Making the most of industrial wastes: strengthening resource security of valuable metals for clean growth in the UK

Resource Recovery from Waste

Industrial wastes have the potential to contribute towards the UK's ambition for clean growth. This policy note will highlight where policy intervention can promote circular economy approaches in industrial waste management.

Overarching recommendation

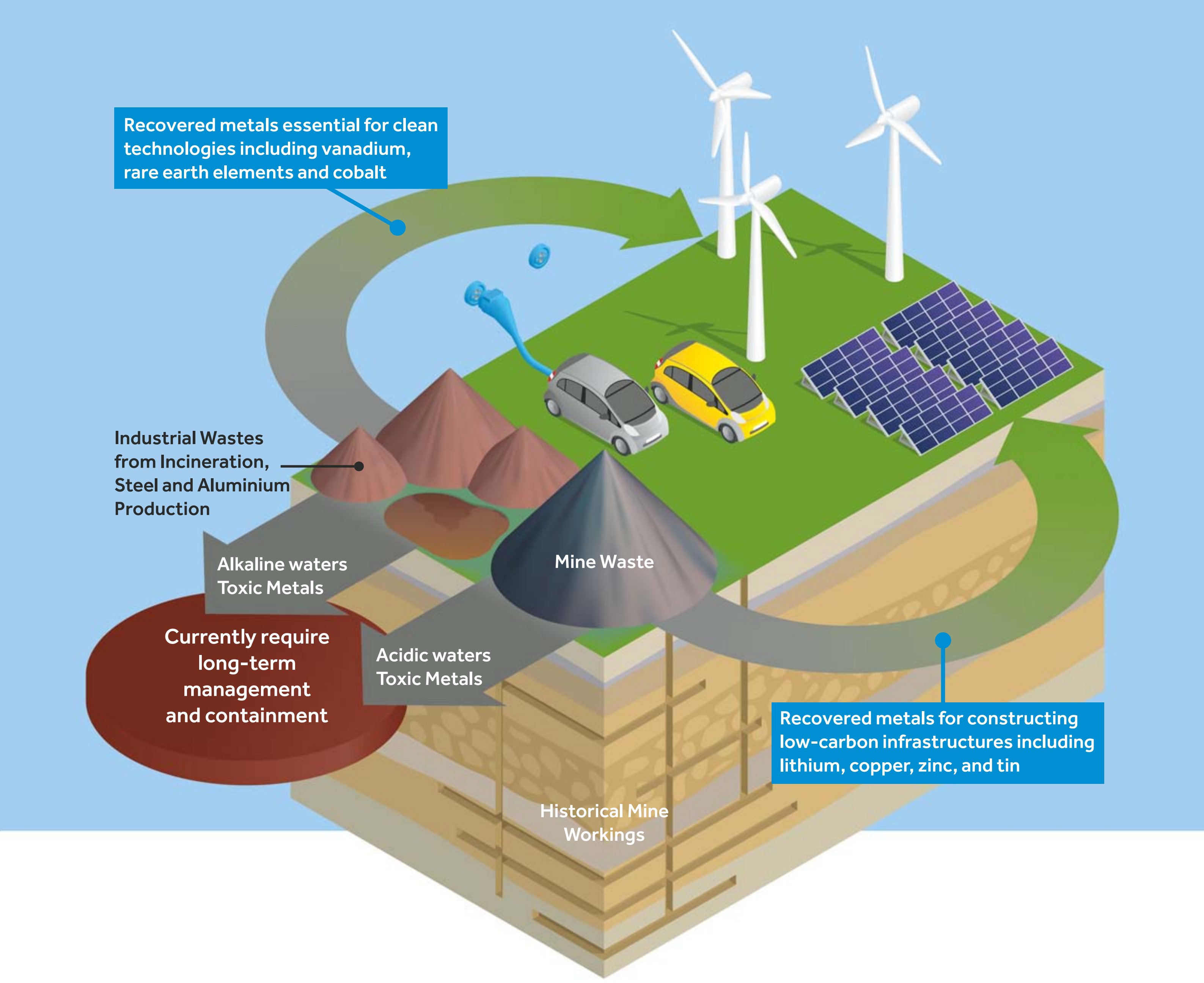
The UK Government should aim to develop integrated policies that unlock the potential of resource recovery to contribute to clean growth, create social benefits and maintain environmental protection. The current regulatory framework for industrial wastes was not designed with the circular economy in mind. In order to design policy and regulation that enables the potential for resource recovery from such wastes, better collaboration between policy makers, industry and academia is essential.

Resource recovery for clean growth

- *Waste materials from the extractive and manufacturing sectors have been described as 'anthropogenic ores' reflecting their potential supply of valuable metals. These include wastes from refining steel and aluminium, and metal mining industries.*
- *Resource recovery from wastes can result in social, environmental and economic wins particularly when using low cost, low environmental impact technologies.*
- *Maximising resource recovery from these anthropogenic ores will improve the UK's resource security. Resources from wastes can contribute to the supply of valuable metals and materials needed for clean growth, many of which are currently 100% imported.*
- *Metals are essential for the production of wind turbines, batteries, solar panels and a multitude of electronics. These resources must be obtained sustainably if the objectives of clean growth are to be realised.*
- *Increased efficiency in the use of resources, including recovery from wastes, can contribute towards reductions in the use of raw materials from finite sources.*
- *Reducing raw resource extraction will minimise the associated negative environmental impacts and carbon emissions.*
- *The growing focus on resource efficiency and the development of increasingly coherent plans across Government is welcomed, but policy and regulation must adapt to facilitate the strategic economic benefits of resource recovery as well as providing environmental protection.*

Why resource recovery from industrial wastes?

- **In order to work towards the aims set out in the Industrial and Clean Growth strategies the UK needs to reduce its reliance on finite resources and those from politically sensitive areas.** The UK government has committed to clean growth and decarbonisation of the energy system, requiring development and growth of the green technology sector[1,2]. The Industrial and Clean Growth strategies aim to see the UK maximise capabilities in the design, development and manufacture of electric vehicles, offshore wind and batteries. These technologies require supplies of metals including lithium, rare-earth metals, vanadium, cobalt – many of which we currently 100% import[3]. Also the global output of these critical metals is concentrated in only a number of countries; for instance, China produces 90% of rare earth metals and over 50% of cobalt is produced in Congo[4]. This has given rise to concerns over the potential for resource nationalism restricting supply of crucial materials[5]. **Extraction of metal resources from industrial wastes in the UK can contribute to a more secure and sustainable source of these valuable materials**[6] (Table 1).
- **A shift to renewable energy will be associated with a shift from one non-renewable resource (fossil fuels) to another (metals and minerals)[7].** In addition to less common metals highlighted above, low carbon infrastructure will require large quantities of materials such as iron, copper, zinc and aluminium. The negative environmental and social impacts of acquiring the materials required for clean growth infrastructure must be minimised in order to realise the benefits of a transition to low carbon technologies. Strategies for this include designing products and infrastructure for reuse and recycling, and ensuring that metals already in the supply chain (e.g. in electronic goods) are recycled[8]. **The recovery of metals from industrial wastes**



provides an additional supply of metals from UK sources, reducing demand on raw material use.

- **A move to circular economy approaches could result in job creation in the historic industrial areas of the UK where unemployment is currently high**[9]. Resource recovery from industrial wastes could promote the development of new recovery businesses, as well as stimulating innovation in industrial areas of the North East[10] and Wales[11]. There is an additional benefit in the proximity of current and historical industrial wastes to the green technology industries that require the extracted metals. **The Clean Growth strategy highlights the North East region for wind turbine production and the West Midlands for development of electric batteries**[2]**. Both these regions have a legacy of industrial wastes containing the valuable metals required in the clean industries of the future.**

- **Resource recovery has benefits across environmental and social domains, primarily driven by reductions in the use of raw resources**[12]. The use of primary resources has negative environmental and social impacts, and there is a growing recognition that this should be factored into the cost of materials and goods in order for a circular economy to be realised[13]. There is a need to stimulate the secondary resources market in order to encourage investment and growth of the sector. This could be through internalising the real societal and environmental costs of primary extraction into the costs of materials. **Many government departments currently focus solely on economic metrics**[14]**, this needs to be replaced by new modelling approaches that integrate values across social, environmental, economic and technical domains if we are to transition to a circular economy.**

Metal / UK Waste	Vanadium	Cobalt	Lithium	Copper	Tin	Lead
Steel slag (annual production)	49%	0.8%				
Steel slag (legacy waste)	638%	11%				
Fly ash (annual production)			11%			
Fly ash (legacy waste)			132%			
Mine tailings (legacy waste)*			**	2.78%	1.82%	1.34%
Market value of 100% annual import (million £)***	£4.2	£293.5	£9.3	£98.2	£64.5	£219.2

Table 1: The potential contribution of a number of UK wastes to the annual UK import of metals. The % contributions presented in this table are based on estimates from RRfW publications[11,15] where the assumptions regarding recovery efficiency and concentrations of metals are described. Import data for metals is based on 2014 figures[4] and does not account for how the import of materials is likely to change as demand for certain metals increases.

*Data is based on a study of only 14 sites of the 8000 disused sites estimated across England and Wales alone[11]

**There are promising prospects for lithium extraction from certain mine wastes (for instance china clay wastes in the SW England) although estimates of potential reserves are not currently available.

*** Market values calculated based on metal prices and exchange rate for 12 Apr 2018. Prices taken from London Metal Exchange (cobalt, copper, tin, lead), Infomine.com (Ferro vanadium) and Metalary.com (lithium).

Metals for clean growth

The development of technologies and infrastructure for reducing carbon emissions associated with our energy systems is key component of the UK (and global) ambition for clean growth. Technologies such as solar farms, wind turbines and electric vehicles have a high demand for metals and materials. These resources must be obtained sustainably if the objectives of clean growth are to be realised. Metals required include:

Vanadium: emerging metal in the production of long-lived batteries for commercial energy storage and a key component in the production of light-weight steel (for use in wind turbines and electric cars).

Lithium: in high demand for batteries required for electric cars, home energy storage as well as personal electronics.

Rare Earth Metals: metals required for technologies including solar panels, wind turbines, batteries and energy-saving light bulbs. Although not technically rare, supply of these elements is controlled by only a handful of other countries.

Opportunities for resource recovery from industrial wastes

- **Resource extraction from industrial residues can provide simultaneous economic, social and environmental benefits.** Environmental and social benefits occur both upstream due to the replacement of raw material extraction and downstream through the remediation of wastes which otherwise can pose risk to environment and human health[12,15]. Many of the metals targeted for recovery are hazardous and can leach into the aquatic environment or carry as dust into the atmosphere. UK regulations protect environmental and human health, which result in the need for long-term management of wastes such as steel slag and mine tailings. Despite protective regulation, chronic pollution is associated with industrial wastes in the UK[11,16]. The longevity of such pollution risks can result in issues with responsibility for management when companies close or ownership changes[10]. **Adoption of resource recovery techniques can accelerate the decontamination of industrial wastes and provide a revenue stream to industry, along with contributing to reductions in the UK reliance on primary resources.**

- **There is potential to extract valuable metals in significant quantities from industrial wastes, including those from steel making, aluminium production and incineration[6,15]** (Table 1)**.** In the UK there are considerable quantities of historical wastes produced through decades of industrial activity, as well as ongoing production of steel wastes and increased production of incinerator ash from energy from waste facilities. **These industrial wastes represent a stockpile for future resource recovery.**

- **Resource recovery techniques can incentivise environmental remediation by off-setting the cost with the metals recovered[11].** Mine wastes do not hold the answer to securing a long-term supply of more commonly used metals (copper, lead and tin) (Table 1); recycling has more impact here. However, where mine wastes are resulting in environmental contamination, resource recovery techniques can accelerate remediation processes; the cost of which can be off-set by the value of the metals recovered[11]. **Resource extraction from mine wastes has been a focus of projects across the RRfW programme.**

- **Some mine wastes are sources of metals that are now extremely valuable for modern technology.** For instance, there is potential for lithium extraction of china clay wastes and from historic tin mines in South West England.

Resource Recovery from Waste programme

'Resource Recovery from Waste' is an academic research programme funded by the Natural Environment Research Council, Economic and Social Research Council and DEFRA, and envisions **a circular economy in which waste and resource management contribute to clean growth, human well-being and a resilient environment.**

The programme develops technologies to exploit the resource potential of industrial wastes. Research projects spanned a number of different waste streams including the recovery of metals from **wastes resulting from steel and aluminium production, and metal mines.** These industries have a legacy of waste material for which environmental protection measures are required for decades.

The programme is developing technologies that minimise physical disturbance of these wastes and utilise **low-impact, low-cost and low-energy** techniques to maximise the environmental and social benefits of resource recovery.

Technologies under development in the programme include:

- Using more environmentally-friendly approaches to dissolving metals from wastes. This leads to the formation of metal-rich solutions (leachates) from which metals can be recovered.

- The use of bacteria, engineered materials (nanomaterials) and ion-exchange resins to selectively adsorb metals from leachates produced.

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Implications for policy and regulation

- **To promote a circular economy, the current regulatory framework for industrial waste needs to be redesigned.** Regulation relating to the industrial wastes discussed in this policy note focusses primarily on environmental and public health protection. There is a need to extend the focus to supporting the opportunities offered by resource recovery[10]. For example, for steel production the EU directive on Integrated Pollution Prevention and Control requires facilities to have permits specifying emission limits, monitoring regime and Best Available Techniques. Whilst these environmental controls are essential, the recognised Best Available Technique for steel slag residue in the UK revolves around safe handling, storage and preparation for bulk reuse, with no option for resource recovery[10]. **Discussions are needed to determine where current UK regulation around end-of-waste for materials are limiting opportunities for resource recovery** (the EU Circular economy package already highlights the need for streamlining provisions on by-products and end-of-waste status[17]). Such discussions will require consultation between policy makers, regulators, relevant industries and researchers in order to identify opportunities and barriers to implementation of emerging technology[13].

- **Assessing the full life cycle impacts of resource acquisition is complex but essential for determining which technologies and approaches are appropriate for the situation[6,18].** This approach allows for a better understanding of the potential negative impacts and positive benefits resulting from decisions around resource acquisition and use. For example, historical mine waste sites in the UK can have cultural and environmental importance, including providing rare natural habitats, leisure and educational services[11]. These factors should be balanced against the potential social value of obtaining a resource from within the UK, the benefits for local employment and reduced reliance on primary resources from politically sensitive countries.

- **There is a need to promote the development of local, circular supply chains through industrial symbiosis.** In the UK there is the opportunity to develop networks linking industrial waste producers with end users for the recovered valuable metals – an example of industrial symbiosis[19]. Industrial symbiosis is most successfully established when policy and regulation supports the investment needed to build relationships[10]. This is highlighted by the success of the National Industrial Symbiosis Programme (NISP) in delivering significant financial, social (including employment), resource and environmental benefits in return for public investment[20]. The UK took a lead in industrial symbiosis in the early 2000's, however since funding of NISP ceased in 2014 the UK has fallen behind compared to other countries where the principals have been adopted and supported by policy. **The role of government in promoting industrial symbiosis should be considered in the development of the 'Resources and Waste strategy'[21].**
- **The recovery of resources from wastes needs to be incentivised through the creation of markets that account for the economic, technical, social and environmental value of a resource.** Accounting for values across these multiple dimensions, instead of a focus on economic benefit alone, is necessary to drive a move away from primary resource use. Frameworks are being developed for the exploration of the effects of recovery decisions on the creation and destruction of economic, technical, social and environmental values along whole supply chains of materials, components and products[18]. This approach can assist decision makers in assessing overall sustainability performance of existing and emerging supply chains. Such tools are essential for developing arguments around choices in resource recovery from waste that can be integrated into sustainability assessments and decision-making processes[22]. The definition of value in global economic systems is being questioned with proposals for alternative models of taxation and metrics that encompass social and environmental costs and benefits[23]. **The UK 'Resources and Waste strategy' is an opportunity to embrace this changing culture and incorporate metrics for measuring value across multiple domains into decision making.**

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