In space, no-one can hear you innovate

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What is the purpose of this paper?

This paper is intended to stimulate discussion and audience participation at the European Biosolids & Bioresources Conference & Exhibition[1], scheduled for November 17-18, 2026. It has its origins in frustration – on the one hand at a lack of UK government policy on any future aspect of bioresources (which could lead to critical resources being locked out of the active economy) and on the other a failure of the UK water sector to capitalize on this policy vacuum to set its own direction of travel (one which would significantly increase the pace of new technology deployment, discarding 'sludge to land' as an antiquated practice with little to no place in future bioresource management). These frustrations reflect the experience and perspectives of the two authors, neither of whom claim to be 'right' but both of whom consider current approaches to bioresource management unsustainable.

Overview

Biosolids recycling to agriculture remains the principal outlet in England and Wales, returning nutrients and organic matter to soil. This is often claimed as the best practicable environmental option and may in some cases be the most cost-effective – but the route now faces interacting agronomic, regulatory, market confidence and logistical pressures. Some of these are more tangible than others, but there is no cohesive plan to address these challenges – whether at a policy level from government or at a water sector level, although pilot studies and optioneering are legion.

Evidence for actual harm from biosolids remains equivocal, despite the ongoing media narrative to the contrary. Long term field studies in Europe support the ongoing safety of agricultural use, but within the constraints of available evidence – and particularly the absence of agreed thresholds of harm for contaminants such as PFAS and microplastics. The inability to quantify risks from simultaneous exposures to multiple hazards also remains problematic. Defra are aware of these challenges and earlier this year gathered evidence from a large cohort of expert stakeholders, which re-emphasized both the evidence gaps and the urgency with which they should be closed.

We find ourselves at a critical juncture. Our peers in Sweden operate a quality assurance scheme for biosolids that has upstream engagement and continuous quality improvement at its core. We do not, but even if we did – what would the target quality be, who would be responsible for closing quality gaps, would they close quickly enough to maintain (or improve) user confidence and would the outcome be the most cost-effective when considered at a system level? Source controls can be effective but aren't available for all relevant hazards and will always leave a residue which needs to be managed at the end of pipe. It's also difficult to foresee a situation in which a UK government department would openly acknowledge that a system it has perpetuated over decades is no longer fit for purpose and that some historic practices might now be considered problematic. Far more likely that the nutrient planning thumb

[1] https://european-biosolids.com/

screws will be tightened until the logistics of land application simply kill the option and force the sector to invest in alternatives.

Shifting away from land via thermal and other treatments is also a long-term play but delivers more certainty of outcome as we define what we want this to be and plan a route to take us there. This future can also be written whether or not there is supporting government policy, with the sector considering the options and planning accordingly – potentially on the assumption that there will be no subsidies to skew the market in a particular direction. The issue with such a policy vacuum is that it (potentially) allows critical materials to be locked out of the economy – particularly phosphorus. Although listed as one of UK government's top ten critical minerals there is little to no economic incentive to recover it. Policy could mandate it, but as we've seen in Germany and Switzerland, these policies need to be implemented over decades, and the value of the recovered resource isn't necessarily going to cover its costs of recovery.

Mandating the use of recovered resources ensures that they have a market (qv. RTFO and SAF mandates) without incentivizing any reduction in recovery costs – and may disincentivize exploration of alternative uses. The experiences of our peers in Germany, Switzerland and Austria may prove instructive as their phosphorus recovery mandates go live, as should the experience of our European peers in implementing the polluter pays and resource recovery principles in the revised Urban Waste Water Treatment Directive. Pinning the costs of end of pipe treatment on manufacturers of consumer products will simply push up the price of those products for consumers, who would have paid through rate rises anyway. Ideally all chemicals placed on the market would be compatible with the waste and wastewater management systems we operate, but fully transitioning to such a utopia is currently unimaginable.

So, do we seek to maintain safe land application while weaning ourselves from our dependence on it? Or acknowledge that the process of proving and delivering safety is going to be so tortuous that we might prefer instead to go cold turkey and map out a landbank-free future? Or can we agree that the ever-increasing costs and regulatory pressures associated with land spreading mean that we will need to consider a landbank-free or landbank-lite future anyway? Can we agree that we should change by choice to a better environmental and cost solution, driven by a meaningful strategy and supportive research – rather than wait to be regulated?

1.1 Is land application safe? Who knows?

Residual chemical contamination in recovered resources is one of the principal constraints on the circular economy. In some cases, contaminants are present at concentrations that represent genuine risks to human health or the environment. In others, uncertainty regarding contaminant presence, behaviour and acceptable concentrations undermines confidence in the recovered resource even where actual risks may be low. These impacts are common across multiple sectors, where contaminated recyclates hamper the circular economy:

Sector	Contaminant	Sector	Contaminant
Textiles	PFAS, flame retardants…	**Food packaging**	PFAS, BPA, BPS…
Plastics	Brominated flame retardants, other legacy chemicals	**Biosolids**	PFAS, pharmaceuticals, bisphenols, microplastics…

In these circumstances a common response is to ‘do a risk assessment’ – which is fine if there are data on contaminant concentrations in the recyclate, clear pathways to receptors that can be robustly modelled and evidence-based thresholds for harm / safety. With ~1000 new chemical substances manufactured per year, such evidence is inevitably sketchy. The important question of synergistic and antagonistic effects from combinations of hazards also remains unresolved. In the meantime – and in apparently direct contradiction to the precautionary principle – we continue to apply biosolids to farmland.

1. Whose responsibility should it be to set acceptable limits for contaminants in biosolids?
2. Whose responsibility should it be to update the regulatory regime to ensure that registration of future chemicals requires manufacturers to consider ‘end of like’ or ‘post use’ impacts of their substances and ensure compatibility with a Circular Economy?
3. Given the timescale for any meaningful change upstream, is it worthwhile for the sector to push for change at this end – or should it focus on improving end-of-pipe outcomes?
4. Should the sector be concerned about future liabilities from historic application of biosolids?
5. Is policy needed to stimulate change, or does the industry already have all the tools it needs?
6. Does the industry have the appetite to change?

1.2 Who is the polluter – and aren’t they paying already?

The Polluter Pays Principle (PPP) is attractive because it seeks to correct a fundamental market failure: environmental costs are often borne by society rather than by those generating the pollution. By internalising these costs, PPP creates incentives for pollution prevention, innovation and source control while reducing the burden on taxpayers and utility customers. The principle is embedded in UK and EU environmental law and is increasingly being used as a mechanism to address emerging pollutants such as pharmaceuticals, PFAS and microplastics. But…successful implementation depends heavily on being able to identify polluters, quantify environmental harm and allocate costs fairly. PPP doesn’t particularly suit situations where the benefits of substances are widely distributed across society or large proportions of emissions arise during consumer use rather than manufacture.

The revised UWWTD introduced Extended Producer Responsibility (EPR) requirements requiring producers of pharmaceuticals and cosmetics to contribute to the costs of quaternary wastewater treatment for micropollutants – possibly the most ambitious PPP application in the water sector to date. It attempts to reallocate costs from water customers to sectors placing substances (that subsequently become contaminants) on the market and has been subject to extreme manufacturing industry push back.

Supporters argue that: Pharmaceuticals and cosmetics are intentionally manufactured and marketed; Water customers currently bear treatment costs despite not being responsible for product design (although they / we may be responsible for product purchase and use); Conventional wastewater treatment wasn’t designed to remove these substances; EPR creates incentives for greener chemistry and biodegradable ingredients.

The pharmaceutical sector has counter-argued that: Medicines are essential products and most emissions arise from normal patient use; Healthcare systems and patients derive substantial societal benefits; Cost attribution between manufacturers, users and healthcare systems is highly uncertain; Quaternary treatment removes many pollutants simultaneously, making cost allocation difficult.

Source controls are the usual counterpart to the PPP and have been shown to deliver long-term societal benefits, but residues of persistent substances are found in wastewater years after their manufacture and sale were prohibited, meaning that end of pipe treatment will be needed in the long term.

1. Given that society will pay one way or other, is PPP really relevant with respect to wastewater treatment and/or improving the quality of biosolids specifically? What can we learn from the design and implementation of the rUWWTD?
2. Source controls may well reduce end of pipe loads (even if they aren't eliminated). Do we have sufficient insight to prioritize between permitted manufacturing discharges to sewer and consented trade effluent discharges?
3. Whose responsibility is it to address contaminant contributions from runoff in combined systems?
4. Is quaternary treatment inevitable? Is it even appropriate for PFAS removal?

1.3 Can we agree on the criticality of phosphorus - and should we do anything about it?

Phosphorus is essential, non-substitutable and geopolitically concentrated. The British Geological Survey's 2024 UK Criticality Assessment identifies phosphorus as a critical mineral for the UK, reflecting both global supply risks and UK economic vulnerability. Phosphorus is fundamental to food production, is derived principally from phosphate rock, and faces growing demand from both agriculture and emerging technologies such as lithium iron phosphate batteries.

Despite formally recognising phosphorus as a critical resource, the UK currently lacks a strategic requirement to recover phosphorus from wastewater, sewage sludge or any other resource. Germany, Switzerland and Austria have responded to similar concerns by introducing mandatory phosphorus recovery policies, reducing dependence on imported phosphates whilst strengthening resource security and circularity. P-recovery targets are also under active development under the rUWWTD, but these may well include land spreading – which wouldn't address our landbank challenges.

Phosphorus in UK wastewater mostly finds its way to soil via biosolids – and this pathway may increase as P limits tighten in final effluent. This is creating landbank challenges which (in the absence of policy change on sludge land spreading) may prompt a strategic shift to thermal treatment processes, some of which could lock phosphorus out of economic use – for example, in construction materials – unless there were an incentive to do otherwise. That incentive could be regulatory and/or economic.

1. Should the sector support a phosphorus recovery policy or should the sector instead highlight the relative proportions in biosolids and other land-applied materials and lay responsibility for this at the door of the livestock sector? Or could the water sector instead push for a cross-sectoral policy to stimulate collaboration and resource recovery from co-processed resources?
2. Do we have the right technologies to support any such policy?

1.4 Should circularity be mandated? Who should pay for it?

The list of resources that can be recovered from wastewater and sludge is extensive, matched (if not exceeded) by the number of bench and pilot studies which demonstrate some of the practicalities, but to date we have seen little adoption of proven recovery processes. This isn't an issue isolated to the water sector – the waste sector has faced similar hurdles when it comes to recycling plastics and the large number of proven nutrient recovery technologies doesn't mean that nutrient recovery has become widespread in the farming or biowaste sectors irrespective of the widespread logistical and sustainability challenges they face.

That resources can be recovered doesn't mean that the market wants to pay for them, and mandates are under discussion that may eventually require European fertiliser manufacturers to incorporate a proportion of recovered nutrients in their products. This would have the benefit of creating market pull, but any additional costs would then be absorbed by fertiliser users. It also has the potential to disincentivise innovations in resource recovery which might target higher value end points.

We have experience of such mandates in other contexts in the UK – with both the RTFO (Renewable Transport Fuel Obligation) and UK SAF ('Sustainable' Aviation Fuel) policy. The SAF Mandate requires aviation fuel suppliers to blend increasing proportions of alternative fuels into conventional jet fuel, rising from 2% in 2025 to 10% by 2030 and 22% by 2040. The policy also contains specific requirements for advanced fuel types and buy-out penalties if suppliers fail to meet their obligations. This is intended to: Create guaranteed long-term demand; Provide investors with visibility of future markets; Encourage development of domestic production capacity; Create differentiated demand for preferred technologies through sub-targets.

The SAF experience also highlights several challenges: Policy uncertainty, with repeated consultations on eligibility criteria, blending targets and feedstocks – which can undermine investor confidence and delay investment decisions; Revenue risk (since the mandate has created demand but not necessarily revenue), which has in this case has had to be addressed through a Revenue Certainty Mechanism using a strike-price style support model; The need to create space for newer technologies and avoid lock-in to the lowest denominator option (in this case the use of fuels derived from vegetable oils) by capping inputs from specific sources / technologies…

1. Is a "mandate and guarantee" approach an essential / inevitable bridge between linear and circular economies – or can government intervention in markets be avoided?
2. Does this transition need to be stimulated through policy?
3. Do we need to step back and take a more holistic review of the opportunity – for example, by considering resource recovery hubs that are feedstock agnostic and focussed instead on output quality?
4. Is the long-term focus on land application of our residues blinding us to alternative outlets?
5. Do we have a good enough system for demonstrating the safety of recovered resources?
6. Do we know what the potential customers for recovered resources actually want, rather than assuming that they'll be interested in whatever we produce?

1.5 Where next for bioresources strategy, innovation and investment?

Innovation in the bioresources sector over the last thirty years has been, well, glacial. There have been advancements in anaerobic digestion efficiency and better use of biogas latterly, and the operational model is undeniably different to the days of rain-gun applications of raw sludge to land, disposal at sea and wholesale incineration – particularly as a result of the investment and change undertaken to meet the UWWTD. But, after that shift, has there been any meaningful impact on the four very current needs of:

- Cost to customers,
- Environmental impact (emissions and pollution),
- Corporate risk, and
- Improved resource recovery?

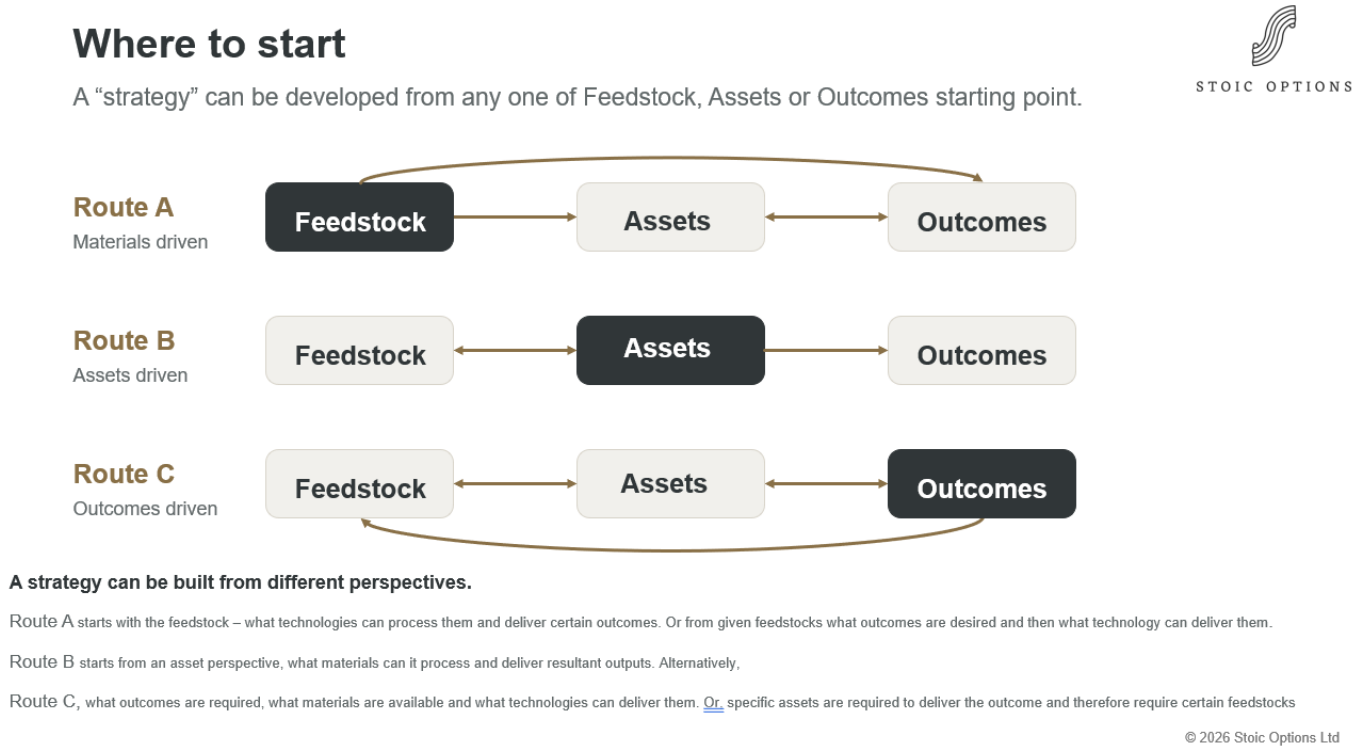
Observationally, the answer is no, there has not been material progress against these four broad outcomes.

1.5.1 Strategy

This apparent lack of progress isn't necessarily due to national policies (or lack of them), nor financial regulation or the interpretation and enforcement of environmental regulation. These are all navigable – and value can be realised by intent, through meaningful long-term and transitional planning supported (or led by) robust and ambitious research, development and innovation (RDI) strategies.

Prior attempts to develop national strategy have attempted to accommodate multiple perspectives through bland and non-committal approaches. Whilst we have seen good intent and some progress in knowledge generation and understanding we are not seeing demonstrable progress to address the four high-level needs mentioned above, or a breaking of ranks to attempt a transformational impact.

The model below shows three starting points in strategy development. The current asset deployment strategy appears to start with Assets = AD/AAD, producing two outcomes: biogas and digestate. Innovation strategies normally follow the same model with technologies identified on the basis of their ability to process the organic feedstock and deliver one or more useful outputs. Rarely does an asset or innovation strategy start with what the company aspires to as an outcome from the organics it produces.



1. What are the strategic outcome options for the processing of sewage sludge? These could be specific e.g. recovery and refining of critical elements like P, production and refinement of VFAs, conversion of biogas to higher value materials etc. Or generic, such as transition to profit from cost centre bioresources; climate positivity; mitigation of published corporate critical risks. All to stated, informed timeframes.

1.5.2 Commercial Investment

The 2019 Ofwat Bioresources Price Control initiative has had some success in improving bioresource derived revenues with more commercial attitudes. Whilst beneficial, the focus has been on efficiency improvements and alternative uses for biogas (large sites moving from CHP to gas grid injection) within the industry standard AD to biogas and biosolids to land model. Attracting commercial investment into this model based upon anything other than high gate fees seems to be a way off. With the current asset groups as the standard, revenues from biogas production and risks associated with digestate management would be understandable reasons to make third party investment unattractive to both investors and water companies alike.

The RCV (regulated capital value) approach prevails, with customer-funded assets. Risk appetite for new methodologies through this model is low and herein lies the challenge. To meet expectations (both customer and regulator), reduce the corporate risk of critical processes (biosolids to land) becoming less tenable, meet pollution and resource recovery targets and increase revenues, new technologies are needed.

Transformative biological, thermal and physical/chemical processes are emerging. In conjunction, many technology providers are offering investment packages. This has the potential to have shared or risk removal for the regulated business model. The missing element is strategy – and strategic alignment away from the current asset and financial models.

1. Is the risk of continuing with the existing model now becoming a greater corporate risk than employing new technologies?
2. What role do third party investment and partnership options (PPP, PFI or simple merchant relationships) now have in the sector?
3. Are high gate fee models tenable alternatives to encourage third party investment, given customers' willingness to pay?
4. What are the true current costs to customers (to enable robust comparison with alternate business models)?
5. If risk / reward ratios are too complex or distorted to meet regulated capital investment requirements for new technologies and products, how should we collaborate to explore alternative models for commercial investment?

1.5.3 Innovation

The adoption of new incremental offerings from the marketplace is a convoluted and frustrating path for supply chain. There is a blurred line between RDI, technical gatekeepers and procurement process with no clear decision makers. This often delivers poor outcomes following multiple "trials" in suboptimal conditions with little or no opportunity to stress test technologies in a commercial environment. This absence of commercial stress-testing has partly contributed to the lack of market uptake of sound technologies.

Larger, commercial-scale innovation initiatives are now more feasible thanks to the scale of the customer investment delivered through Ofwat and other partners – and is most welcome.

There is a common "but" when it comes to the implementation of successful outcomes. This should be relatively straightforward for incremental innovations which can be demonstrated to address an identified need with sufficient clarity to warrant investment and deployment. For transformational innovations – and particularly in bioresources – implementation is proving extremely difficult. There is clearly a vibrant and well-funded innovation buzz about the UK with no shortage of ideas and projects, but no one is committing to the fundamental overhaul of the system which is now possible.

The status quo with sludge to AD to biogas and land is now increasingly challenging. The value recovered is not high enough, support funding is dropping away, demand for biosolids is declining and more restrictive regulations are making logistics more complex. All compounded by greater understanding of pollution risk and customer expectation. But strategies have not shifted with this change.

1. If the sector agrees that the status quo is untenable, what does it propose to do about it – and when?
2. What's needed to stimulate the necessary transformation?
3. Are innovation projects operating at an investor-appropriate scale?
4. Should innovation funding be conditional on clear alignment of the proposal to a specific and committed company strategy outcome (and implementation funding plan)?
5. Are regulators ready to allow the adoption of new best practice techniques and technologies?

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