CHAPTER 15

Governing resource flows in a circular economy: rerouting materials in an established policy landscape

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Abstract

The development of a Circular Economy, whereby resources are kept in circulation for the extraction of maximum value, has captured extensive policy and academic attention. The circularisation of material flows is likely to prove a task for a generation: the challenges are only beginning to be explored and the wider implications seldom considered. However, circular economy-relevant policies are not new; EU policy makers have already made adjustments to remove inadvertent barriers to resource recovery. This chapter considers how resource recovery in the UK steel industry has been influenced by environmental policies, particularly the 2008 Waste Framework Directive's approach to enabling residues to lose, or avoid altogether, identification as waste. In this context we also consider the response to a proposed novel technology to recover vanadium, a high value component, from steel slag. Extensive analysis of policy-related documents at EU and UK level was carried out along with semi-structured stakeholder interviews (including producers of steel slag, industry bodies and regulators). Findings suggest that implementing reforms to earlier regulations necessitates changes to practices engendered by previous institutional arrangements. There is a risk of adding to layers of complexity rather than removing them. Circular economy theory and policy needs to be aware of policy legacy.

Key words:

Circular Economy, Industrial Symbiosis, Waste Framework Directive, policy, steel slag, vanadium

15.1 Introduction

In this chapter we examine the governance of resource recovery in the context of the circular economy. The circular economy (CE) is an economic system within which the maximum use is extracted from resources and minimum waste is generated. Definitions abound which emphasise various means to progress towards this ideal (including recycling, re-use, dematerialisation etc.) and/or the assumed benefits (primarily economic, occasionally including environmental issues and more rarely touching on social aspects of sustainability).[1] The concept is therefore more an umbrella term for an array of activities and aspirations rather than a specific concept.[2] Using CE as an umbrella term may indeed be a necessity as the means by which it might be implemented are tremendously varied. The repercussions of instituting reforms will also reflect the means selected for, and the effectiveness of, implementation, which will be in turn be related to the geographic context within which it occurs.

Many of the ideas for resource recovery and environmental design within CE build on earlier initiatives such as industrial ecology,[3,4] a term used for approaches to resource efficiency which draws parallels with natural ecosystems and notably looks beyond the scale of individual enterprises.[5] The term 'circular economy' is a reference to the ecological concept of an ecosystem, wherein resources used by each part of the system are being constantly broken down, reformed, and reused by different component parts, whilst retained within the ecosystem. Early industrial ecologists proposed that the same approach to materials and energy could be applied to an industrial ecosystem.[6] Although the CE has quickly become a more ambitious concept than industrial ecology, with potentially far reaching implications for business models and social organisation, most academic work on the circular economy focuses on the earlier resource-centred and normative notions.[1] In part academic enthusiasm for the CE responds to a strong drive from policy makers firstly in China, and subsequently by the EU[7,8] . The polic approach appears to be embedded in the UK[9], but the impact of the UK's departure from the EU on UK CE policy remains to be seen. Policies are motivated by presumed benefits for resource security, carbon emissions, and economic competitiveness with a further assumption of consequent employment opportunities.[8] The CE is also promoted with enthusiasm by industry-backed bodies such as the Ellen MacArthur Foundation in the UK (see Chapter 1).[10] Environmental groups and some industry bodies are actively lobbying for the development of policies which will encourage the development of a CE.[11] A basis for comparison of practices between different locations is provided by studies of national-scale institutional arrangements for promoting the CE.[12,13, 14] Additional focussed case studies are needed to provide an understanding of how institutional arrangements contribute to circumstances in specific contexts, especially as new approaches emerge to both resource recovery and its regulation.

This chapter contributes a detailed analysis of how a particular example of industrial residue recovery has been shaped by environmental policies, which comprise the building blocks for the EU's CE policy. The case study relates to the use of residues from the steel industry, and to research attempting to develop a new recovery route for extracting vanadium, a metal with an increasing market through its use in renewables technologies.[15] We examine how CE-related regulations have impacted on resource recovery, especially in response to efforts in the revised Waste Framework Directive (WFD: 2008)[16] to remove barriers to recovery that come from materials being legally labelled as waste. The theoretical and policy significance of this study is re-emphasised by the latest revision to the WFD (2018/851) which has been published since the completion of the research on which this chapter draws. The 2018 WFD makes explicit mention of the circular economy and industrial symbiosis, increasing the significance of the issues addressed here. However, while the 2018 revisions clarify some procedures relevant to CE, the criteria for defining by-products and end of waste vary little from the 2008 version. This further emphasises the premise of the present chapter, i.e., that new regulations are built on to earlier ones, and that the consequent issues are important in theorising the CE.

The following sections review literature around policy in the CE and IS, focusing on the definition of waste;

review the methodology and methods of the study; present the findings with respect to the influence of environmental policies on slag management; stakeholder responses to the Waste Framework Directive, and related perspectives on vanadium recovery from steel slag, before offering some conclusions.

15.2 Literature review

15.2.1 Governing a circular economy

From the introduction of the idea of a waste hierarchy in the original EU Waste Framework Directive (1975)[17] (in order of preference reduce, re-use, recycle, recovery of materials, energy recovery), numerous environmental policies in the EU can be seen as promoting elements of the CE. These include the Producer Responsibility Directives and landfill reduction targets.[12] Notwithstanding the common backdrop of EU regulation, member states have been variable in implementing these and achieving targets, for example in terms of recovery of domestic waste.[4, 12] For example, the UK has made significant strides over the last decade at implementing EU policies to divert waste from landfill, but largely by relying on strategies such as recycling and energy from waste.[18] Other options such as eco-design, re-use, remanufacturing, which are higher up the order of priorities according to the waste hierarchy, but which are more difficult for policy makers to directly influence, have yet to receive comparable regulatory, industry or individual effort either in the UK or elsewhere in the EU. A new departure in the EU and UK policy strategy specifically addressing the CE, is a reference to the well-established industrial ecology concept of industrial symbiosis as a means to use resources more effectively in industry.[9, 19]

Industrial symbiosis refers to the transfer of residue from one entity to use as input to another.[20, 21] The idea is that the total use of resources and production of waste by the companies involved is decreased, to the mutual economic benefit of the parties involved. Discussions about the efficacy of policy for IS development have been ongoing,[5, 22, 23, 24] though a distinction needs to be made between underlying policies relating to the context of resource recovery, prominent in the EU[25, 26] and policies attempting to foster IS between firms which have achieved some success in South Korea[27] and China.[24,28] The UK uniquely, but temporarily (2005-2012), had a national policy for directly facilitating industrial symbiosis (NISP: National Industrial Symbiosis Programme) by building connections between companies.[29] NISP's premise, that collecting information on companies can be a step to building links between them, continues to be influential.[30] One such study, identifying potential symbioses in the Taranto region of Italy, found that only some of the potential symbioses were present in practice.[30] This was partly through a lack of awareness of possibilities, but also reflected the companies' limited interest in what is seen as a distraction from their primary business activity. That suggests a role for policy in incentivising, if not requiring, resource efficiency measures if the CE is to take a significant step forward.

There is, a long tradition in industry, and in some strands of industrial ecology literature, contending that environmental regulations are unhelpful at promoting environmentally beneficial practices.[31, 32] Early industrial ecology work from the USA posited voluntary environmental practices as an alternative to governmental policy,[33] at a time when industry was in a process of adjustment to early environmental regulations. However, industrial ecology, and especially industrial symbiosis, initiatives were taken up more in the public than the private sector[22]. This lack of success in generating IS in the US despite numerous attempts may indicate the necessity of supportive underlying institutional contexts. A more supportive institutional environment exists in the EU compared to the US, where when IS-supportive regulation occurs it is at the state rather than federal level.[13] Although concerns expressed by industry relating to regulation may not come as a surprise,[33] they are not unfounded. To design a policy which will accomplish its aim without unintended consequences is a challenge. Policies designed to promote technological innovation in industry by enforcing ambitious standards, can in practice merely achieve the enforcement of minimum standards.[34] Other regulations have not always achieved their broader objectives because organisations have chosen to comply by means of organisational changes rather than technological innovation.[35] Achieving something meaningfully identifiable as a CE will require a higher level of compliance, if not widespread engagement beyond regulatory requirements. As discussed below, by the early 2000s, EU policy makers were beginning to re-consider the body of environmental regulations and its implementation with a view to improving environmental performance.

15.2.2 Defining waste, by-products, and end-of-waste in the steel industry

Despite some considerable success in environmental policies such as increasing recycling rates in the EU, by 2002 policy makers observed with concern that waste, and other environmental regulations, experienced difficulties when implemented[36]. Environmental problems changed, and in some cases lessened, but were not being resolved. In 2002 a decision statement was issued by the EU resulting in a Thematic Waste Strategy on the prevention and recycling of waste (2005).[37] This identified increasing total volumes of waste in the EU and considerable confusion over the definition of waste, specifically in relation to when waste ceases to be a waste. Procedures for achieving a non-waste designation for materials were complex, time consuming and expensive for companies; individual court cases to obtain non-waste designation did not provide sufficient clarity to prevent other companies to going to court.[38] The Strategy also noted confusion between different regulations and proposed what it termed a 'simplification and modernisation' (page 6).[37] Processes set in motion by the Strategy culminated in the 2008 Waste Framework Directive, which provides formal definitions of by-products and end-of-waste.

Waste regulations are trying to shape behaviour around substances that are effectively defined as unwanted.[39] This creates a delicate balance between strongly incentivised recovery on the one hand, and on the other hand risking significant numbers of waste holders simply abandoning the substances outside of the law. Waste regulations were designed with the primary intention of protecting the environment from inappropriate disposal, before the more recent emphasis on recovery.[40, 41] The various safeguards and licencing requirements put in place (1975 Waste Framework Directive: WFD) are considered a costly inconvenience for substances for which there is a ready use.[38] Prior to the 2008 WFD, complicated, expensive and uncertain procedures were involved in establishing a substance as a by-product or determining when it had ceased to be waste.[38] The terms 'waste' and 'by-product' have tended to be treated in the industrial symbiosis literature either as synonyms or as though the meanings need no explanation.[21] This risks some ambiguity given the terms reflect policy and practice, and may very likely have different implications in different contexts. In the EU, though, the WFD provides legal definitions with repercussions for how materials can be handled and used. The WFD acknowledges that a substance may be generated as a consequence of a production process with no direct use within that process, while fulfilling a recognised purpose in another context and therefore potentially having commercial value. Such a substance, termed a by-product, is expressly not waste and is exempt therefore from waste regulations. The conditions involved in determining the designation of a residue as waste or by-product are shown in Figure 15.1. The designation of a specific item at a given time is not solely a matter of the characteristics of that item. It is contingent on context-dependent circumstances, such as the market for the item in the location where it is available. If a substance has a clearly defined route to re-use it might qualify as a by-product, but would become waste if no specific buyer could be found at the time.[41]

[Figure 15.1 near here]

A further development of the 2008 WFD was to institute the concept of end-of-waste. A basic premise of recycling is that a substance (or object) that is unwanted at a certain point (in time, place or stage in a production process) may undergo processing to render it economically useful. It could therefore be beneficial in terms of the marketability of a product to be able to remove the label (and potentially stigma) of being derived from something unwanted and in practical terms remove the product from the remit of waste regulations. The conditions for achieving end-of-waste status are similar to those for official designation as a by-product (Figure 15.1). There is a European-scale process for establishing how the end-of –waste criteria should be applied for given materials. However, member states can set their own standards for materials not yet covered by the EC,[42] providing that a process is followed that is compatible with those set by the Joint Research Centre of the EC.[43]

The UK instituted a quality protocol procedure to consider a range of materials in terms of end-of-waste. The devising of quality protocols is the work of a Technology Advisory Group comprising representatives of the Environment Agency[44] (with responsibilities including environmental protection), WRAP (the Waste Resources Action Programme,[45] with responsibilities including increasing use of recovered material), and industry bodies relevant to the material in question.[41] In accordance with the EU guidelines, the definition of a quality protocol and quality standards for reused materials involves an environmental risk assessment to ensure the implications of a recovery process are not more detrimental than alternatives i.e., removing barriers to recovery of certain materials should be on the grounds of environmental benefit, and not result in a shift of environmental impact.

Comparing the approaches to WFD implementation in Finland and the UK, Pajunen and co authors[41] observed advantages in the UK system, which aims to produce market confidence in the end products and which also included free-to-user support from NISP. Salmi and co authors[38] also thought the UK initiative to identify initial waste streams for end-of-waste proceduers was promising. A similar process could help to reduce at least some of the uncertainties faced by potential IS partners in the steel industry around the Gulf of Bothnia (Finland and Sweden). At the time these groups of authors were writing, however, the UK process was at a very early stage. Their comments are therefore based more on what was intended in UK policy than what would subsequently be achieved. Indeed, as the interest in the overarching concept of the CE appeared on the horizon, the UK's most explicit policy for supporting IS (i.e., NISP) ceased to be publically funded.[46]

In the following sections of this chapter the industry and regulator response to the quality protocol process for steel slag in the UK are examined, in the context of previous environmental regulations and considering the implications for a proposed technological development.

15.3 Methods

Employing a critical realist approach, our intention is to increase understanding of the causal factors which contribute to IS, and those factors which limit IS in the specific context of our case study site.[47] By a contextualised examination of events, and the opinions and motivations surrounding them, we can attempt to shed light on the underlying influences.[48] This chapter uses a mixture of primary and secondary data to examine stakeholder responses to policy and policy-related technical research initiatives to promote resource recovery. The technical research initiative which accompanied this empirical work relates to recovery of a (relatively) high value metal, vanadium, from a (relatively) low value bulk residue, steel slag. The technical aspects of the project are considered in chapter 7 in this volume.[49] The case study site is a large integrated steel works in northern England with production up to 1.5 million tonnes of steel per year. The 800 hectares site has been in operation since the 1860s, producing steel since the 1890s. Further information is available in a previous publication by the authors.[50]

Documentary analysis comprised EU and UK policies governing environmental aspects of steel production, including the storage of slag; company and news websites for recent and more distant historical information; governmental and industry guidance; company and trade body perspectives on the recovery of iron and steel slag and their definition as waste, by-product or end-of-waste. 18 semi-structured interviews were conducted during 2013 and from October 2015 to June 2017 with a total of 21 interviewees (number of individuals in brackets) (producer (two); regulators (Environment Agency, EA; seven representing different levels and specialisms within the organisation), policy maker (Department of Environment, Food and Rural Affairs: DEFRA (two); EU (two)) and industry body (one) and consultants specialising in industrial symbiosis and/or waste (four); scientist (one). Appropriate risk and ethics protocols were followed. Interviews, most face-to-face, others by telephone, were transcribed and subsequently analysed using NVivo software. Issues covered at the interviews included challenges and opportunities involved in steel slag management, and policy influences and relationships between stakeholders in terms of the potential for recovery of vanadium from steel slag.

15.4 Findings

Here we review the environmental policies influencing the management of iron and steel slag in the steel industry, considering their relationship to the circular economy. We assess how regulations have helped to bring about the present situation regarding recovery of resources, the response of industry and regulators to the formalisation of definitions in the WFD and responses to the prospect of vanadium recovery.

15.4.1 Influence of environmental policies on slag management

A resource-intensive and historically polluting industry, steel production is influenced by a wide range of regulations. Key UK environmental regulations relevant to the CE and their relationship to it are shown in Table 15. 1. These policies can be seen as seeking to provide a context favourable to IS in various ways that stop short of directly mandating IS – indeed of these policies the Environmental Permit[51] is the most significant mandatory regulation. This permit, which implements the IPPC Directive (2008)[52] amongst others, constrains the operating conditions including slag management and is a key priority on the company's agenda.[50] Other policies, including climate change and waste reduction, are in the form of financial instruments, which at least theoretically allow a company to choose its level of engagement according to the relative costs of paying for relevant improvements to performance and the financial penalties associated with not improving. The 'lean production' policies (a key strategy in WRAP's vision for the CE[53]) may not relate directly to the steel industry, but would reduce demand for its product if other manufacturers adopted them. The efficiency measures relate primarily to energy use in steel production (a major consideration for steel producers, and argued by government analysts to be part of the context of current challenges in competitiveness).[54] Such challenges have helped bring about changes in ownership of some steel works in the UK during the lifetime of this project (2013-2018). The move to reduce carbon emissions has also created a driver for increasing use of renewable energy sources, which in turn has created a new market for vanadium and other metals.[15] Thus a circular economy approach may be promoted as part of the solution to a potential resource security issue, which has been brought about by a regulation that is not itself conceived as being circular. Whilst CE approaches would favour energy efficient solutions, the drive to energy efficiency is climate change-related and pre-dates the current policy drive for CE.

[Table 15.1 near here]

The UK landfill tax, which was introduced in 1996 and has significantly increased in the amount levied since, has been influential in changing the company's approach to managing steel slag. The two major residues produced at the site are iron and steel slag. Iron slag has a long history of use as a substitute for aggregates (e.g., in road construction; see Chapter 6). Steel slag can be used for the same purpose, but not directly (as discussed below this difference is critical to the distinction between the two now institutionalised by the WFD). Historically, steel slag has been stockpiled (essentially a polite term for landfilled), and drawn on only as and when there was more demand for secondary aggregates than could be met by iron slag supplies. There is, therefore, an extended, but intermittent, record of steel slag recovery (according to the environmental manager for the site).

Having an onsite quarry space to fill, landfill of steel slag and other production residues was historically a convenient and very cheap option for the company. This changed with the Landfill Directive which meant that any hazardous wastes and liquids could no longer be disposed of in this way. The Directive also requires active management and monitoring of the gases/liquids produced within the landfill. Furthermore, the landfill tax sent a signal, to which the company responded, that even relatively benign materials (i.e., non-hazardous and not generating carbon emissions) could in the future only be landfilled at a substantial cost. The tax is payable even though the company is putting its own residues in its own onsite landfill. In some respects the costs of the tax were less than expected, as inert material (such as secondary aggregates) can be argued to be needed for the management of the landfill and therefore only taxable at a very low rate. Nonetheless, the company had set itself a target of not landfilling iron-bearing residues and to this end entered into a long term contract with an aggregate company. Under this arrangement the slag producer benefits from a tax reduction and both companies benefit from any sale to an end user. In practice, the steel slag is still stockpiled until/unless used on facilities owned by the producer, but operated by the aggregate company. The environmental liabilities for the site are shared by both companies, with primary responsibility for environmental monitoring and reporting resting with the producer.

Fluctuations in the market for aggregates has been the primary determinant in the proportions of slag (especially steel) stockpiled on site. The aggregate tax (from 2002 onwards) attempts to reduce the environmental harm from quarrying activity, by increasing the cost of virgin materials. The impact of that is hard to measure, as the landfill tax is considered to have had significant effect by generating a large supply of cheap secondary aggregates (e.g., from construction and demolition waste).[55] Thus these two environmental taxes appear to be mutually re-enforcing. Of note, though, is the overarching presence of the regulations governing production. The principle of best available techniques (BAT) specified in the IPPC directive[56] covers movement and management of slag as well as iron and steel production. Encapsulated in the Environmental Permitting regulations,[51] issues of particular note for steel producers are dust and leachate generation from the slag – either or both of which might be increased in quantity or changed in composition by processes put in place to capture vanadium.[50]

15.4.2 Removing the barriers to recovery?

Discussions around the WFD in the steel industry were initiated in a context where there were already established practices for recovery of the major residues, albeit the end market is more assured for iron than steel slag. As a major waste stream (21.8 million tonnes in the EU in 2010)[57] steel slag was subject to early discussions to formulate an end-of-waste process. The steel industry campaigned over a number of years to establish both iron and steel slags as by-products,[57] which could therefore be managed, stored and transported without consideration of waste management regulations. The terminology of the 2008 WFD put the industry in the position where it had to concede the slags might constitute waste at some point in order to be able to argue for end-of-waste criteria. However, EUROSLAG, a trade association for producers and processors of metallurgical slags, has not changed its position that steel slag should be considered a by-product.[58]

There are important differences between iron and steel slags, summarised in Table 15.2, which are critical to how they are viewed by industry, the regulator and their suitability for further use. Iron slag can be air cooled, but at the case study site is mostly water cooled, or granulated, in keeping with the environmentally approved process governed by the IPPC Directive.[56] Both physically and chemically stable, granulated iron slag bears a close resemblance physically to the virgin aggregate material it displaces in road construction. Other uses include cement manufacturing, ceramics and as a soil improver.[59]

As part of the WFD discussions at EU-level, iron slag was formally recognised as a by-product residue (i.e., never a waste). Indeed it is used by the European Commission as an exemplar of such a material.[60] At the time, the UK EA was considering iron slag as part of its quality protocol programme for devising end–of-waste criteria. However, the EC designation of iron slag caused the UK EA to review its own position. The EC, and industry, view was adopted by the EA following consideration of the key criteria used by the EC.[61] Nonetheless, industry bodies point to variations in practices for the status and usage of iron and steel slags across different EU countries.[57]

[Table 15.2 near here]

Central to the criteria for accepting material as a by-product is the need for no additional processing before re-use, but this is defined in a way that 'normal industrial processes' are accepted, even if strictly speaking they are not part of the production process.[42] Thus the granulation process (and crushing if employed) for iron slag are accepted as standard processes and not seen as disqualifying iron slag from being a by-product. Significant in this is that the granulation and crushing occur as part of a process continuing on from the production of the molten iron.

Not having the chemical and physical stability of iron slag, steel slag requires a weathering process before being suitable for use as an aggregate (Table 15.2). The material sits in the open for a period of six months during which time oxygen, CO_2 and water from the atmosphere infiltrate the sediment and result in the precipitation of calcium carbonate. This is actually a process of atmospheric carbon capture, albeit one that is not accounted for currently by the industry.[49] After six months, the capacity for expansion of the steel slag has been exhausted and it is ready for use as aggregate. The break in continuity caused by the need for weathering is critical to its designation as a waste residue. The UK EA considers the weathering as a waste management process and this is the reason provided why steel slag must be considered a waste residue, not a by-product.[63] Conversely, the granulation and crushing of iron slag are considered part of the production process. One difference is that the weathering causes a chemical alteration whereas the crushing is a physical process, merely changing the grain size. An EC interviewee emphasised the difference in continuity – the iron slag processing is effectively continuous to its production, whereas weathering marks a distinct break in continuity. European-level industry bodies[57] have argued that any by-product, or product might exceptionally need to be disposed of as unwanted or unusable, implying that the occasional storage of steel slag ought not to be considered problematic. The possibility of steel slag having been designated a by-product was remote, however, according to a senior EA interviewee, given the routine stockpiling of steel slag (for steel the use is intermittent, for iron slag not being used is more the exception). Thus, at the case study site the steel slag is considered a waste by the regulator at the point it passes from the producer to the (same) aggregate company as the iron slag, and remains waste.

In the UK, the steel industry and slag-using companies engaged with the process of negotiating the steel slag quality protocol to determine end-of-waste criteria, without prejudice to their view that steel slag should be considered a by-product (interpretation based on industry interviews and unpublished documents). The end-of-waste process involved research into the composition of slag and modelling of likely dispersal mechanisms to establish whether there would be a potential source-pathway-receptor links for specified substances found in steel slag. [64, 65] The assessment, though likely of interest to other national agencies undertaking a similar process, is not directly applicable elsewhere. It draws on composition data from UK-steelmakers and on climate/vegetation information relating specifically to the UK. There are national variations in protocols for modelling the flow of leachate and therefore the likely impact on a given timeframe, or even what the appropriate timeframe for consideration may be (again, based on industry interviews and unpublished document).

The quality protocol offers a route to end-of-waste, but it is not a simple path to follow and has highly specific stipulations.[66] These relate to the inputs (types of steel slag that can be used), processes of stabilisation (or alternative routes to usability), monitoring and end use. Detailed records must be kept; treatment has to follow certain routines and is subject to regular testing, in accordance with standards related to the specific end use in mind. A residue therefore has to be pre-determined for a certain end market – if a buyer does not emerge at the right time, the product would remain a waste. In fact, the material undergoing the process remains waste until it has reached its final destination – i.e., it remains technically a waste throughout the processing and during transportation. If the end-of-waste material has to be stored for an extended (though unspecified) time, whether in the hands of the processor of the potential end user, it again becomes a waste.[66].

There is an ambiguity, therefore, about the advantages and disadvantages of having the protocol. While the designation 'waste' once applied is very difficult to remove (acknowledged by an EA representative), and can be seen as placing barriers to re-use (in the view of a waste consultant), the relevance of that varies between different materials. A minerals industry representative commented that the concept of using waste is not off-putting to industry in the way that consumers might perceive waste as designating something as undesirable, or somehow tainted. To industry the significant factor is the ability of the material to do its intended job (alongside cost and availability, presumably). A potential user of vanadium concurred with this view. However, the producers are sensitive to terminology, and a steel industry representative conceded that while staff might well refer colloquially to slag as waste to distinguish from the steel itself, this is not the official position. In addition to EUROSLAG, the World Steel Association (claiming to represent 90% of the world's largest steel manufacturers, and based in Brussels) resolutely refers to slags as a by-product.[67] Noticeably the vast majority of information provided on its website relating to the circular economy extolls the durability and recyclability of steel itself,[68] rather than considering the residues from production. This is an interesting case, perhaps, of industry adopting an extended producer responsibility outlook rather than focusing on the processes it can more directly control. In interviews for the project reported in this chapter the terminology used, determined by the funder's (a government body) focus on recovery of resources from waste,[69] caused a level of consternation from respondents in case cooperation with the project could be interpreted as an acknowledgement of slag as a waste.

One potential disadvantage of end-of-waste criteria is that the resulting product would then come under REACH regulations.[40, 70] The 2006 EC REACH Regulation for the Registration, Evaluation, Authorisation and Restriction of Chemicals seeks to increase environmental protection (including human health) by increasing the knowledge of characteristics of chemicals produced and used in industry.[70] Compliance with the regulation would be a significant cost for a small company or one with a unique product. Given the scale of the European steel industry, the level of cooperation through organisations like EUROSLAG, and the fact that the compositions of different types of steel slag are consistent within acceptable limits, REACH registration does not appear to have been problematic. There is a registration for each of the three major steel slag types, which industry argues demonstrates their confidence that the slags should be treated like products.[71]

Industry therefore appears sensitive to steel slag's designation as waste, but still use the term themselves. Designation as a by-product would make more difference to practice around the slag than following the quality protocol to achieve end-of-waste. Even if the end-of–waste procedures are followed, that achievement of end-of-waste would not occur until the material reached the end user. The producer, therefore, has a duty of care for the steel slag whilst in the hands of the aggregate company that it does not have for the iron slag.[50] Thus under the Environmental Permitting terms and conditions the producer has to take some responsibility for checking that the operating practices of the aggregate company meet regulatory expectations.[72]

Notably, following the quality protocol, for steel slag as for other materials, is voluntary. In practice, despite the confirmation that steel slag is a waste residue, its usage at the case study site to a large extent presently mirrors that of the iron slag. At the time of interviews there was sufficient demand for secondary aggregate to take that supplied by both waste streams. Ironically this is in part due to a downturn in steel production reducing the amount of iron slag available. At times of lower demand for secondary aggregates, though, the more problematic steel slag would be the one stockpiled. Thus the economic demand for aggregate for certain uses is blind to its regulatory status and to a certain extent the quality protocol for steel is a distraction. However, the discussion around the protocol impacted on stakeholders' views of the potential to recover vanadium.

15.4.3 Implications for vanadium recovery

Critically, government-industry discussion over the quality protocol (published in April 2015)[73] was underway during the first phase of interviews for this study (2013). The environmental impact study and associated discussions[65] considered surface, groundwater and airborne pollutant pathways. Vanadium was specifically considered as a substance of interest within the risk assessment. It is considered to be tightly bound within the slag, but almost by definition the object of the routes to vanadium recovery proposed within this study was to increase its mobility in slag.[50] Emissions limits and controls regulated via the Environmental Permit would need careful consideration if its recovery were to be implemented, as would the establishment of vanadium recovery as an acceptable BAT.

Two other issues emerged by which the proposed recovery mechanisms were potentially in contradiction to issues around bulk recovery. The original proposal for this study to use organic waste to increase the mobility of vanadium in steel slag was not seen as a viable proposition.[50] Given the specific designation of materials allowed for end-of-waste and composition of final products, the mixing of different materials is problematic. In particular, mixing of a waste and a not waste invariably results in a waste.[66] The recovery of a component of bulk residue is considered by the EC WRD guidelines[42] as an indicator that the remaining material is a waste – based on the assumption that the separation decreases the certainty of the rest being used.[42] This would indeed be the situation for some of the routes to vanadium recovery that have been tested at laboratory scale. The method currently being developed by the technical work packages of this project [49] would not impede the use of the steel slag for standard purposes. It might, however, infringe on current stipulations of the quality protocol, necessitating the establishment of an additional approved operating procedure and output.

A final highly significant point emerges from the prioritisation of the producer of its core business (steel production). Given the outsourcing of slag recovery to a third party, under a long term contract, the steel slag is no longer owned by the producer. This arrangement was designed to increase the bulk recovery of slag, and though highly dependent on the market for secondary aggregates, that appears to be working. It means, though, that the producer retains an environmental liability for the slag (via duty of care and ownership of the weathering/storage site) without having the control to select the end use. For the aggregate company, use as an aggregate comprises its core business; vanadium extraction would be a very considerable departure that could risk being a hindrance rather than a parallel venture.

4.5 Conclusions

The case study presented in this chapter indicates a strong influence of environmental policies relating to the circular economy on the management of steel industry residues. These influences have been both direct and indirect, and are difficult to disentangle either from each other or non-regulatory influences. As discussed elsewhere[50] the strongest influence has come from the environmental protection regulations, but this is in part because there is already a long history of residue recovery in the steel industry.

Landfill tax may have been a successful impetus for waste reduction in other areas of activity in the UK,[18] but its impact on steel slag is difficult to calculate in terms of tonnage diverted from landfill. Depending on the strength of demand for aggregates and the supply of iron slag, the steel slag used as aggregate over the last 20 years might not have been landfilled anyway. The tax does seem to have contributed to the case study company's decision to out-source slag management, which would complicate the recovery of vanadium or other components of slag from the bulk residue. As shown here something can be technically a waste, and therefore to be discarded, but in practice can be wanted, owned, managed and potentially destined for an economically useful purpose.

The EU's process attempting to impose a terminology of by-product and end-of waste around residues enjoyed the cooperation of the slag producers and users in the UK, but was a contested process. Industry continues to apply the terms it seeks to establish (steel slag as a by-product), despite assertions and market evidence that industry buyers are not deterred by waste in principle. The WFD terms have gained legal weight but are contrived to serve the purposes of regulators (that is, to clarify when, how and which regulations need to be applied) and to provide assurances for end users.[41] Confident customers are a benefit to a producer, but the wisdom of following the protocol is unclear given that there are already very well established routes to bulk use of slag. Indeed, while the legal definitions are clear enough in principle, the situation is such that a given substance can have a different classification simultaneously at different locations, or from week to week at the same location, depending on the availability of a buyer. These stipulations are safeguards against the misuse of the WFD definitions as a means to the environmental protection elements of waste regulations.

As noted in the literature much research and implementation relating to the CE is a continuation of earlier practice[4]. However, the CE brings is a renewed determination and desire to implement some of the more ambitious ideas of resource efficiency that have not yet received a strong regulatory push. Attempting to achieve the latter will entail engaging with what is already a very crowded policy landscape, replete with stakeholders who are practiced at navigating within that landscape, relating to it on (and using) their own terms. Our attention has been very much on UK and EU practice, but whilst the institutional arrangements around resource recovery differ elsewhere,[12, 13] it is difficult to imagine a circumstance where a new policy does not enter into an existing policy landscape of some relevance. This study has helped to illustrate the complexity of responses, the challenges of circumventing vested interests and potentially contradictory effects of supposedly complementary regulations. Theoretical understandings of the CE therefore need to take account of influences (actual and perceived) and existing and evolving policy landscapes. A policy as far reaching as the CE, which is precisely trying to pull together and expand on existing efforts, is going to have to overcome all these to accomplish its aims. Further research is needed to assess the factors at play in other locations and/or with respect to other materials so that a picture can be compiled as to the most effective approaches to designing CE residue policy.

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Table Captions

Table 1 5 .1 Circular economy-related environmental policies relevant to industry in England and Wales. These are listed as EU directives, but key policies for UK and/or England and Wales are also included.

Table 15.2 Compares the properties of iron and steel slag and consequent treatment for re-use as practiced at the case study location. The order of events proceeds from the top to the bottom of the table

Figure Captions

Figure 4.1 Diagrammatic representation of the requirements for establishing whether a given material is legally a waste in the light of criteria for establishing by-product or end-of-waste status. Based on the WFD (2008); EC JCR (2008) and ECDG Guidance (2012).

Table 15.1

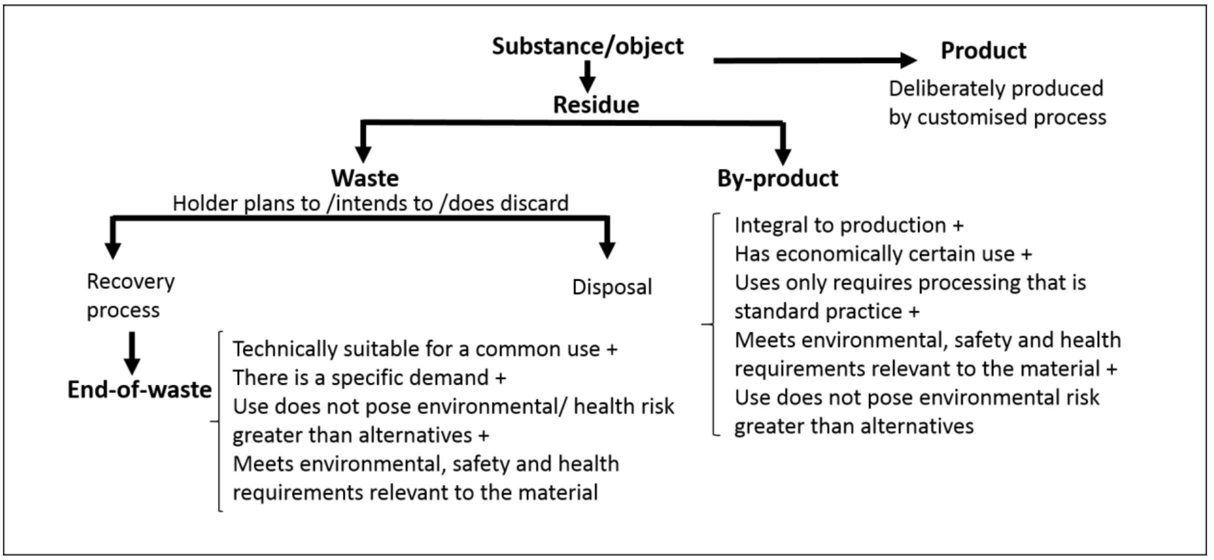
Relationship to CE	Policy (EU unless otherwise indicated)	Approach to CE	Impact
Lean production	Eco-design Directive 2009 Producer Responsibility Directives (various since 1994)	Mandates energy efficiency in energy using products (scope to be expanded to include materials related elements) Encourage design for end of life criteria for specific products by imposing some liability for end of life disposal costs	Reduces demand for resources and increases likelihood of a circular solution
Reduce waste	UK Landfill tax 1996; Landfill Directive 1999:	Financial incentive to companies/local authorities to seek routes to recovery Mandates practices including monitoring emissions	Creates supply of residue by increasing costs of disposal
Incentivise recovery	UK Aggregate Levy; requirements 2002	Financial incentive to avoid virgin aggregates (sand, gravel) thereby protect the environment by reducing quarrying /dredging	Creates demand for specific types of residue
Increase efficiency of production	Renewable Energy Directive 2009; EU Emissions Trading Scheme 2005; UK Climate Change Act 2008	Financial incentive to reduce carbon emissions for energy intensive industries and requirements to source energy from renewables	Create markets for new technology
Facilitate resource recovery	Waste Framework Directive 2008 UK Natural Environment Research Council programme for Resource Recovery from Waste UK WRAP, Technical Advisory Groups	Procedures to determine end of waste and clarify definitions of by-products Development of recovery technology e.g., for residue components Quality protocols; product standards for recovered materials	Reduce regulatory barriers to recovery; Generate knowledge to match supply and demand for secondary resources;
Environmental protection	IPPC Directive, 1996, 2008; Industrial Emissions Directive 2010; Environmental Liability Directive 2004; Waste Framework Directive 2008 UK Environmental Protection Act 1990 Environmental Permitting Regulations (England & Wales) 2010 +	Set emissions limits, establish and require Best Available Techniques; establish licencing requirements relating to waste and liability beyond ownership Duty of care; waste handling regulations Implement Directives for operation of industrial facilities	Prevent ongoing harm, remediate and restore previous damage

Table 15.2

	Iron slag	**Steel slag**
Source	Molten material produced at rate of 150-400 kg/tonne pig iron (known as blast furnace slag, BSF)	Molten material produced at rate of 85–165 kg per tonne of molten steel (known as Basic Oxygen furnace Slag, BOS)
Iron content	Low	High: slag is demetallised and recovered iron returned to production
Initial processing	Air or water cooling (granulation); may also be crushed	Cooling and crushing to 20 mm grain size
Characteristics	Resembles virgin aggregate chemically and physically	Expandable due to free lime content
	Low generally immobile presence of metals	V, Mo, Pb, Cr, Al present in slag and can be mobilized in highly alkaline leachate to varying levels
Management	Stored by onsite aggregate company until sold for re-use	Exposed to atmosphere for 6 months' weathering: reduces free lime content; effectively completes expansion process
	Water used to control fugitive dust emissions from stockpiles	Water used to control fugitive dust emissions from slag and legacy residue
		Leachate monitored to safeguard surface and ground water
Uses (potential alternatives in brackets)	Road aggregate, cement, concrete (soil improver, ceramics)	Road aggregate; (soil improver, favoured by the lime content; or water treatment once trace metals recovered)

Drawn from [56, 59,62, 63] and interviews.

Figure 15.1


Substance/object
Product
Deliberately produced
by customised process
Residue
Waste
By-product
Holder plans to /intends to /does discard
Recovery
process
Disposal
End-of-waste
Technically suitable for a common use +
There is a specific demand +
Use does not pose environmental/ health risk
greater than alternatives +
Meets environmental, safety and health
requirements relevant to the material
Integral to production +
Has economically certain use +
Uses only requires processing that is
standard practice +
Meets environmental, safety and health
requirements relevant to the material +
Use does not pose environmental risk
greater than alternatives