecycle.com – [2], [6], [7], [8], [14]). Long contracts with local authorities, typically of the order of 15 years, guarantee the supply of waste and thus plant throughput that secures the financial investment on multi-million pound capital plant. This has led to concentration in the sector, with a few firms dominating the market. Inside plants, segregation and sorting rely on a small number of manual 'pickers' and mechanised processing. Incoming waste is tipped and materials are placed on conveyor belts for pre-screening. Pickers remove all materials that are either non-recyclable or too problematic to be mechanically processed. These residue materials are sent to 'dirty MRFs' for further recovery, for incineration or to landfill. Then mechanised processing separates materials using material recognition technologies. Trommel systems separate different

[3] The case studies are based on interviews conducted in 2011/12 with 16 facilities, of varying scale and size, spread equally across both sectors, and analysis of policy documents and the trade press from 2011-14.

types of paper and card; optical recognition technologies separate plastics; and magnets and eddy currents ferrous metals from aluminium. A final line of pickers removes anything that has come through processing that should not be there, before the materials streams are sent for baling. Typically some 95% of materials received by any one plant would be recovered to be sold into the commodities markets.

For circular economies to work, MRFs must not only be a means of diverting materials from landfill but also the means to supply quality recycled materials for (re-)manufacture (WRAP, 2009). The relation between diversion, recovery and recycling, however, is complex and contradictory. For both waste companies (seeking to amortise large capital investments) and local authorities (looking at 'diversion' targets), what counts remains the tonnage through the gate. Weight is the primary financial driver. In terms of circular economies, however, what counts is the usability of the outputs.

Output quality has very little to do with the volume or weight of materials processed by a MRF. Instead, quality has everything to do with collection systems, the categories used to turn materials to products, and the quality of segregation, sorting and treatment inside a MRF plant. The development of the UK's MRF infrastructure has been keenly influenced by simple costing tools based on Excel spreadsheets. Two tools are of particular importance: KAT (a kerbside analysis toolkit) and a MRF costing tool. KAT is a public domain model developed by WRAP which allows local authority waste managers to make projections for the numbers and kinds of kerbside collection required to deliver different patterns of waste streams to facilities (WRAP, 2008). It is therefore a calculative market device: one which translates a public sector statutory service (household waste collection) into a calculative economic task, in which collection becomes an economic cost calculation. KAT uses categories to turn wastes into potential saleable materials, so called 'dry recyclables': 'news and pams' (newspaper, magazines), plastic bottles, mixed steel and aluminium cans, various types and colours of glass, and textiles. Largely as an effect of the KAT tool's modelling assumptions, collection systems for dry recyclables in the UK mostly collect comingled, rather than source-segregated, waste. That is, all the materials are placed in a single container and in the same truck rather than being sorted into and collected in different containers. Comingled systems are controversial, particularly at EU-level, because although they lead to higher diversion rates from landfill for the least cost, but also increase cross-contamination of materials, making them harder to reprocess (http://www.letsrecycle.com – [10], [17]).

The MRF costing tool - also developed by WRAP - works on similar principles to KAT (WRAP, 2006a). It assumes economies of scale coming with increased processing capacity, the importance of guaranteed tonnage to achieving economies of scale, and hence the desirability of commissioning large MRFs and assuring guaranteed tonnage throughput. Using it predetermines that outcome. As with KAT, the costing tool emphasises a limited range of eight materials categories: three grades of paper and five types of containers.

Both costing tools have encouraged local authorities to continue to think about materials recovery through weight and volume of a relatively small number of categories of materials. This has had profound effects. For local authorities, dry recyclables become a source of revenue, but revenue derived from material categories, tonnes and price/tonne. In recyclables markets, however, value is added through the work of separation and sorting (Rivoli, 2005; Crang et al. 2013; Gregson et al. 2013), with an open question being just how much separation and sorting is economically optimal (Spencer, 2005). Segregation and sorting are closely related to the categories and grades of materials used. The more separation and sorting the finer the grades produced, with less contamination in the end product and the more value realised. Some international MRFs work with as many as 16 or more grades (WRAP, 2006b). By contrast, UK municipal MRFs work with 5 – 10, with most below 8. So, whilst UK MRFs accept a considerable array of material, they reduce this to a relatively small number of output categories, which means many of those outputs are mixed and thus have, at most, the value of the lowest grade.

Looked at in this light, it is difficult to avoid the conclusion that not only is value being lost by UK MRFs but that far from capital intensive processes creating high quality output, their products are often low grade. As such, they are destined inexorably for global export markets, where lower labour costs allow for bales to be broken, re-sorted and the untapped value to be realised -- although at times the quality of UK recycled materials has been so poor it has led to them being rejected from markets such as China. Contamination controversies over UK MRF outputs abound, with a number of high profile cases demonstrating the rejection of MRF output by both UK manufacturers and Chinese importers as it fails to pass quality criteria (http://www.letsrecycle.com –[12, 13]). UK paper mills have stated publicly that they will not accept paper that has been collected with glass, and thus most municipal MRF-sourced paper (WRAP, 2006a), whilst cross-contamination with plastics poses another set of problems. Glass recovery firms too find municipal MRF-sourced glass to be low grade material which is hard to separate to the purity levels required by glass manufacturers (http://www.letsrecycle.com – [1]).

Issues with product quality go to the heart of the challenge in constituting circular economies in the EU. To succeed as a circular economy these MRFs must turn waste to a recovered resource suitable for EU processors and, at the same time, recovery operations themselves must be economic. Yet, the UK's municipal MRFs are the effect of a political settlement with municipal waste in which diversion from waste, rather than resource recovery, has been the driving metric. Further, the low quality outputs are materialisations of modelling tools and long contracts which meet statutory targets for diversion from landfill by guaranteeing long term financial returns on capital investment, based on volume throughput, for MRF operators. This processing infrastructure is a weighty legacy for any attempt to create markets in recyclates. The disjuncture of diversion and recyclable outputs has registered at many levels, from pronouncements by ministers in 2011 and 2012 affirming the need for quality uplift (http://www.letsrecycle.com – [4], [16]), to repeated journalistic exposés that threaten continued public participation in recycling. At EU level, this issue is recognised in the revised WFD (rWFD) which added the criterion that collection systems and infrastructure must deliver high quality recyclate, with a clear preference for separate collection systems. Yet, although challenged through Judicial Review in 2013, the UK government remained committed to comingled systems of collection (http://www.letsrecycle.com – [20]). As we write (in August 2014), the political imperative to upgrade UK MRF products to comply with the rWFD is signalled strongly in Defra's Quality Action Plan (Defra, 2013a) and by new requirements on local authorities to review existing arrangements and instigate separate collection systems for dry recyclables by 2015 unless comingling can be demonstrated to provide high quality recycling (EA, 2014). But it is an open question whether one form of waste processing based on the financialization of weight and volume can easily be shifted to produce recyclables of the material quality demanded by EU processors.

3.2: Formatting organic wastes for markets: qualifying materials as by-products, or wastes?

Dry recyclables are not the only materials that need to be diverted from landfill. Defra's 2014 figures show that the UK produces some 7.2 million tonnes per annum of food waste whose decomposition is a major source of green-house gas emissions, and which, since the 2001 foot and mouth epidemic, has been debarred from being recycled as livestock feed. In 2011, the UK government identified Anaerobic Digestion (AD) as the best strategy to divert this material from the waste stream. At that time there were 214 AD facilities, classified as: agricultural (farm-fed), 'community' food waste treatment plants, taking food waste from consumers/households, supermarkets and the hospitality/catering sector; and industrial on-site plants for food processors (WRAP 2011a). 2011 figures showed 46 were new 'community' plants with the capacity to process 1.8 million tonnes per annum, and to generate 5 MW of electricity, with an additional 12 at various stages of construction (0.68 milion tonnes; 30 MW). Those under construction are thus 50% larger by input and geared much more strongly to energy production. The sector continues to grow, with a goal of 3 – 5 TWh heat/electricity generation by 2020 (Defra, 2013).

Agricultural, farm-based AD operations are predominantly small-scale, closed loop systems mostly based on cow slurry or crops which exemplify the circular economy principles of industrial symbiosis.

With rising costs of fertiliser, and ‘peak phosphate’, digestate has commercial advantages for farmers who can operate a credentialised system, providing bio-fertiliser to spread on-farm at radically reduced costs. The requirement for credentials showing the agricultural provenance of digestate means this circuit is separate from food waste diversion. In contrast, larger AD plants are open systems, sourcing heterogeneous feedstock, including food waste, from a wide geographical area. They rely financially on a combination of an energy product (electricity, heat or biogas) and gate fees. The demand for such energy and its price are driven by incentives from the renewables electricity generation market in the form of Renewable Obligation Certificates (ROCs), Feed in Tariffs (FiTs) and Renewable Heat Incentives -http://www.letsrecycle.com – [3], [5], [9], [15]. As with MRFs, these AD operations are dominated by the majors in the waste management sector, and often form parts of PFI-financed waste recovery complexes.

Farm-based AD operations frequently describe the material process of anaerobic digestion in ways that draw analogies with a cow’s stomach. Quality, clean feedstock with the right bacteria present is seen as important; the digester’s operation is seen as a bio-process, and tinkering is commonplace. By contrast, larger scale ‘community’ plants render a bio-process industrial-mechanical. By common consent in the sector, this is where problems arise. Food waste, particularly in large quantities, is a problematic feedstock. Its material composition is highly variable seasonally and it is often contaminated with inorganic matter. Cautionary tales of cutlery, trolley wheels, whole trolleys and even televisions, as well as of plastic, packaging and pallets being mixed into waste consignments, abound in the sector. This contamination means there has to be pre-screening, and animal by-products biosecurity regulations mean the input or output has to be pasteurised. The added difficulty in reprocessing means companies charge higher rates for handling it, or in waste economics terms, it commands high gate fees. These high gate fees, together with the large plants favoured within PFI set-ups, have effects. The former encourage the acceptance of more tonnage and the latter put pressure to increase throughput to spread overhead costs, encouraging minimal pre-screening and sorting and shorter times within the digester. This may be economically rational, but digesters and digestion object. Although the process continues to produce energy and hence money (in the form of ROCs and FiTs), there are major odour issues and ensuing public objections – http://www.letsrecycle.com – [19]).[4] A number of 'pollution incidents' are also cause for concern (Defra, 2013b). Contamination also causes blockages which are costly to remove, creating a process with more than a hint of indigestion about it.

The current challenge for commercial AD plants is to turn food waste into enough money via gate fees, ROCs and FiTs. At the same time, the plants generate approximately 90% of the tonnage input as digestate (whole, liquid and fibre). UK regulators are attempting to redefine that digestate from a waste to a by-product. In the AD Strategy Defra state:

> "Digestate from AD plants is still considered a relatively new material (...). There is a need to develop markets for digestate, and to build confidence within these markets on the safety and efficacy of its use. Lack of such markets could significantly constrain the development of the AD sector (...) and will be a missed opportunity to recycle valuable nutrients to the soil" (Defra, 2012, paragraph 28).

The approach combines product qualification via quality protocols and certified standards, with demonstration through experimental field trials.

Quality protocols such as that produced for AD (ADQP - EA/WRAP, 2010; WRAP/EA, 2014) seek to establish the point at which 'waste having been the subject of a complete recovery operation may become a non-waste product or material that can be either reused by business or industry, or supplied into other markets, enabling such recovered products to be used without the need for waste management controls' (ibid, 2010, p 3). To qualify, digestate must have been produced using only specified source-segregated input materials; it must demonstrate compliance standards; but it still has limited approved uses, currently agriculture, forestry, soil/field-grown horticulture and land

[4] The most high profile case of odour 'overflow' in the UK AD sector is Biffa's Cannock plant, which was forced by the EA to undertake £800k of odour abatement measures in 2012, just one year after opening.

restoration. PAS 110 is the UK-certification process by which AD-derived digestate may be qualified as a bio-fertiliser (PAS 110 – BSI, 2010).[5] It has four main criteria: pathogens, potential toxic elements, stability (volatile fatty acids and residual biogas potential) and contaminants. The last two are problematic for food waste-based AD plants. The main element of the test is the residual biogas potential but short containment times driven by turnover needs result in higher residual gas content. The visible presence of plastic in fibre digestate, exacerbated by reduced sorting and screening, is another difficulty (http://www.letsrecycle.com – [22]). Correspondingly, only a small number of plants have PAS 110 accreditation (http://www.letsrecycle.com – [11], [18]). In 2014 food waste AD operators were pushing to replace volatile fatty acid tests within PAS 110 with a more 'flexible' biogas test with wider limits that might give more favourable results to food waste processors. Qualification is thus emerging as a key criterion in the struggle to turn digestate to a by-product of AD, and the material qualities of digestate also need to be shown as comparable to established, non-renewable bio-fertiliser products.

The technical viability of AD plants was shown through a series of demonstrator projects (Reno 2011); now the potential of their digestate is likewise being demonstrated as a replacement bio-fertiliser for agricultural use in a series of field trials (WRAP 2011b). These trials require farmers to bear witness to the beneficial effects of digestate (WRAP 2011c; 2012b). Demonstration field trials are also currently being conducted for digestate applications as a soil additive/improver in sports turf, soil manufacture and energy crop production on post-industrial land. They ask businesses to bear witness to the effects of digestate, but this time in amenity and landscape grass, tree species, and biomass crops. Recent market-based research in landscaping, sports turf, land remediation and horticulture, however, has raised the material properties as an impediment, with odour, wetness, and variability emerging as problems when compared to established products (WRAP, 2011d, 2013).

[5] PAS 110 is a Publicly Available Standard, designed as a fast-track precursor to a potential future British standard (BSI, 2010). It is 'a voluntary, industry-led specification (which) sets out the minimum quality required for whole digestate, separated liquor and separated fibre which may be used as a fertiliser or soil improver' (BSI, ibid 0.2).

An open question, however, is the degree to which these trials can demonstrate that liquid digestate has a sufficiently large market, given its material qualities restrict economically viable haulage distances and low concentrations of nutrients make it difficult to apply. Volume reduction, in the form of drying and pelleting, or catalytic nutrient extraction is therefore necessary to extend agricultural markets beyond the immediate geographical locale and to a sufficient scale to support large plants. Qualification alone then does not turn digestate into an economically viable bio-fertiliser or soil additive/improver. For digestate to become a bio-fertiliser a wet, slurry-like and strongly waste-odoured material requiring high-volume application rates needs to be rendered more akin, both in substance and nutrient balance, to the standardised bags of dry fertiliser which currently dominate these markets (WRAP 2011d). For food waste-fed 'community' AD plants, the future for digestate appears likely to be limited to a (free) soil additive in post-industrial land remediation and/or energy crop production; the latter itself supported by the market in carbon credits by offsetting CO_2 emissions through planting biomass crops.

Whilst the struggle to marketise AD-derived digestate continues, a further political qualification trial lies ahead. This is the EU-wide End of Waste Directive. EU bio-fertiliser qualifications currently are tied to German AD plants, these being the acknowledged industry leaders. The AD industry in Germany is widespread with nearly 7000, mostly farm-based, plants dependent upon either crops (maize for the most part) or slurry. Containment times are long (130 days, compared to an average of 40-50, and sometimes shorter, in the UK). The result is that there is very limited residual biogas present in German digestate. Materially there is no possibility for digestate derived from food-waste based UK plants to pass this qualification trial. Given UK food waste plants are already trying to loosen the existing UK-test standards, a move to this even higher standard would result in large volumes of AD digestate in the UK becoming categorised as an organic waste (http://www/letsrecycle.com - [5]). With moves to ban food waste from landfill across the EU, this could become a pressing problem indeed.

In AD, as with dry recyclables, the onus is on UK regulators to intervene to bolster a waste-to-resource regime which threatens to be politically disqualified on the grounds of doing resource recovery the wrong way. As the drive to create circular economies in the EU intensifies, the question of whose technologies, and whose regime, get to define the measurements which determine which wastes qualify as products and become tradable goods, and which remain wastes, will become increasingly contentious. The case demonstrates conclusively that, at the heart of the EU's emerging circular economy are questions of material politics as well as of moral markets.

4: Conclusions

This paper has subjected the concept of the circular economy to critical interrogation, by examining its instantiation in real world economies. The concept is an endlessly recited ideal. Yet, to effect a circular economy driven by producers through either industrial symbiosis or cradle-to-cradle manufacturing would require radical transformations to the economic order, including fundamental recasting of manufacture, retail, consumption and property rights. Beyond the ideal, in the messy world of how circularity is being enacted in actual economies, post-consumer wastes have become the basis for circular economies. One way in which this occurs is through global recycling networks, and new research has done much to make these activities visible. However, they do not count as appropriate forms of resource recovery and recycling in EU policies, where they are regarded as deeply suspect. Instead, under the rubric 'high quality recycling', policy aims for the transformation of waste to resource within the EU. However, as we have shown through an examination of dry recyclables and organic wastes in the UK, the challenges of turning waste to resource within the boundaries of the EU are considerable. 'High quality' EU recycling can struggle to meet the quality standards demanded by the market for recycled products and products are (politically) disqualified from the recyclate market. Further, EU circular economies are moral economies; not only do they say that global recovery and recycling is the wrong way to ensure the extended circulation of materials in economies, they also define some forms of European resource recovery as wrong. The question that remains is what form of politics lies behind this increasingly moral European market in resource recovery.

There are three answers to this question. The first is a technocratic politics. One element to this rests in the EU's condemning of landfill. Landfill is the bête noir of circular economy ideals; its function as a 'grave' enables the persistence of the 'linear' economy. Landfills should be obsolete in a circular economy. So, part of the argument about low quality recycling in the Global South is that it continues to depend on dumping materials, often harmful ones, into the environment, often in uncontrolled landfills. Landfills beyond the EU are thus doubly wrong as inadequate versions of an inappropriate technology. The underlying premise of this technocratic politics, however, is the technical dream of the perfect circle achieved via perfect recovery. This is technologically impossible, as is illustrated by both dry recyclables and anaerobic digestion, both of which, whilst they recycle, also generate troublesome wastes as remainders of processing, and which continue to rely on landfill and/or incineration for their disposal.

The second form of politics is environmental, driven by environmental justice concerns. In continuing to portray global recycling as the global dumping of wastes on the people and environments of the Global South by the consumers and businesses of the Global North, accounts imply that global circuits of materials break the circular economy. While most materials are not dumped but recycled, these global recycling networks are seen as the wrong form of resource recovery enacted by unprotected labour working in both socially and environmentally degrading ways. A more accurate reading would be to see this kind of resource recovery operation as allied to the global shift – primarily to Asia - of low value manufacturing activities and as responding to that manufacturing demand. Recognising that much resource recovery is a low value activity, akin to resource extraction, a very real question is just how profitable such activities can be when located within European economies, or whether, in order to be financially viable, plants within the EU must sacrifice the very quality of output that their location is meant to guarantee. Moreover, there are now numerous waste management/resource recovery facilities in China particularly which fully comply with international standards in resource recovery (Minter, 2013). To continue to insist that resource recovery can only be done appropriately within the EU, then, is not just incorrect; it is also an example of a wider Euro-centrism with respect to China, in which the EU continues to figure itself as the model and/or leader for the rest of the world (Jacques, 2012).

The third form of politics framing the morality of the EU's circular economies is located in the political economy of resources and particularly resource security. For the most part, this politics is articulated in terms of the degree to which EU resource demand can be met through secondary resources. Answers range from around 50% with respect to certain materials, such as paper and iron and steel, but much less for many others, even with a technically impossible 100% recovery rate, and there are some 14 raw materials, mostly metals, which feature on the high supply risk list for the EU economies. These are metals critical to high value EU-based manufacturing, including in the aerospace, automotive and communications sectors. The figure that haunts these discussions though is China, and its resource-intensive form of development, particularly fears that it is securing control of resources from Africa. Indeed, the vulnerability of important sectors of EU manufacturing to Chinese resource use has been demonstrated recently through China's dramatic cut backs in rare earth metal exports. With China accounting for 95% of global rare earth supply, the 30% export reduction of 2010 led to rapid price hikes and a much publicised rare earth panic in the US, EU and Japan. Along with opening up new and abandoned mines, and the possibilities of mining waste tailings, recovering rare earths from end-of-life goods, including e-waste and fluorescent light bulbs, has emerged as one response. In agricultural sectors, dependence on phosphate fertilizer was highlighted by the ten-fold surge in mineral phosphate prices in 2007-8 which was seen as presaging the effects of increasing non-western demand. EU resource recovery, then, is couched as a means to resource efficiency, but it is also a form of mercantilism. It is a means of capturing end-of-life goods within the boundaries of the EU, to stretch resources to accommodate a multi-polar development. Increasingly, it appears as a form of geo-political insurance; in a world where rampant economic growth in the developing world threatens the stability of economies long accustomed to having resources their own way, it offers insurance against the EU's increasingly apparent resource insecurity.

We end the paper, however, back with the laudable attempt to decouple economic growth from primary resource consumption that sits at the heart of the idea of a circular economy. The EU roadmap for the current year (2014) states the priority is to 'Stimulate the secondary materials market and demand for recycled materials through economic incentives and developing end-of-waste criteria' (p 8). To achieve this requires close scrutiny of how materials qualify for such markets. But it is also increasingly apparent that previous technologies of waste diversion do not fit smoothly with the current goal of recovering secondary resources from waste materials. Just as the UK is wrestling with a high volume, low quality output problem, systems in Scandinavia, previously held up as exemplary, are struggling with how to shift from recovering energy to recovering materials, given huge infrastructural commitments and the need to change incentives for different actors in the value chain (Corvellec and Hultmann 2012). To turn wastes to resources, then, is a challenge in which different logics clash. This is not just the familiar case of business logics pitted against environmental ones. Rather, as we have shown, in forging circular economies EU policy is creating markets and proxy markets in materials recovery in increasingly moral and moralising ways.

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Websites

http://www.biogas-info.co.uk/ - Last accessed 11 April, 2013

http://www.ellenmacarthurfoundation.org/circular-economy - Last accessed 8 January, 2014.

http://www.euractiv.com/ - Last accessed 31 January, 2014

11 October 2011: Dirty trade challenges EU vision of recycling society (http://www.euractiv.com/specialreport-recycling-society/dirty-trade-challenges-eu-vision-news-508255)

http://ec.europa.eu/environment/resource_efficiency/about/roadmap/index_en.htm - Last accessed 1 February 2014

http://www.letsrecycle.com

[1] 29 June 2007: Mixed blessings for the future of glass recycling

[2] 19 May 2009: MWDA signs £640 million deal with Veolia

[3] 15 January 2010: Anaerobic digestion – let's not waste the opportunity

[4] 31 October 2011: Minister warns recycling market needs to improve

[5] 26 January 2012: AD industry 'under threat' from End of Waste

[6] 2 April 2012: Shanks and SSE sign £750m Yorkshire PFI deal

[7] 6 June 2012: Veolia opens £20 million Merseyside MRF

[8] 19 June 2012: Wakefield PFI deal to complete in September

[9] 21 June 2012: Gate fees are key part of AD financial model

[10] 25 June 2012: Comingled recycling allowed, says Commission

[11] 9 July 2012: PAS110 awarded to Cassington AD plant

[12] 16 July 2012: China clamps down on imports of poor quality paper

[13] 19 July 2012: Market for waste paper recycling under pressure

[14] 23 July 2012: Viridor signs £250 million Glasgow contract

[15] 25 July 2012: ROCs banding review 'a disaster' for AD industry

[16] 27 July 2012: Lord Taylor interview exclusive

[17] 1 August 2012: Welsh Councils appeal for clarity over comingling

[18] 15 August 2012: Number of plants to achieve PAS 110 grows

[19] 28 January 2013: Odour main cause of biowaste permit breaches

[20] 11 March 2013: Judicial Review ruling: analysis

[21] 5 March 2014: Progress towards circular economy 'disappointing'

[22] 31 July 2014: PAS 110 Anaerobic Digestion specification updated

http://www.nispnetwork.com/ - Last accessed 8 January, 2014.

http://www.waste-management-world.com/index.html

Recycling: rarely so critical - http://www.waste-management-world.com/articles/print/volume-12/issue-5/features/recycling-rarely-so-critical.html

http://www.wrap.org.uk/content/digestate-use-landscape-and-regeneration - Last accessed 11 April, 2013

Reports and policy documents

British Standards Institute (2010). *PAS 110: 2010. Specification for whole digestate, separated liquor and separated fibre derived from anaerobic digestion of source-segregated biodegradable materials*, Retrieved from: http://www.biofertilser.org.uk/pdf/PAS-110.pdf

DEFRA (2012). *Anaerobic Digestion Strategy and Action Plan – Annual Report 2011/12*, Retrieved from: https://www.gov.uk/government/publications/anaerobic-digestion

DEFRA (2013a). *Quality Action Plan: proposals to promote high quality recycling of dry recyclables,* Retrieved from: https://www.gov.uk/government/uploads/system/uploads/attachment

DEFRA (2013b). *AD Strategy and Action Plan, Annual Report 2012 – 13*. Retrieved from: https://www..gov.uk/government/publications/anaerobic-digestion

Ellen MacArthur Foundation (2012). *Report Volume 1: Towards the circular economy: economic and business rationale for an accelerated transition,* Retrieved from: http://www.ellenmacarthurfoundation.org/business/reports/ce2012

Ellen MacArthur Foundation (2013). *Report Volume 2: Towards the circular economy: opportunities for consumer goods*. Retrieved from http://www.ellenmacarthurfoundation.org/business/reports/ce2013

Ellen MacArthur Foundation (2014) Report Volume 3: Towards the circular economy: accelerating the scale-up across global supply chains. Retrieved from http://www.ellenmacarthurfoundation.org/business/reports/ce2014#

Environment Agency/WRAP (2010). *Quality Protocol: anaerobic digestate*, Retrieved from: https://www.gov.uk/government/publications/quality-protocol-anaerobic-digestate

Environment Agency (2014). *Separate collection of recyclables – Briefing Note 27 June 2014*, Retrieved from: www.biffa.co.uk/assets/.../EA-briefing-note-seperate-collections-2014.pdf

European Commission (2005). *Taking sustainable use of resources forward: a thematic strategy on the prevention and recycling of waste (COM 666)*, Retrieved from: http://europa.eu/legislation_summaries/environment/sustainable_development/l28168_en.htm

European Commission (2011a). *Roadmap to a resource efficient Europe (COM 2011, 571),* Retrieved from: http://ec.europa.eu/environment/resource_efficiency/about/roadmap/index_en.htm

European Commission (2011b). *Commission Staff Working Paper: analysis associated with the Roadmap to a Resource Efficient Europe, Part II,* Retrieved from: http://ec.europa.eu/environment/resource_efficiency/about/roadmap/index_en.htm

European Commission (2014). *The Circular Economy: connecting, creating and conserving value*, Retrieved from: http://ec.europa.eu/environment/circular-economy/

European Environment Agency (2009). *Waste without borders: transboundary shipments of waste*, Retrieved from: http://www.eea.europa.eu/publications/waste-without-borders-in-the-eu-transboundary-shipments-of-waste

European Environment Agency (2011). *Earnings, jobs and innovation: the role of recycling in a green economy,* Retrieved from http://www.eea.europa.eu/publications/earnings-jobs-and-innovation-the

WRAP (2006a). *MRF Costing Model,* Retrieved from: www.wrap.org.uk/sites/files/wrap/MRF_v6_19Dec06_LC.pdf

WRAP (2006b). *Materials Recovery Facilities. An Introduction to MRFs and Comparison of Sorting Operations Based on Site Visits to Selected Facilities in England, Europe and North America,* Retrieved from: www.wrap.org.uk/sites/files/wrap/MRF_v6_19Dec06_LC.pdf

WRAP (2008a). *Kerbside Recycling: Indicative Costs and Performance,* Retrieved from: www.wrap.org.uk/node/3594

WRAP (2009). *Final Report: MRF Output Material Quality Thresholds: a Report on Materials Quality Standards, Quality Measurement Techniques and the Implementation by UK MRFs and Materials Reprocessors*, Retrieved from: www.wrap.org.uk/.../wrap/MRF%20Output%20Material%20Quality%20*...*

WRAP (2010). *Analysis of Kerbside Dry Recycling Performance in the UK 2008/9*, Retrieved from: www.wrapni.org.uk/.../wrap/EVA143-000%20Kerbside%20Dry%20Ben...

WRAP (2011a). *Anaerobic Digestion Infrastructure in the UK: September 2011,* Retrieved from: http://www.organics-recycling.org.uk/page.php?article=2201&name=Anaerobic+Digestion+Infrastructure+in+the+UK

WRAP (2011b). *Climate Change Drives High Profile Farmer-focused Digestate and Compost Research Project*, Retrieved from: www.wrap.org.uk/.../wrap/Bulletin%201%20-%20project%20overview_...

WRAP (2011c). *Beat Rising Cost of Fertiliser and Extreme Weather by Using Digestate and Compost*, Retrieved from: www.wrap.org.uk/.../wrap/Bulletin%202%20-%20agronomic%20benefit...

WRAP (2011d). *New Markets for Digestate from Anaerobic Digestion,* Retrieved from: www.wrap.org.uk/.../wrap/New_Markets_for_AD_WRAP_format_Final...

WRAP (2013). *Market expectations and requirements for digestate*, Retrieved from: www.wrap.org.uk/.../market-expectations-and-requirements-digestate

WRAP/Environment Agency (2014). *Quality protocol for Anaerobic Digestate: end of waste criteria for the production and use of quality outputs from anaerobic digestion of source-segregated biodegradable waste*, Retrieved from: https://www.gov.uk/government/publications/quality-protocol-anaerobic-digestate

References

Alexander, C. & Reno, J. (Eds.) (2012). *Economies of recycling: the global transformation of materials, values and social relations*. London: Zed Books.

Boulding, K. (1966). The economics of the coming spaceship. In H. Jarett (Ed.), *Environmental Quality in a Growing Economy* (pp. 3 – 14). Baltimore: John Hopkins University Press.

Bras, B & McIntosh, M. (1999). Product, process and organisational design for re-manufacture – an overview of research. *Robotics and Computer- Integrated Manufacturing* 15 (3): 167 – 78. doi: 10.1016/S0736-5845(99)00021-6

Brings Jacobsen, N. (2006). Industrial symbiosis in Kalundborg, Denmark: a quantitative assessment of economic and environmental aspects. *Journal of Industrial Ecology* 10 (1 – 2), 239 – 58. doi: 10.1162/108819806775545411

Carson, R. (1962). *The Silent Spring*. Cambridge MA: Riverside.

Chen, C., Wang, Y., Ou, H., He, Y. & Tang, X. (2014). A review on remanufacture of dies and remoulds. *Journal of Cleaner Production* 64: 13 – 23. doi: 10.1016/j.jclepro.2013.09.014

Chertow, M. & Ehrenfeld, J. (2012). Organising self-organising systems: toward a theory of industrial symbiosis. *Journal of Industrial Ecology* 16 (1), 13 – 27. doi: 10.1111/j.1530-9290.2011.00450.x

Chertow, M. (2007). 'Uncovering' industrial symbiosis. *Journal of Industrial Ecology* 11 (1): 11 – 30. doi: 10.1162/jiec.2007.1110

Clapp, J. (2001). *Toxic Exports: the Transfer of Hazardous Wastes from Rich to Poor Countries*. Indiana: Cornell University Press.

Cooper, T. (2005). Slower consumption: reflections on product life spans and the 'throwaway society'. *Journal of Industrial Ecology* 9 (1-2): 51 – 67. doi: 10.1162/1088198054084671

Cooper, T. (Ed.) (2010). *Longer lasting products: alternatives to the throwaway society*. London: Gower.

Corvellec, H. & Hultman, J.(2012). From "less landfilling" to "wasting less": Societal narratives, socio-materiality, and organizations. *Journal of Organizational Change Management* 25 (2):297-314. doi:10.1108/09534811211213964

Costanza, R., D'Arge, R., de Groot, R., Arber, S., Grasso, M., Hannon, B., Limburg, K., Naeem S., O'Neill, R., Paruelo, J., Raskin, R., Sutton, P. & van den Belt, M., (1997). The value of the world's ecosystem services and natural capital, *Nature* 387: 253 – 60. doi: 10.1038/387253a0

Crang, M., Hughes, A., Gregson, N., Norris, L. & Ahamed, F. (2013). Rethinking governance and value in commodity chains through global recycling networks. *Transactions Institute of British Geographers* 38 (1), 12 – 24. doi: 10.1111/j.1475-5661.2012.00515.x

Deschenes, P. & Chertow, M. (2004). An island approach to industrial ecology: toward sustainability in the island context. *Journal of Environmental Planning and Management* 47(2): 201 – 17. doi: 10.1080/0964056042000209102

Deutz, P. & Lyons, D. (2008). Editorial: industrial symbiosis – an environmental perspective on regional development. *Regional Studies* 42 (10): 1295 – 98. doi:10.1080/00343400802382190

Ehrenfeld, J. & Gertler, N. (1997). Industrial ecology in practice: the evolution of interdependence at Kalundborg. *Journal of Industrial Ecology* 1 (1): 67 – 79. doi: 10.1162/jiec.1997.1.1.67

Frosch, R. & Gallopoulos, N. (1989). Strategies for manufacturing. *Scientific American* 261: 94 – 102. [no doi]

Geng, Y. & Côte, R. (2002). Scavengers and decomposers in an eco-industrial park. *International Journal of Sustainable Development and World Ecology* 9 (4): 333 – 40. [no doi]

Geng, Y., Zhu, Q., Doberstein, B. & Fujita, T. (2009). Implementing China's circular economy concept at the regional level: a review of progress in Dalian, China. *Waste Management* 29 (2), 996 – 1002. doi: 10.1016/j.wasman.2008.06.036

Georgescu-Roegen, N. (1971). *The Entropy Law and the Economic Process*. Cambridge MA: Harvard University Press.

Gibbs, D. & Deutz, P. (2005). Implementing industrial ecology? Planning for eco-industrial parks in the USA. *Geoforum* 36 (4): 452 – 64. doi: 10.1016/j.geoforum.2004.07.009

Gille, Z. (2010). Actor networks, modes of production, and waste regimes: reassembling the macro-social. *Environment and Planning A* 42 (5):1049-1064. doi:10.1068/a42122

Gregson, N., Crang, M., Ahamed, F., Akter, N., Ferdous, R., Foisal ,S. & Hudson, R . (2012). Territorial agglomeration and industrial symbiosis: Sitakunda-Bhatiary, Bangladesh, as a secondary processing complex. *Economic Geography* 88 (1): 37 – 58. doi: 10.1111/j.1944-8287.2011.01138.x

Gregson, N., Watkins, H. & Calestani, M. (2013). Political markets: recycling, economization and marketization. *Economy and Society* 42 (1): 1 – 25. doi: 10.1080/03085147.2012.661625

Guitimi, R & Guadette, K. (2003). Remanufacturing: the next great opportunity for boosting US productivity. *Business Horizons* 46(6): 41 – 48. doi: 10.1016/S0007-6813(03)00087-9

Hatcher, G., Imojah, W. & Windmill, J. (2011). Design for remanufacture: a literature review and future research needs. *Journal of Cleaner Production* 19 (17 – 18): 2004 – 14. doi: 10.1016/j.jclepro.2011.06.019

Hewes, H. & Lyons, D. (2008). The humanistic side of eco-industrial parks: champions and the role of trust. *Regional Studies* 42 (10): 1329 – 42. doi: 10.1080/00343400701654079

Hultman, J. & Corvellec, H. (2012). The European Waste Hierarchy: from the sociomateriality of waste to the politics of consumption. *Environment and Planning* A 44 (10): 2413 – 47. doi:10.1068/a44668

Imojah, W. (2010). The application of remanufacturing in sustainable manufacture. *Waste and Resource Management* 163 (4): 157 – 63. doi: 10.1680/warm.2010.163.4.157

Imojah, W., McMahon, C., Hammond, G. & Newman, G. (2007). Development of robust design-for-remanufacturing guidelines to further the aims of sustainable development. *Robotics and Computer-Integrated Manufacturing* 23 (6): 712 – 19. doi: 10.1016/j.rcim.2007.02.017

Jacques, M. (2012, Second Edition). *When China Rules the World*, London: Penguin.

Jensen, P. D., Basson, L., Hellawell, E., Bailey, M. & Leach, M. (2011). Quantifying 'geographic proximity': experiences from the United Kingdom's National Industrial Symbiosis Programme. *Resources, Conservation and Recycling* 55(7): 703-712. doi: 10.1016/j.resconrec.2011.02.003

Korhonen, J. (2002). Two paths to industrial ecology: applying the product-based and geographical approaches. *Journal of Environmental Planning and Management* 45 (1): 39 – 57. doi: 10.1080/09640560120100187

Korhonen, J. (2001). Regional industrial ecology: examples from regional economic systems of forest industry and energy supply in Finland. *Journal of Environmental Management* 63 (4): 367 – 75. doi: 10.1006/jema.2001.0477

Laybourn, P. & Lombardi, R. (2012). Industrial symbiosis in European policy: overview of recent progress. *Journal of Industrial Ecology* 16 (1), 11 – 12. doi: 10.1111/j.1530-9290.2011.00451.x

Lombardi, R. & Laybourn, P. (2012). Redefining industrial symbiosis: crossing academic-practitioner boundaries. *Journal of Industrial Ecology* 16 (1), 28 – 37. doi: 10.1111/j.1530-9290.2011.00444.x

Matthews, J. & Tan, H. (2011). Progress toward a circular economy in China: the drivers (and inhibitors) of eco-industrial initiative. *Journal of Industrial Ecology* 15 (3), 435 – 57. doi: 10.1111/j.1530 doi:9290.2011.00332.x

Minter, A. (2013). *Junkyard Planet: travels in the billion dollar trash trade*. London: Bloomsbury.

Minx, J., Wiedmann, T., Wood R., Peters, G.P., Lenzen, M., Owen, A., Scott, K., Barrett, J., Hubacek, K., Baiocchi, G., Paul, A., Dawkins, E., Briggs, J., Guan, D., Suh, S. & Ackerman, F. (2009). Input-output analysis and carbon footprinting: an overview of applications. *Economic Systems Research* 21 (3): 187-216. doi: 10.1080/09535310903541298

Mirata, M. & Emtairah, T. (2005). Industrial symbiosis networks and the contribution of environmental innovation: the case of the Landskrona industrial symbiosis programme. *Journal of Cleaner Production* 13 (10-11): 993 – 1002. doi: 10.1016/j.jclepro.2004.12.010

Pearce, D. (2002). An intellectual history of environmental economics. *Annual Review of Energy and Environment* 27, 57 – 81. doi: 10.1146/annurev.energy.27.122001.083429

Reno, J. (2011). Managing the experience of evidence: England's experimental waste technologies and their immodest witnesses. *Science Technology and Human Values* 36 (6), 842 – 63. doi: 10.1177/0162243910376158

Rivoli, P. (2005). *Travels of a T-shirt in the Global Economy*. London: Wiley.

Russell, S., Morley, N., Tipper, M., Drivas, I. & Ward, G. (2010). Principles of the recovery and reuse of corporate clothing. *Waste and Resource Management* 163 (4): 165 – 72. doi: 10.1680/warm.2010.163.4.165

Shi, H., Chertow, M. & Song, Y. (2010). Developing country experience with eco-industrial parks: a case study of the Tianjin Economic Technological Development Area in China. *Journal of Cleaner Production* 18 (3), 191 – 99. doi: 10.1016/j.jclepro.2009.10.002

Spencer, D. (2005). The high speed identification and sorting of non-ferrous scrap. *Journal of Minerals, Metals and Materials Society* 57 (4), 46 – 51. doi:10.1007/s11837-005-0081-6

Su, B., Heshmati, A., Geng, Y.,&and Yu, X.(2013). A review of the circular economy in China: moving from rhetoric to implementation. *Journal of Cleaner Production* 42:215-227. doi: 10.1016/j.jclepro.2012.11.020

Van Beers, D., Corder, G,, Bossilkov, A. & van Berkel, R. (2007). Industrial symbiosis in the Australian mining industry: the cases of Kwinana and Gladstone. *Journal of Industrial Ecology* 11 (1): 55 – 72. doi: 10.1162/jiec.2007.1161

World Economic Forum, with the Ellen MacArthur Foundation and McKinsey & Company (2014). *Towards the Circular Economy: Accelerating the scale-up across global supply chains*. Geneva: Switzerland.

Xu, H., Jia, X-P., Shi, L. & Zhang, T-Z. (2008). Societal metabolism in Northeast China: case study of Liaoning Province. *Resources, Conservation and Recycling* 52 (8/9), 1082 – 86. doi: 10.1016/j.resconrec.2008.04.007

Yuan, Z-W. & Shi, L. (2009). Improving enterprise competitive advantage with industrial symbiosis: case study of a smeltery in China. *Journal of Cleaner Production* 17 (14), 1295 – 1302. doi: 10.1016/j.jclepro.2009.03.016

Zhu, Q., Lowe, E., Wei, Y. & Barnes, D. (2007). Industrial symbiosis in China: a case study of the Guitang group. *Journal of Industrial Ecology* 11 (1), 31 – 42. doi: 10.1162/jiec.2007.929