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Circulating blame in the circular economy: The case of wood-waste biofuels and coal ash

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ABSTRACT

The transition from coal-based electricity to 'carbon neutral' biofuels derived from forests has catalysed a debate largely centred upon whether woody-biofuels drive deforestation. Consequently, a crucial point is often missed. Most wood pellets used in electricity production are derived from waste-wood; a practice considered acceptable by many otherwise strongly opposed to the industry. We highlight that, precisely because waste-wood is a 'waste', its carbon-neutral credentials should be questioned. We then examine a parallel development occurring within the same industrial system; the recovery of electricity producers' combustion-ash residues for concrete production. Contrasting how accounting practices allocate upstream carbon to these 'wastes' in the cases of wood pellets and coal-ash reveals how decisions are shaped by industry imperatives, rather than established lifecycle techniques. If the politics of emissions allocation continue to evolve in this way, it may become increasingly difficult to distinguish where progress towards a low-carbon, environmentally sustainable and circular economy is real, from where it is an artefact of biased and inconsistent accounting practices.

1. Introduction

The last time that a major USA-based airline recorded a fatal crash was in 2001. In fact, no US commercial carriers have had any fatal crashes since 2009 and, both in the USA and globally, aviation safety has been improving continually over the last 50 years, due to decades of effort by regulatory bodies, engineers and numerous others (B3A, 2018). On the 2nd of January 2018, however, the American President attempted to claim credit for this himself, tweeting, out of the blue (Time Magazine 2018): "*Since taking office I have been very strict on Commercial Aviation. Good news – it was just reported that there were Zero deaths in 2017, the best and safest year on record!*" He was immediately and widely ridiculed, as it was clearly absurd that, in under a year, he had managed to play a significant part in what was clearly a pre-existing, ongoing and long-term trend. And no one appeared able to think of anything he'd actually done.

Another very different trend has also been observed in the USA in the 20th century. After centuries of mass deforestation, forests in Northern America began to expand, particularly after the 1940′s (FAO, 2000). The growth was driven by (relatively) sustainable timber practices as well as conservation efforts and – although various problems still remain – the result has been a long-term trend of significantly increasing carbon stocks. The timber industry has unavoidable inefficiencies – it's not possible to fully convert a felled tree into building components or other timber products – so much of the carbon sequestered by timber plantations has always ended up in waste-wood (Booth, 2018). Around 2010, the electricity industry – led by Drax, a large coal-fired power station in the UK – began to use this wood to replace coal and an international market in wood pellets emerged.[1] However, although the growth in carbon stocks in North American forests is also a pre-existing, ongoing and long-term trend, power producers that utilise waste-wood argue they can now count the carbon sequestered in this waste on their balance sheet to offset the carbon they emit when it's burnt.

This claim that woody biomass is carbon neutral is underpinned by the idea that – unlike fossil fuels – burning biomass can essentially become embedded in the natural carbon cycle, provided the forests from which the wood is obtained are managed 'sustainably'. The carbon released when biomass is burnt for energy is thus assumed to have been previously captured by forests that are managed well enough that it will be recaptured by a new stock of trees. So for biomass advocates, it becomes irrelevant that producing a kWh of electricity from wood causes significantly more CO_2 to leave the chimneys of power stations than producing a kWh of electricity from coal.

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[1] See www.draxbiomass.com (accessed 04/02/2019) and various other sources.

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But what happens when the biomass in question is derived from waste-wood? Is the reasoning underpinning these carbon-neutral claims still applicable? Or have the nuances of the argument been clouded over by an unscrutinised intuition that wastes should be used rather than 'wasted', even if this emits carbon? Are consumers of waste-wood simply taking credit for things that would happen whether they burnt the waste-wood or not, rather like the attempts at misappropriation by President Trump?

The answer to this question revolves around an issue familiar to the field of Life Cycle Assessment (LCA; Guinée et al., 2010). When a process produces a 'waste' alongside its primary product, should users of such wastes – which are increasingly referred to as 'secondary products' or 'recovered resources' – be considered partially responsible for the impacts of this upstream process or not? Or, similarly, should producers split the attribution of their impacts between the primary products and wastes they produce? If so, to what degree should they be responsible and under what conditions? How, then, should responsibility be apportioned to encourage environmentally and socially beneficial practices?

Such questions are increasingly important given the role that biofuels – particularly combined with carbon capture (*BECCS*) – are assumed to play in mitigation scenarios from the Intergovernmental Panel on Climate Change and others such as the International Energy Agency. In perhaps the most extreme uptake projection, the IPCC's latest report on limiting warming to 1.5 degrees highlights that (globally) 20 Gt of CO_2would need to be captured by BECCS by 2060 if drastic cuts to energy use are not made immediately (IPCC, 2018). This equivalent to half of all the emissions occurring in the present day from fossil fuel use and industrial activities being captured post bioenergy combustion.

In this short article, we consider two cases in detail to highlight the political and technical challenges decisions regarding responsibility bring. First, we discuss waste-wood derived biomass in the context of resource recovery and the circular economy. Drax power station forms the focal point for much of our discussion as it has been at the centre of previous debates regarding biomass sustainability, due both to the vast government subsidies it receives (and relies upon) and the scale of its operations (Drax alone accounted for over 20% of global wood-pellet use in 2015; Thrän et al., 2017). We note, however, that Drax is one part of a much larger biofuel industry and hence should not be the sole recipient of critical analysis. Second, we discuss a closely related development occurring within the same industrial system, namely, the recovery of coal-fired power station residues by concrete and cement producers, and the associated dilemma of assigning responsibility.

2. Case studies

2.1. The wood-waste fallacy

The opening analogy makes salient an obvious point about waste-based biomass-fuels that is easily missed, especially given the direction that discourses between opponents and proponents often take. For the conventional carbon-neutral claim of biofuel advocates to have any solid footing in the context of waste-wood, it must be shown that using this biomass results in more carbon being captured (i.e. more reforestation taking place) than would have occurred due to pre-existing forestry activities. It is particularly important to demonstrate this as there is no direct link between wood producers and electricity generators; power station operators do not generally own forests, nor vice versa. For wood-based biofuels, therefore, it must be proven that biofuel markets provide an economic driver for commercial forest management that causes total wood stocks to *increase more rapidly* than they would have in the absence of this market. If forests were cultivated on marginal lands specifically for biomass, such a driver obviously exists; but where biomass is derived from the waste of an industry primarily concerned with producing other wood products such as construction timber or wood pulp for paper, the existence of such a driver cannot be taken for granted.

This has contradictory implications. For example, 99% of the wood pellets sourced by Drax are, according to self-reported statistics (Drax Group, 2017), derived from forestry waste (residues from sawmills and other forestry operations). Around 85% of these come from North America and most of the rest from Europe. Drax claim that their biomass supply is legitimately low-carbon.

But many others are not convinced. Biofuel opponents claim that demand for wood pellets has grown too quickly (Climate Central, 2015) for waste-wood alone to meet, and the definition of 'residues' used by woody-biomass users is fuzzy enough to allow for whole trees (Pierce, 2017). They argue this results in unsustainable markets for woody-biomass that drive increased deforestation in the USA and illegal deforestation in Europe (Nelson, 2016). Critics also highlight the crucial issue of time (Brack, 2017) – even if trees are grown today to replace those used for fuel, the process of regrowth takes decades (if replacement trees are grown at all) and climate change requires immediate emissions reductions. More broadly, they highlight the issues for carbon and biodiversity when mature forests are replaced with monoculture plantations (NRDC, 2018). Thus, in contrast to the carbon-neutrality claim, woody biomass is accused of being, in some cases, even worse than coal.[2] Nonetheless, in the EU and the USA biomass is now officially recognised as a 'zero carbon' energy source, provided it meets a variety of sustainability criteria (Heikkinen, 2018).

Wood pellet users respond to these objections with the same defence, claiming that their inputs are derived entirely from *abundant* forestry sector wastes and that they are thus *not* causing whole forests to be cleared in North America or elsewhere (Drax Group, 2018b). From a cursory read, the debate can thus appear somewhat like a pantomime, with one side exclaiming "*don't worry, we only burn waste*", the other replying "*no you don't*", and the first returning "*yes we do!*" This leaves the question of whether burning waste-wood for energy is good or not receiving insufficient scrutiny, and can lead to many of the crucial points that environmental scientists make being overlooked.

Using wood-waste as an energy source has a strong intuitive appeal (Styles, 2016). Trees capture carbon as they grow, waste-wood is an inevitable outcome of producing timber, and utilising wastes as resources rather than disposing of them is generally a good thing. Burning waste-wood becomes seen as part of the broader transition from the concept of 'waste management' to 'resource recovery'. It's thus easy to conclude that burning wood waste must also be good (Juniper, 2017), but things clearly aren't that simple.

Statements from forestry experts in the USA (Drax Group, 2018a) and a UK Government study (Howes et al., 2016) point out that North American markets for woody-biomass are insignificant next to timber markets, which are the real drivers of forest expansion and management. Wood pellet buyers are, in short, 'bottom feeders' (Forisk, 2015), a perspective both good and bad for pellet consumers. It's good as it means they cannot be accused of significantly driving deforestation. But by the same logic, they cannot take credit for any reforestation either (and the associated carbon sequestration). Waste-wood thus appears no more carbon neutral than coal.

And so precisely because the wood they use is *waste-wood* – which has negligible value compared to the primary products of the timber industry – waste-wood consumers cannot reasonably be held responsible for activities happening further up the supply chain. Consequently, they should not be assigned any of the benefits of forest carbon sequestration. As we describe below, this is exactly how assignment of the impacts of industrial processes to economically insignificant 'waste' products works under standard LCA methods.

[2] See, for example an open letter to the EU signed by various academics (*EU must not burn the world's forests for 'renewable' energy;* https://www.theguardian.com/environment/2017/dec/14/, accessed 04/02/2019).

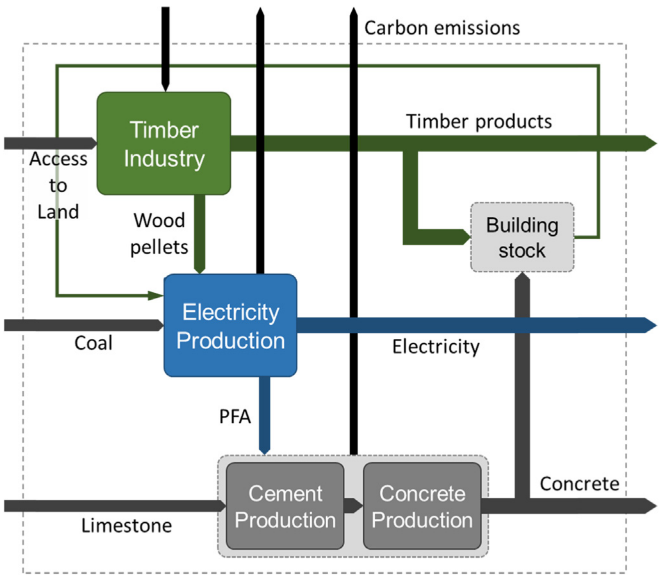

Fig. 1. Schematic of the main processes and flows in the system. 'Carbon emissions' at the top refers to all three black arrows. Note, the illustration is highly simplified and includes only those processes most relevant to our discussion, and the most significant flows linking them together.

2.2. Low carbon (coal-based) concrete

An interesting comparison emerges from looking to another process in the system within which major electricity producers and the timber industry coexist. Such electricity producers are one part of a vast, interconnected system of industries, around which it's impossible to draw an unambiguous boundary, and through which biomass is far from the only flow. The main processes and flows of relevance to this article are illustrated in Fig. 1. A substantial fraction of the wood pellets derived from timber industry waste are used to partially (or fully) replace the fossil-fuel input at power stations previously reliant upon coal. Such power stations have thus historically produced pulverised fly ash (PFA), a valuable 'waste' residue (more correctly, co-product) from coal combustion that can be used in concrete production (Yao et al., 2015). We can now see how interlinked the system is, as there is considerable overlap between the roles of concrete and timber in construction.

Cement is the key ingredient in concrete and its production – currently at around 3 billion tonnes per year – accounts for at least 5% of anthropogenic greenhouse gases (IPCC, 2014). PFA can replace up to half of the cement content of concrete, and it is usually assumed to be carbon neutral as its economic value has historically been negligible compared to the parent product (electricity). Consequently, replacing cement with PFA is considered a key action for reducing the carbon footprint of concrete (Yao et al., 2015). Further, the massive quantities of PFA and other coal ashes that are produced – closing on 1 billion tonnes per year globally (*ibid*) – can present major disposal problems if they're not utilised. Poorly managed disposal sites have resulted in numerous environmental catastrophes (Ruhl et al., 2010). Utilising PFA thus appears a win-win situation: it avoids precarious, costly disposal challenges, and substantially reduces cement consumption and hence the emissions associated with concrete.

However, it is clearly problematic to have the carbon reduction strategy of a major global industry like concrete dependent upon a high-carbon, coal-based energy system (Millward-Hopkins et al., 2018). And, crucially, PFA derived from biomass is typically not suitable to substitute high quantities of cement (Iacovidou et al., 2017a; Kalembkiewicz and Chmielarz, 2012; Sarabèr, 2012); burning biomass changes the chemical composition of the ash such that it reduces the durability of the concrete.

Furthermore, PFA is now an internationally traded commodity with non-negligible value: it is regularly shipped from the Far East to the USA, and from Europe to the UK (Harris, 2017). The economic value has been growing and, along with it, the significance of the revenues it brings to coal-based electricity producers (Millward-Hopkins et al., 2018). In this sense, sales of PFA now make coal power more financially viable, albeit in a minor way.

Clearly, it is no longer appropriate to consider PFA a *waste*; it should instead be considered a *resource* and hence it should be allocated a proportion of the CO_2 emissions associated with electricity production. However, it is still considered a 'carbon neutral' material by most stakeholders: When coal-based electricity production produces PFA that is then utilised in concrete (or cement) production, none of the upstream carbon emissions from electricity are assigned to the concrete, under the assumption that these ashes are 'wastes' that would have arisen whether or not the concrete producer wanted them (Imbabi et al., 2012).

3. Discussion

3.1. Contested responsibilities

The practices of using wood pellets for electricity generation and PFA in cement and concrete production share the important similarity of utilising a material that was previously disposed as a waste. But the methods of carbon accounting in regulatory and industrial practices are reversed in each case.

Electricity producers that utilise biomass derived from wood-waste want to be allocated a share of the carbon benefits occurring upstream in the timber industry through carbon sequestration, even though their own statements suggest that the revenues offered to – and thus the market linkage with – the timber industry may be insignificant (Drax group, 2018a). And this is how regulation has been implemented; waste-wood is considered zero carbon in Europe (EU Renewable Energy Directive; 2009/28/EC) and now also in the USA (Heikkinen, 2018). In a different part of this system, concrete producers who utilise waste coal-ash don't want to be allocated any share of the carbon impacts occurring upstream in electricity generation, even though the revenues they offer to electricity producers are increasingly non-negligible (contributing around 5%; Millward-Hopkins et al., 2018, Seto et al., 2017). And this is exactly how emissions accounting is undertaken when carbon reduction targets and mitigation roadmaps are drawn out by cement and concrete industry associations (MPA, 2013) and global research institutes such as the International Energy Agency (IEA, 2017).

If established lifecycle methods were applied things may look very different. Standardised LCA procedures (ISO 14044:2006) indicate that when a primary process – be it a factory or a forest – produces a 'waste' or co-product, an allocation of primary process emissions to the co-product is only necessary when it contributes more than 1% to the total revenues of the process. Thus, if wood pellet manufactures really are 'bottom feeders' to the timber industry, it is very likely that they contribute less than 1% to the revenues of these timber forests – either at the aggregate level, or at least in any regions in which waste arising are relatively small and the value of timber high. By definition, then, they should take no credit for their carbon sequestration activities.

However, neither in the case of waste-wood nor that of PFA has such a revenue-based approach been used to inform regulations or carbon accounting decisions, even though useful studies exist in the literature (Guinée et al., 2009; Röder et al., 2015; Seto et al., 2017; Millward-Hopkins et al., 2018Instead, assumptions have been made that have ended in decisions that suit each industry's' interests.

3.2. Counterfactuals

This line of argument doesn't imply that either the replacement of coal with wood-waste, or the replacement of cement with PFA, are bad ideas from a climate change perspective. Rather, it implies that the carbon sequestered by waste-wood is potentially irrelevant, and utilising PFA may have subtle consequences for transitions away from coal-power that need to be closely examined.

Regarding biomass, this re-orientates the debate in the appropriate direction. The carbon credentials of waste-wood need be assessed only relative to the counterfactual: what will happen to it if it's not turned into pellets and shipped across the Atlantic? This is where it gets complicated, but the system is increasingly well understood.

Drax, for example, report that their input is currently 40% forest residues, 40% sawmill residues, and nearly 20% thinnings (Drax Group, 2017).

Broadly, using fine forest residues to manufacture wood pellets – which will otherwise be left in the forest to decompose, releasing their carbon within a few years – can offer carbon savings relative to fossil fuels (Giuliana et al., 2012). Using larger residues for wood pellets – like stumps, which are slower to decompose – may not have the same benefits. Recent studies have suggested that, from the point of view of keeping CO_2 out of the atmosphere, it's better to leave these in the forest than burn them (Booth, 2018; Law et al., 2018). This is hugely important as the IPCC's 5th assessment report finds that forestry and agricultural residues may offer an energy resource approaching the magnitude of that offered by dedicated bioenergy crops (IPCC, 2014). While the IPCC distinguishes the carbon benefits and impacts of using fine and coarse residues, respectively, they do not recognise UK government findings showing that forestry experts report that pellet manufacturers generally favour larger residues, as finer residues are far more difficult and expensive to recover (Howes et al., 2016). Indeed, the many published studies that report the carbon benefits of harvesting fine forestry residues for bioenergy may be lent upon by large-scale bioenergy users to justify their low-carbon credentials, even if they are aware that fine residues are far from their primary source of fuel.

The impacts of using sawmill residues to produce wood pellets are also not clear. Such residues can be made to look very low-carbon as, historically, they were burnt in huge 'wigwam burners' with no recovery of energy and no attempt to capture hazardous particulate emissions. Replacing fossil fuels with sawmill residues appears a very reasonable option if this is considered their alternative fate. But that's not a very reasonable baseline; other disposal options should be considered instead. Counterintuitively, it may be more climate-friendly to leave sawmill residues to decompose in landfill: recent research suggests that wood decomposition in landfills may be much slower than was previously thought (O'Dwyer et al., 2018).

Thinnings are perhaps the most controversial source of wood-waste for pellet manufacture (Booth, 2018). The perspective of many biomass advocates is that small trees, which are normally thinned out of the forest to make the rest healthier, are a harmless, sustainable source of wood for pellets. But clearly the definition of thinnings can be contorted to rationalise harvesting more trees. And even looking beyond this, there are obvious time issues – whole trees would take decades to decompose if permitted to, yet burning them releases carbon immediately.

Accurately determining when waste-wood is appropriate to convert to biomass, from both a climate and broader ecological perspective, is clearly a complex task. But our intention here is not to offer concrete answers to this question. Rather, we aim to shift debate in the right direction and highlight how, in this case, the method of assigning emissions responsibility has been shaped by industry interests, rather than being guided by objective evidence and established carbon accounting techniques.

4. Conclusions and policy implications

The two case studies we have briefly described highlight the contested nature of allocating environmental impacts to products and industries in highly connected systems, in which materials previously considered wastes have become increasingly valuable resources. Given the momentum towards moving to a more circular economy – in which resources are recirculated and their technical value maintained for as long as possible (Iacovidou et al., 2017a, 2017b) – the need for such decisions to be made will, by definition, become far more frequent (Guinée et al., 2009); connectedness between industries will continue to intensify and ever-more process 'wastes' will find a market. Without well-informed policy design, it is clear that accounting frameworks can easily be designed which support activities and industrial transitions that appear to be aligned with a low-carbon or circular economy agendas, but are far from optimal.

In the case of pulverised fly ash from coal, there is no doubt that using this to replace cement is a sensible activity once the ash has already been produced. But it is necessary to ensure that this doesn't offer (1) a non-negligible incentive for coal-power producers to continue their high-carbon activities, or (2) an excuse for producers and consumers of concrete to devote too little attention to deeper (and essential) objectives such as material efficiency (Allwood et al., 2012). This is particularly true given the availability of suitable quality ash is dropping owing to (ironically) the replacement of coal by biomass.

In the case of waste-wood-based biomass, regulation offers a strong incentive to burn waste that, from a climate change perspective, may very often be better off left in the forest or disposed to landfill; in other words, better off dealt with by means further down the 'waste hierarchy'. From this perspective, the transition to such biomass with its highly questionable sustainability credentials is not so much a failure of land use management, conservation efforts or related policies – it is a failure of circular economy principles to produce positive outcomes, due to the distortion that follows their application within a political landscape shaped by industry interests.

In this short article, we have intentionally been more descriptive than prescriptive. But we hope that we've offered a reality check into how the politics of emissions responsibility may evolve under low-carbon and circular economy agendas given current trends. Unless such tendencies can be broken, it will be impossible to distinguish where measured progress towards a more environmentally sustainable future is real, from where it's an artefact of accounting systems hijacked by industries attempting to shape the agenda to gain themselves a competitive edge.

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