Pluralizing and Problematizing Carbon Finance

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Abstract

Growing emphasis on finance as key to decarbonization requires social science research that critically attends to the emergent and diverse forms taken by carbon finance. First, we pluralize research into carbon finance, building on existing work to identify four main forms: carbon markets; ecosystem services; natural capital investment; and, capital allocated to low-carbon enterprises and projects. Second, we propose that research should problematize the processes through which carbon is variously translated into financial value. Illustrated with reference to low-carbon investment in electricity generation, our agenda thereby extends from the difficulties of producing carbon-as-commodity to the uncertainties of constituting carbon-as-asset.

Keywords: carbon markets; ecosystem services; low-carbon investment; commodification; assetization;

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23 **I Introduction: from carbon markets to carbon finance**

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25 The strategic significance of financial markets to climate change policy was confirmed at COP21 by the
26 Paris Agreement of 2015 (Andresen et al., 2016). As stated in Article 2, the Paris Agreement entails a
27 commitment to 'making finance flows consistent with a pathway towards low greenhouse gas emissions and
28 climate-resilient development'. Financial markets are positioned within climate change governance as key to
29 unlocking action to prevent global warming in excess of 2 degrees Celsius by enabling investment in a low-
30 carbon transition at scale. It is estimated, for instance, that an additional $800 billion of investment in low-
31 carbon activities will be required each year in order to stay under this threshold (Campiglio, 2016; European
32 Commission, 2018; McCollum et al., 2013; Global Commission on the Economy and Climate, 2016). However,
33 current investment levels fall well short of what is calculated as necessary to meet global targets (Buchner et
34 al., 2017; Campiglio, 2016), despite the unprecedented policies of cheap money pursued by the leading central
35 banks in the wake of the global financial crisis and the recent expansion of financial markets that are variously
36 termed 'green' (City of London Corporation, 2016), 'sustainable' (DB Climate Change Advisors, 2012), or
37 'environmental' (Bertl, 2016). The growing emphasis on 'finance flows' as a means to decarbonization is
38 significant, nonetheless. It not only marks a significant shift away from carbon trading and heralds a
39 recognition of its limitations as a market-based strategy for low-carbon transition (Bryant, 2018; Ervine, 2014;
40 Lane and Newell, 2016), but also requires a critical social science agenda capable of attending to the diverse
41 forms of what we term 'carbon finance' that are now being mobilized towards this end. In this paper we seek
42 to both *pluralize* the understanding of carbon finance within human geography and the social sciences, and to
43 *problematize* the various processes through which carbon is translated into financial value.

44 First, we seek to map out the terrain of multiple and relatively discrete forms of carbon finance that
45 explicitly seek to act on carbon emissions alongside the extraction of financial value. We adopt the term carbon
46 finance to expressly avoid confusion with the alternative rubric of 'climate finance' that conventionally and
47 narrowly refers to donor funding or development aid consistent with the principles of the United Nations
48 Framework Convention on Climate Change (UNFCCC) (Ballesteros et al., 2010; Clapp et al., 2012; Godinot et
49 al., 2017; World Bank, 2017). To delineate carbon finance, we draw into conversation literatures on the
50 governing of climate change, the political and cultural economies of carbon markets, and wider bodies of
51 research concerned with 'neo-liberal natures' (Bigger and Dempsey, 2018) and the 'financialization of nature'
52 (Ouma et al., 2018). While it is indeed the case that, as Felli (2014: 252) observes, "the climate governance
53 'regime' appears extraordinarily complex, specialised, even unfathomable", this body of work enables us to
54 identify the principal forms which carbon finance adopts as its strategic significance grows within that regime.

These include: markets that price and trade emissions rights (Callon, 2009; Knox-Hayes, 2016; McKenzie, 2009; Lovell, 2015) and ecosystem services (e.g. Asiyanbi, 2016; Corbera, 2012; Fletcher et al., 2016; Gupta et al., 2012); forms of investment in natural capital designed to generate value through conservation and carbon sequestration (Dempsey, 2015; Fairhead et al., 2012; Kay, 2018; Sullivan, 2018); and, raising capital expressly for low-carbon investment in enterprises, projects and initiatives (Bracking, 2015; Christophers, 2016, 2018; Karpf and Mandel, 2018), especially to provide for the greening of urban infrastructures (Castree and Christophers, 2015; Knuth, 2018a) and the renewable and 'clean tech' energy sectors (Hall et al., 2017; Knuth, 2018b; McCarthy, 2015).

Our second motivation in this paper is to problematize carbon finance in all of its different forms. In the context of contemporary climate change governance, problematizing carbon finance is essential if we are to move beyond narrow questions about the scale of finance flows that - animated by assertions of a 'carbon finance gap' between the size of the decarbonization challenge and the current levels of finance being directed towards it - tend to preoccupy policymakers. In the first instance, 'problematization' is a methodological approach (Foucault, 2003). It directs our attention to consider how the problem of climate change is itself rendered governable in such a way that carbon finance appears capable of providing for solutions and securing the future of life (Langley, 2019). As Sullivan (2018) has shown for investment in biodiversity and ecosystem services, for example, the method of problematization lends itself to the grounded investigation of the conditions of possibility and practicalities of carbon finance. Such a method is also broadly consistent with wider calls for a more pragmatic research orientation to the financialization of nature (Castree and Christophers, 2015; Ouma et al., 2018), particularly one that suspends theoretically-driven judgements on the systemic contribution of capital switching via the financial markets for addressing the 'second contradiction of capitalism' and providing a purported 'socio-ecological fix' (Ekers and Prudham, 2015; see Harvey 1978, 1982). Notwithstanding that carbon finance is conducted on the basis of the maximization of (albeit more sustainable) capitalist growth, problematization is a method that questions the privileged role of carbon finance in meeting the challenges of climate change and which pragmatically centres on the relational processes, contingencies and limits of the various and discrete forms taken by carbon finance.

Our agenda for problematizing carbon finance is thus also an intervention in theoretical and conceptual debates that are present across the literatures we bring into conversation here. We will develop two related lines of argument that cut across the political economy and cultural economy approaches which dominate the literature. First, the critical analysis of carbon finance as a broad research terrain requires specific attention to the variegated processes through which carbon is incorporated into the extraction of financial value. Considerable work is necessary for carbon - as a material and discursive quality (e.g. high vs. low-carbon) - to be translated into financial value. We take seriously, then, recent arguments which stress that even though the abstraction of value from its material forms is a necessary part of the financialization of

nature, “it is vital that we do not portray the environment as a flat terrain over which financial investment can be unproblematically stretched” (Kay 2018: 172; see also Asiyanbi, 2017). The materiality and spatiality of carbon matter to the ways in which carbon finance is made, and to the political economies it enables. While we draw on a broader literature concerning the financialization of nature that stresses the “frictional encounters of finance and nature” (Ouma et al., 2018: 501), we focus specifically on the frictions that arise from carbon’s particular social, political, spatial and material qualities.

Second, no single category can adequately conceptualize the contingent processes through which carbon is translated into financial value across carbon finance’s multiple forms. Although it is now widely questioned by political economists who have recently settled on the category of ‘rent’ for analysing the extraction of financial value from nature (Andreucci et al., 2017; Felli, 2014), we find commodification provides for an effective conceptualization of processes of carbon finance that feature speculative trading, especially when rights to emit carbon are priced and exchanged on carbon markets. However, speculation on carbon is but one mode of financialized accumulation on nature (Bryant, 2018; Ouma et al., 2018). Recent research into investment in natural capital and low-carbon technologies and infrastructures – some of which explicitly conceptualizes the extraction of financial value in these forms of carbon finance as ‘rent’, and some which does not - is pointing to the important ways in which carbon is figured as an ‘asset’ that can generate future revenues, and thereby act as collateral for the leverage of debt and creation of interest-bearing capital (Kay, 2018; Knuth, 2018a, 2018b; Sullivan, 2018). Our conceptual contribution explicitly connects this research with an emerging body of work in cultural economy that, via the categories of ‘assetization’ and ‘capitalization’, furthers critical analysis of economization processes that leverage debt for capital investment (Birch, 2017a, 2017b; Muniesa, 2017; Muniesa et al., 2017; Ouma, 2016, 2018). Assetization is the process of turning all manner of things into “*capitalized* property” that generates an income stream and entails liabilities and obligations (Birch, 2017a: 468, *original emphasis*). It is thus inseparable from capitalization as “a technique for prospective valuation” (Muniesa et al., 2017: 12), wherein, from the perspective of the investor, “financial value amounts to a future return anticipated through a calculation of the cost of capital rather than to a ‘price’ given to the asset on the market” (Muniesa 2017: 449). We seek to contribute, then, to calls for further research into how nature comes to be regarded as an investable proposition (Ouma et al., 2018), but suggest more rigorous understanding of these processes in carbon finance also requires insights from studies of assetization and capitalization in other domains. In sum, our agenda for the problematization of the processes of carbon finance in all of its forms extends from the relatively well-known difficulties of making carbon-as-commodity to the presently under-researched impediments of producing carbon-as-asset.

The remainder of the paper is divided into five sections. Section II reviews research on carbon-as-commodity within human geography and allied fields. Section III turns to consider research that questions the relevance of commodification processes for critical understanding of the extraction of value across carbon

finance. We explain why we want to retain a concern with carbon-as-commodity whilst, at the same time, developing a conceptualization of carbon-as-asset through the cultural economy literature on assetization and capitalization. Section IV illustrates our agenda for pluralizing and problematizing carbon finance by focusing on a key form of carbon finance – raising capital for low-carbon investment – that has received comparatively little attention to date. Our specific focus is on low-carbon investment in electricity generation, and we draw critically on applied and policy research to tease out some of the difficulties of rendering carbon-as-asset in this domain of carbon finance. Section V offers concluding reflections on how an agenda that pluralizes and problematizes carbon finance can be taken forward in human geography and related fields.

II Commodifying Carbon

Carbon markets price and trade two kinds of carbon credits: allowances, which are permits for regulated organizations to emit carbon dioxide; and offsets, transferrable credits that result from reduced emissions. That legally defined rights to emit carbon could be made to hold value in markets was initially recognised during the 1990s, leading to the suite of economic instruments that accompanied the 1997 Kyoto Protocol, including the Clean Development Mechanism (CDM) and various voluntary offset schemes. Development of carbon markets continued apace with the formation of the EU Emissions Trading Scheme (ETS) and various other regional carbon markets based on carbon allowances, including in Australia, China, Canada and the USA. Carbon markets are widely envisaged as a response to 'negative externalities' - i.e. the emissions that are produced but not owned by market actors. Producers are incentivised to not only reduce emissions, but also to 'direct investment into lower-carbon technologies' (Keohane, 2016: 27). As with all forms of market exchange, however, carbon markets rely on creating carbon as a commodity that can be priced and traded. Commodification, therefore, has been the primary focus for critical geographical and social scientific research over the past decades into the making of carbon markets.

Research on carbon's commodification has been shaped by two broad perspectives: political economy and cultural economy. Those working within the tradition of geographical political economy have approached carbon markets with an eye for the dynamics of commodification they set in train, informed by wider interests in the forms of appropriation (property) that underpin the creation of markets and the growing role of "nature as accumulation strategy" (Smith, 2006). Others highlight more directly how carbon's commodification has created specific opportunities for finance capital, and the constellation of financial actors associated with the promotion, implementation and monitoring of carbon markets. Janelle Knox-Hayes (2016), for example, skilfully shows how the market infrastructures that produce carbon-as-commodity divorce the use value of resources from the exchange value of financial instruments, unleashing a financialized form of accumulation centred on speculation around fluctuating prices (see also Bigger, 2016; Knuth, 2015). A related line of political

economy inquiry examines how markets for carbon and ecosystem services enable accumulation, but at the expense of landscapes and communities drawn into the production of carbon offsets or reliant on such ecosystem services for their livelihoods and survival (Bachram, 2004; Bumpus and Liverman, 2011; Fairhead et al., 2012; Paterson, 2010). Bumpus and Liverman (2008), for example, argue that offset schemes rely on existing patterns of uneven development to find 'efficient' forms of carbon reduction, enabling a process of "accumulation by decarbonization" in the global North through production of carbon credits in the global South.

Research on the commodification of carbon from a cultural economy perspective has also addressed carbon markets and markets for biodiversity and ecosystems services. It points to the development of elaborate apparatus through which carbon is either made into a unit commensurate with both other sources of (reduced) emissions and with monetary worth, or which enable the capacities and qualities of a range of entities (from forests to houses) to forego (future) carbon emissions to hold value. This suggests that processes of carbon-as-commodity take multiple forms around which different kinds of economy are assembled, allowing for (and excluding) different kinds of socio-material relations and their outcomes. Here the seeming intangibility of carbon has led to a focus on the performative socio-technical processes through which carbon is commodified (Callon, 2009; McKenzie 2009). Because "carbon is a new and unusual commodity", cultural economy thus emphasizes how "credible systems of measurement and calculation are especially important" to the development of carbon finance (Lovell, 2015: 127; see also Asiyanbi, 2017). The stabilization of carbon-as-commodity requires significant work, as Lovell (2015: 127) explores in the context of the forest carbon market where marketization "has been, to date, almost entirely centred on debates about the measurement, reporting and verification of the carbon stored in forests".

The complex processes of carbon-as-commodity are tied up with the nature of carbon itself. Rather than being a commodity in the strictest sense of being a good that can be bought or sold, the trading of carbon is more like the buying and selling of services – where the service is the calculated and qualified ability to contribute to reducing atmospheric carbon. The development of markets around the potential of forests and land cover to sequester carbon from the atmosphere has attracted sustained critical attention, particularly the rapid development of so-called Reduced Emissions from Degradation & Deforestation schemes (REDD, or REDD+ where additional sustainability benefits are involved) (Asiyanbi, 2016; Corbera, 2012; Fletcher et al., 2016; Gupta et al., 2012). As one of a number of processes that have expanded through the development of the concept of ecosystem services and its circulation in global environmental governance, REDD schemes may well be an example of "accumulation by conservation" (Büscher and Fletcher, 2015). Work in cultural economy, however, reveals the complex set of calculations and translations required for forests (and other ecosystems) to generate financial returns from for the 'services' they provide.

Reading across the political economy and cultural economy literatures that foreground the processes of carbon-as-commodity in carbon markets and ecosystem services, we can highlight two insights that are particularly relevant for problematizing the processes of carbon finance. First, research has shown how commodification is a precarious achievement, "a process of ontological reconfiguration through which different qualities of nature and resource-based production are translated into a financial value form to be traded in specialized markets" (Ouma et al., 2018: 2). The key point here is that value is neither latent in material things (an inherent property, awaiting capture) nor a product of discursive claims (a projection onto the world), but an achievement that entails bringing materialities, relations and discourses into alignment. Through the production and maintenance of these alignments, carbon can be made to bear value as a commodity that can be priced, traded and speculated upon. In turn, the performativity of markets should not be read (only) as an abstract set of techniques or forms of calculation by which carbon comes to be made valuable and fungible, but also as "practices that are imbued with a materiality … [such that they] become material interventions into how economic action unfolds" (Lansing, 2012: 207).

Second, research into the peculiar 'immateriality' of carbon-as-commodity highlights processes of abstraction and "matters of measure" that are "used…to define adequate bearers of value" (Robertson, 2012: 388). Early work on markets in ecosystem services commented frequently on their strangely 'immaterial' character - i.e. how value is expanded not by the circulation of carbon per se, but by the exchange of a qualified abstraction acting as a proxy for an environmental service. However, as Robertson (2012) points out, markets in ecosystem services only look peculiar because we are accustomed to value circulating in the form of physical commodities (such as copper, coal or grain). Furthermore, he argues, the reason we see this as the normal way of things is that getting many classic materials (like coal) to bear value requires their physical displacement. Or, to put it another way, capital has been unable to figure out a way to commodify coal without its physical extraction and circulation. Ecosystem services, on the other hand, can be made to bear value in ways that do not require physical circulation of the underpinning materials: markets for ecosystem services rest on "the creation of a set of general abstractions adequate to allow nature to circulate – not just as commodified bits of material, but as financial and service commodities" (Robertson, 2012: 388). By taking seriously the "process of creating socially-necessary abstractions that are adequate to bear value in capitalist circulation", Robertson (2012: 386) opens up for discussion the different forms in which carbon can be made to bear value, the techniques of classification and categorization through which this occurs, and the "the work (that) must be done to convince observers that these simplifications are adequate to the task of representation" (ibid., 396). At the same time, recent research demonstrates that while such processes of abstraction are essential and often centre on the making of nature as 'natural capital' (Sullivan, 2018), they are also shaped by the spatiality and materiality of the commodities/services themselves. In her account of the development of conservation finance in the US, for example, Kay (2018) shows how different practices of

abstraction, qualification and circulation were developed in relation to rangelands and woodlands, creating different vehicles for investment and for capital accumulation.

III From carbon-as-commodity to carbon-as-asset

We find commodification provides an effective conceptualization of processes of carbon finance that feature speculative trading on prices, even though achievements of carbon-as-commodity tend to be experimental and incomplete. Yet whether carbon markets are indeed a matter of commodification is moot (Bigger and Demspey, 2018). Felli (2014) argues, instead, that emission allowances and carbon offsets are a kind of 'climate rent'. His Marxian analysis hinges on the distinction between accumulation via commodity production (i.e. creation of value through expanded reproduction) and accumulation via the appropriation of value produced elsewhere (or what Harvey (2003) terms "accumulation by dispossession"). Felli (2014: 271) observes that the right to emit greenhouse gases has "legally become a necessary condition of production", "both a limitation and a right of access" for capitalist commodity production. As a consequence, "the distribution and circulation of (carbon allowances) through market-based mechanisms" should not be understood as speculative accumulation on carbon-as-commodity, "but rather as a form of rent" (2014: 254). Felli's intervention has stimulated a growing body of work on financialization and nature that foregrounds "the circulation of money and profit through non-productive forms of value appropriation" via the conceptual category of 'rent' (Andreucci et al., 2017: 28; see also Kay, 2018, Kay and Kenney-Lazar, 2017; Knuth, 2015).

We read Felli's (2014) objections to the efficacy of the concept of commodification as productive for the problematization of carbon finance in three main ways. First, Felli (2014) reminds researchers that the critical analysis of carbon finance needs to recognise the significance of acts of sovereign power, an argument that is consistent with wider calls for analyses of the financialization of nature to engage with "the multiple roles of the state in mediating the circulation of finance in and through nature" (Ouma et al., 2018: 500). Felli's (2014: 251) starting point is that rights to emit greenhouse gases created through international law are actually "a form of public property" rather than commodities, such that the unequal distribution of these legally defined rights amongst states "amounts to the distribution of rights to climate rent". More than simply affirming the systemic role of the capitalist state in securing the conditions for expanded reproduction (Felli, 2014: 255-6), Felli highlights how specific juridical techniques and regulatory provisions are necessary (alongside socio-technical achievements and abstractions) for carbon to be translated into financial value.

Second, Felli's (2014) novel account of the carbon market encourages us to specify more precisely what the concept of commodification brings to critical analysis of carbon finance. Here we underscore how commodification centres attention on the extraction of value through speculative trading on the price of things that have been made exchangeable. Rights to emit carbon may be analogous to land as property and have no

value in strict Marxist terms, as Felli argues, but they nonetheless do have a use- and exchange-value. In other words, Felli's analysis does not foreclose the critical purchase of commodification for understanding speculative trading within carbon markets. In Kay's (2018) detailed study of the emergence of conservation finance in the US, for example, such schemes are shown to feature arbitrage pricing that depends upon existing markets for land and other physical commodities. Precisely because it centres attention on speculation, the concept of commodification is similarly important to Bryant's (2018) nuanced analysis of the development of the EU ETS. He is clear that, notwithstanding the processes of carbon-as-commodity, "to date, carbon has become capital only occasionally rather than systemically" due to the political conditions of its making and its persistent low market worth (ibid., 615). Carbon markets are therefore not witnessing the leveraging of debt against carbon (i.e. they have not enabled interest-bearing capitalization). In practice, the logics and mechanisms of carbon commodification have developed in ways that allow for only the restricted and speculative extraction of financial value.

Third, we regard Felli's (2014) contribution to be productive for the problematization of carbon finance because it highlights the need to go beyond the category of commodification for understanding processes of carbon finance. His analysis points to how other political economies – in this case, of rent extraction and circulation – are constituted, at least in part, through the translation of carbon into financial value. It is clear for Felli (2014) that these processes rest primarily on the making of property relations. However, it is significant, we suggest, that others developing Felli's (2014) analysis tend to slide from his concern with property rights and "pseudo-commodities" into a concern with 'assets', a category that Felli does not use in his essay. For Andreucci et al. (2017: 33), for example, accumulation by dispossession and rent-seeking include processes that create "Pseudo-commodities … as socio-ecological assets that can be incorporated within private property regimes, such as carbon credits, patents on genetic material, ecosystem services, and so on." Recent research into investment in natural capital and low-carbon technologies and infrastructures – some of which explicitly conceptualizes the extraction of financial value in these forms of carbon finance as 'rent', and some which does not - is also pointing to the important ways in which carbon is figured as an 'asset' (Kay, 2018; Knuth, 2018a, 2018b; Sullivan, 2018). This work recognises the creation of assets that can generate future revenues as crucial to the extraction of financial value, not least because assets simultaneously act as collateral for the leverage of debt and creation of interest-bearing capital. Sullivan (2018: 56), for example, explores how framing nature as 'natural-capital' has led it to being considered more or less literally as "a bank of financial assets … [or] 'countable capital'". In this sense, nature (and carbon more specifically) come to be regarded as 'financial' when they attract financial investment, that is, when they become 'assets'.

To advance this analytical turn towards processes of asset-making taking place across different forms of carbon finance, we suggest that it is productive to connect with emerging cultural economy research that explicitly articulates the categories of 'assetization' and 'capitalization' (Birch, 2017a, 2017b; Muniesa, 2017;

Muniesa et al., 2017). Others are also beginning to forge this connection in relation to the financialization of nature, broadly understood (Ouma, 2016, 2018). For Ouma et al. (2018: 501), then, nature's financialization is "linked to the more general assetization of almost everything" (see Leyshon and Thrift, 2007). For us, however, the key point from this emergent cultural economy work is that the contingent processes that turn carbon into assets are quite different to the making of carbon-as-commodity. This is because, in contrast with commodities, assets are always already "*capitalized* property" (Birch, 2017a: 468, *original emphasis*); that is, they leverage debt against an expected income stream and necessarily entail liabilities, repayments and other obligations to investors.

To be regarded as an investable proposition in the first instance, an asset is deemed to be capable of bearing financial value not primarily because of its potential use- or exchange-value (although it might subsequently be commodified and speculated upon as a transferable ownership claim). The process of 'becoming asset' is primarily a matter of the potential to generate future returns on capital (Muniesa et al., 2017: 128-131), regardless of whether the assets in question are capitalized through the issuance of loans, debt instruments or other securities. Indeed, such is the difference between the valuation processes of commodification and assetization that, for Muniesa and his colleagues (2017), the separate category of 'capitalization' is used to refer to the processes of prospective valuation – both by and for investors - that are integral to assetization. It is the streams of repayments and other obligations inherent to financial assets which, strictly speaking, ensure they are not property relations as such, but are actually investor claims on credit-debt relations. Contrary to Andreucci et al. (2017), we thus find that the analogy that Felli (2014: 268) draws between property relations for land and rights to emit carbon is not easily generalizable to the relational processes of carbon finance and the financialization of nature. While each enable rentiership broadly understood as the extraction of value by owners of resources (Birch 2017b), contingent assetization processes are nonetheless not the same as making things into property rights.

In sum, the extraction of financial value across the various forms of carbon finance certainly features secondary trading and speculation on prices, and focusing on the contingent processes of carbon-as-commodity is crucial to the problematization of carbon finance in this respect. However, this should not obscure significant differences between capital and (pseudo-)commodity marketizations, regardless of how 'immaterial' and speculative the commodity markets in question might be. The problematization of carbon finance therefore also needs to be attuned to the production of carbon as an 'asset class' (see Kay, 2018), foregrounding the exigencies of assetization and capitalization processes and the difficulties of rendering carbon-as-asset. Crucial to the juridical and socio-technical achievements and abstractions that stabilize carbon-as-asset, we argue, is capitalization: that is, how a specific carbon sequestration initiative or low-carbon investment is deemed valuable and able to realize returns because it is capable of bearing debt.

IV Making carbon-as-asset: investment in low-carbon electricity generation

In this section of the paper, we concentrate on an important form of carbon finance that - compared to carbon markets, payments for ecosystem services and investment in natural capital - has received relatively little attention in human geography and social science research: the raising of capital for low-carbon investments in enterprises and projects (cf. Bracking, 2015; Christophers, 2016, 2018; Karpf and Mandel, 2018; Tripathy, 2017). Our aim is to illustrate our agenda for problematizing carbon finance, especially as it mobilizes the insights from the literature we developed above and pertains to the processes of carbon-as-asset that are at the heart of low-carbon investment. Specifically, we focus on low-carbon investment in the renewable energy sector and, in the interests of brevity, we concentrate on the USA and UK where energy provision is largely already privatized and marketized. The energy sector's contribution to global greenhouse gas emissions has made it a logical first target of public and private initiatives aimed at a low-carbon transition. As revealed by existing critical research (e.g. Eadson and Foden, 2018; Mazzucato and Semieniuk 2018; McCarthy, 2015; Webb and Hawkey, 2017), decarbonization efforts in the energy sector tend to target electrical power generation, given the prevalence of large point-source emissions (e.g. coal-fired power stations), concentrated patterns of ownership (e.g. utility companies), and opportunities for shifting investment towards renewable energy sources. Conventional narratives around energy and climate change governance also identify a 'finance gap' in this domain, and highlight the challenges of turning low-carbon forms of energy into investible propositions (Hall et al., 2017; Webb and Hawkey, 2017).

Low-carbon investment in the power sector is a process of assetization that turns, first, on classifying and categorizing the carbon qualities (low/high) of different forms of electricity generation by reference to regulatory, market or other governance criteria; and, second, on assembling assets that qualify against these criteria – i.e. forms of capitalized property which yield an income stream, and which are sufficient to bear debt. The first dimension ensures the low-carbon qualities of the investment are a crucial consideration, but certainly does not guarantee they will figure in the related valuations and associated calculations about the cost of capital. Put another way, low-carbon investments in renewable electricity generation are not collateralized against future low-carbon impacts in ways that would parallel social impact bonds and environmental impact bonds (which only make payments to investors when measureable targets for the impact performance of the capitalized projects in question are met (Christophers, 2018; Langley, 2018a).

A broad body of applied and policy work in this domain speaks to the processes through which low-carbon assets are constituted in the power sector. This research leads us to make four general points about the production of carbon-as-asset that are especially relevant to our research agenda for problematizing carbon finance. First, assetization processes in low-carbon electricity generation do not take a singular financial and organizational form: low-carbon 'becomes asset' via several financial mechanisms and

organizational structures. A range of structured debt, bond issues and equity models have also emerged, bringing lower costs of capital to the renewable energy sector (EWEA, 2018). We interpret this profusion of financial and organizational structures as experimentation with alternative assetization processes for unlocking income streams and attracting investors to the sector. Capital market creation is an incomplete and adaptive process in the renewable energy sector (Hall et al., 2017), with new actors and organizational structures emerging over time in response to policy shifts (e.g. in relation to energy price support and taxation) and broader developments in capital markets. That said, experimentation in the US and UK has largely centred on two models of assetization to date.

In the more widely used project finance model, assetization occurs at the level of a specific project (e.g. a wind farm or solar park): project developers establish a special purpose vehicle (a legal entity to undertake the project) and debt is raised against future sales of electricity from the project. Thus, the capitalization of low-carbon investment in the electricity generation sector is not simply "a dual process of valuation" (Muniesa, 2012: 31) that centres on the current and future economic prospects of the corporations and institutions involved. This is because project finance is provided on a limited or non-recourse basis – i.e. investors' claims as creditors are restricted to the assets and income streams of the new project, and do not extend to the wider assets and cash flows of the consortium of companies that own and operate the project (Finnerty, 2013; Langley, 2018b). In this way, project financing of a low-carbon asset works "like a giant mortgage" as the only security for the loan is the project itself (EWEA, 2018). The project model brings together a consortium of actors (project developer, operator, contractors) with debt finance typically provided by a bank. Since the global financial crisis, however, bank lending to renewable energy projects has sharply reduced and key lending terms (such as the loan period) have tightened. In its place, securitization and other alternative techniques of project finance have emerged and, with this, institutional investors, sovereign wealth funds and others that comprise the so-called 'shadow banking' sector have come to play a growing role. Miller et al. (2018) highlight the diverse sources of capital currently associated with low-carbon assets in North American renewable energy, including project financing via public market capital (asset-backed securities and various debt products), hybrid bond financing, and even crowdfunding. Hybrid bonds are raised against a portfolio of renewable energy projects with a common owner rather than an individual project, and address key challenges (of space and time) associated with financing renewable energy projects. A portfolio of projects – geographically distributed and utilizing different technical designs - reduces risks to revenue associated with localised weather conditions (around wind and solar power), simultaneous design faults and, if the projects are in different jurisdictions, regulatory risks (EWEA, 2018). More generally, hybrid bonds can "expand the pool of available candidates" who can finance new projects: in the US context, for example, where production tax credits are a key driver of investment in renewables (see below), these bonds reach investors beyond those with heavy tax obligations (Tang et al., 2012: 693). Crowdfunding – such as through the Abundance generation

platform in the UK – is a further example of assetization processes of project finance in low-carbon energy, although currently limited to early-stage start-ups where high risks and the lack of collateral mean project developers cannot "assemble debt finance from banks or venture capitalists easily" (Lam and Law, 2016: 12; Vasileiadou et al., 2016).

The project finance model contrasts with green bonds that, despite funding a specified project or initiative, are assets that are issued against the issuer's full balance sheet and earnings potential rather than against the specific credentials and returns of the decarbonizing project(s) to be funded. In the renewable energy sector in the US and UK, green bonds are one of the ways in which on-balance sheet funding is raised (via corporate debt, or internal cash flow management for small projects), especially where larger companies, such as utilities, have entered into renewables (Coughlin, 2012; EWEA, 2018; Hall et al., 2017). As a range of geographic research into the emergence and development of green bonds reveals (Bracking, 2015; Christophers, 2016, 2018; Clapp et al., 2015; Karpf and Mandel, 2018; Tripathy, 2017), these assetization processes are also a feature, more broadly, of low-carbon investment as a form of carbon finance. Over the space of a decade, green bonds as an example of so-called 'labelled debt' have "become a mainstream financial instrument" (Karpf and Mandel, 2018: 161), and ostensible "successor" to the CDM in the governance of climate change (Bracking, 2015: 2338). Globally, these fixed-income instruments are variously issued by corporations, banks, multilateral institutions, sovereign states and municipalities to fund specified projects and initiatives. In aggregate, they are roughly distributed between the renewable energy sector (~40 percent), retrofitting buildings and improving energy efficiency in industrial plant and processes (~20 percent), and new and renewed transport infrastructures (~15 percent) (author calculations, based on data from Climate Bonds Initiative, 2017).

A second key point emerging from the applied and policy literature attests to the work involved in assembling low-carbon-as-asset – i.e. as an abstraction and organizational form sufficient to bear debt – and how traditional sources of energy finance have found low-carbon challenging. Investors conventionally perceived low-carbon projects as illiquid and relatively high risk, involving relatively immature technologies across a limited number of sites. That green bonds are issued against the issuer's full balance sheet and earnings potential has, for example, been crucial to their appeal to risk-adverse investors in renewable energy projects (Christophers, 2016). More specifically, adapting energy finance to the material qualities of renewables has challenged processes of assetization: the intermittent and weather-dependent character of wind and solar power generation, for example, accentuates commercial risks for developers (Tang et al. 2012; Lam and Law, 2016; Miller et al., 2018). Owners and developers of low-carbon assets have created financing structures that attempts to work around the material challenges of renewables. This includes, for example, modifying the project finance model associated with conventional infrastructure and resource projects, where income streams are relatively predictable and pension funds and institutional investors have been ready to

enter into project finance. This widely-used model has been tailored for financing renewables, where revenues are subject to the stochastic variability of physical environmental systems, through a combination of organizational, calculative and regulatory adaptations.

Initially, banks provided an organizational fix that enabled project finance to take hold in the renewable energy sector, drawing on their capacity to issue long-term debt and negotiate key assumptions of the loan agreement to translate technical assessments of energy generation into expected revenues and repayment schedules. Further adaptations to the distinctive material qualities of renewables were necessary to draw non-bank actors into low-carbon project finance. On the calculative side, growing availability of operational data from projects has enabled more accurate projections of electricity production, and the use of increasingly robust algorithms for converting local weather and climate data into calculations of revenue; and in terms of regulation, price support mechanisms have evolved to bring more security to revenues. The UK government, for example, has sought – with some difficulty – to implement an approach to energy policy (and infrastructure more generally) that gives capital markets a central role (see Langley, 2018b). To further this objective in relation to low-carbon energy sector specifically, it has recently replaced a renewables incentive scheme, based on tradeable green certificates (Renewable Obligations Certificate), with a Feed in Tariff structure (via Contracts for Difference). The significance of the latter, as Hall et al. (2017: 291) explain, is that it "socialise(s) price risks by guaranteeing the subsidy support price (and)…. eliminates both the risks of the support mechanism price being defined by a relative scarcity of tradable certificates, and wholesale price risk."

This leads us to the third issue about the processes of carbon-as-asset that is, in effect, highlighted by the applied and policy literature on the financing of renewable energy: the growing involvement of mainstream investors in this discrete form of carbon finance has driven significant shifts in how assetization occurs (Hall et al., 2017). Rather than assembling a low-carbon asset sufficient to bear bank debt – characterised by long loan terms and specialist in-house/boutique knowledge - low-carbon electricity generation is increasingly assembled to perform as an 'asset class'. The renewable energy sector is certainly not alone in this respect, as the drive for the so-called 'mainstreaming' of low-carbon investment is producing similar pressures to standardize assets across the broader market for green bonds, for example (G20 Finance Study Group, 2016). The consequences of this shift in the renewable energy sector extend beyond diversification of the organizational forms and devices associated with 'becoming asset' discussed above to the ecologies of finance created around low-carbon energy. Specifically, it extends to how assetization and capitalization may "affect the direction of the evolution of renewable energy" by differentially empowering some financial actors over others (Mazzucato and Semieniuk, 2018: 11). Researchers have found significant differences in risk appetite among investors in low-carbon projects with private actors favouring "low risk

much more than public ones", highlighting the importance of understanding the consequences of privileging carbon finance as a mode of climate change governance (Mazzucato and Semieniuk, 2018: 18).

The fourth general finding we derive from the applied and policy literatures is that, as a consequence of the challenges of enacting this form of carbon finance in the renewable electricity generation sector, processes of becoming asset and capitalization feature various kinds of state interventions and public support. State support has played a very significant role in creating carbon-as-asset in relation to the energy sector, notwithstanding the way private finance in energy initially emerged via de-regulatory initiatives, limits on public sector borrowing, and the introduction of price-based competition in sectors like gas and electricity (Jensen and Dowlatabadi, 2017; Knuth, 2017). Particularly important have been a raft of public policy initiatives that includes tax credits, price support mechanisms (e.g. feed-in-tariffs) and renewable obligations (Tang et al., 2012: 693). This is illustrated, for example, by the wide-ranging mandate of the UK Government's Green Investment Bank. Tax legislation is very significant in the United States, where the Production Tax Credit available for renewable power is a key influence on techniques of project finance for utility-scale renewables projects (Bolinger et al, 2009; Bolinger, 2011; Regante, 2012; Vasileiadou et al., 2016). More fundamentally, the making of low-carbon assets rests directly on differentiations and qualifications around carbon initiated and sanctioned by the state (Bridge, 2017). These include, for example, government rulings on the technological form and scale of electricity generation qualifying for price support or tax credits; the systems of green certification around low-carbon generation it either directly supports or rules admissible in law; and enabling acts of legislation that mandate action on decarbonization, differentiate low-carbon and renewables from other forms of generation and, as in the case of the UK Climate Change Act, set carbon budgets and legally-binding targets.

V Conclusions

The landscape of climate change governance has shifted since human geographers first critically engaged with carbon finance. There is now growing realization of finance's "profound potential to remake the arteries through which capital flows and that are the lifeblood of the biological and social reproduction of most of contemporary humanity" (Castree and Christophers, 2015: 385). This paper is an attempt to respond to these developments by critically reviewing state-of-the-art research within human geography and related fields in order to advance an agenda that both pluralizes and problematizes carbon finance.

Drawing on the existing literature on carbon markets and ecosystem services, we identified key insights essential for problematizing the proliferating and multiple forms of carbon finance. The commodification of carbon is a precarious achievement inexorably tied to both the means through which it is achieved and to carbon's materialities, and abstractions and calculations are central to ensuring carbon-as-

commodity is able to bear value. From Felli's (2014) significant intervention and a rapidly growing literature that subsequently rejects a focus on commodification in favour of the production of property relations that enable rent-seeking, we draw the importance for critical analysis of the significance of sovereign power, the specific utility of commodification as a concept for centring attention on the extraction of value through speculation, and how processes of carbon finance cannot be adequately understood as commodification. To open up for analysis the forms of carbon finance that, in particular, invest in nature and raise of capital for low-carbon investment, we have built on existing research that highlights how carbon is figured as an 'asset', connecting our research agenda with wider cultural economy work that articulates the categories of assetization and capitalization to analyse economization processes that leverage debt for capital investment. From these starting points, the paper has sought to extend the problematization of carbon finance in all its forms from the relatively well-known difficulties of making carbon-as-commodity to the presently under-researched impediments of producing carbon-as-asset. Demonstrating the potential of such an approach, we turned to low-carbon investment in electricity generation, largely as it is taking place in the USA and UK. Here we highlighted how the processes of carbon-as-asset do not take a singular financial and organizational form, entail attempts to work around the material challenges of renewables, change as mainstream investors become involved, and feature various kinds of state interventions and public support.

Rather than seeking to set out a singular agenda for work on carbon finance, we would hope that our paper will generate further research centred on the diverse, contingent and problematic ways in which carbon-as-commodity and carbon-as-asset are constituted, and the consequences that this has for prospects of decarbonization. Although we have drawn attention to four main forms of carbon finance – markets for carbon allowances and offsets, ecosystem services, investment in natural capital for carbon sequestration, and the raising of capital for low-carbon investment – there are also several further forms of carbon finance that remain under-explored. For example, few studies have examined how carbon comes to be commodified beyond cap and trade carbon markets or offset schemes. Work on low-carbon housing and property markets is perhaps an exception, with research demonstrating how delivering carbon savings in this sector rests on the identification of metrics, monitoring, standardization and verification to attract investment (Edwards and Bulkeley, 2017; Lovell, 2004, 2015). Carbon savings of this kind do not function within traditional markets, but come to be commodified in quasi-markets that distribute and exchange forms of government subsidy or philanthropic donation. Often the assumption behind these forms of low-carbon qualification is that once their carbon value can be accounted for, markets will form around them. Yet so far there is limited evidence of the spontaneous formation of markets around these qualified commodities in relation to housing. Recent research suggests, however, that within certain urban markets for commercial property in the US, "many players are now working to convert green building into a resource for real estate developers, owners, and investors, and to harness those streams of green value added for new financial instruments and investment markets" (Knuth,

2015: 637). This shift is significant, in terms of our argument in the paper, as it indicates a move from away from a direct interest in the value of energy savings that can be derived from green buildings to "more speculative manoeuvring around the investment potential of green property" (Knuth, 2015: 637).

Equally, we are wary that problematizing the processes of carbon-as-asset is not narrowed to the financing of the renewable energy sector. Rather, we would want to encourage research that might investigate why carbon finance can be secured in relation to some forms of carbon – for example to its *absence* in renewable electricity generation – rather than others, such as the carbon content of the retail sector or energy-intensive industries, such as steel, plastic or cement. Similarly, we would also want to guard against the assumption that, paralleling the attention given to carbon markets by research into carbon-as-commodity, the problematization of carbon-as-asset necessarily entails a focus on processes that are solely located in capital markets. Chinese banks, for instance, are the subject of incentives and guidance by the People's Bank of China and other regulatory agencies designed to privilege loans in support of low-carbon entities and projects, and there is pressure for similar arrangements that reward the capitalization of low-carbon assets to be incorporated into the macroprudential regulation of banking elsewhere (Campiglio 2016). Banks are increasingly interested in the carbon credentials of the assets in their loan portfolios, not least because central banks are coming to regard climate change and the prospect of a sudden collapse in the valuations of carbon-intensive economic entities as material to financial stability. The Financial Stability Board's Task Force on Climate-Related Disclosures (2017) has, for instance, recently published a set of voluntary metrics and measures that seem likely to feature strongly in the processes by which banks calculate the 'high carbon' qualities of the brown assets on their balance sheets and thus the extent of their exposure to the so-called 'carbon bubble'. Climate change risk and the production of what we might term 'high-carbon-as-asset' is also presently at the heart of divestment campaigns in support of decarbonization by pension funds and other institutional investors, although it is noticeable that not all pension funds regard divestment as necessary or as the most appropriate response to climate change (Stausball, 2015). A pluralized research agenda for carbon finance that extends to problematizing the processes of carbon-as-asset can, therefore, be taken in new directions, where the pertinent questions centre on the 'unbecoming' of high-carbon assets and asset classes. What is clear, however, is that interrogating the relations between carbon's material form, its abstraction, capitalization and political economy will be key if we are to understand the potential for carbon finance to act as the 'game changer' for climate futures it is presently heralded to be.

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