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The Matter of Carbon: Understanding the Materiality of tCO_2e in Carbon Offsets

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Adam Bumpus

Abstract

This paper examines the socio-natural relations inherent in the commodification of carbon reductions as they are generated in energy-based carbon offset project activities, and abstracted to wider market systems. The ability to commodify carbon reductions takes place through a socionatural-technical complex that is defined by the material nature of technology's interaction with the atmosphere, local social processes and the evolving governing systems of carbon markets. Carbon is not unproblematically commodified: some projects and technologies allow a more cooperative commodification than others. The examples of a hydroelectricity plant and an improved cookstove project in Honduras are used as empirical case studies to illustrate the difficulties and opportunities associated with the relational aspects of carbon commodification. Drawing upon select literatures from post-structural thought to complement the principal lens of a more structural, materialities of nature analysis, the paper also outlines the reasons why carbon offset reform is needed if offsets are to more progressively engage debates about climate mitigation and North-South development.

Key words: clean development mechanism (CDM), voluntary carbon offsets, socionatures, commodification, sustainable development, Honduras

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Introduction

Carbon offsets exist as a new socio-ecological interface in the management of the environment and economy. Offsets are tools to manage anthropogenic climate change and, in some cases, contribute to international sustainable development (Bumpus & Liverman 2008; Lovell & Liverman 2010; Liverman 2009). In addition to supposedly cheap, fast carbon reductions, offsetting also speaks to ethical debates when offsets allow those who can afford it to continue to pollute (Lovell et al. 2009; Lohmann 2006; E. Boyd 2009; Vandenbergh & Ackerly 2008). Key to certain offsets is their promotion as channels of finance for local sustainable development in developing countries (Bumpus & Liverman 2008; Brown et al. 2004; Figueres 2006). Offsets are complex, and centre around the creation of emissions reductions that are then traded as tonnes of carbon dioxide equivalent (tCO_2e) on international markets (Hepburn 2009; Bailey & Maresh 2009). In contrast to emissions allowances that are allocated and either given away or auctioned by governments in cap and trade systems, offsets employ specific technologies or forestry mechanisms to reduce emissions in specific project activities. The material differences between different offset project types are significant because they enable and constrain the social relations necessary for offset production (Bakker & Bridge 2006: 21). These differences have relevance for use of offsets as effective instruments to reduce climate-forcing greenhouse gases and promote sustainable development (Bumpus & Cole 2010; Olsen & Fenhann 2008a; UNFCCC 2001). Importantly, offsets also have relevance for long-running debates and scholarship exposing dialectic interactions in nature-society relations (FitzSimmons 1989; Robertson 2006; Bakker 2005; Bridge & Jonas 2002; Castree 2003; 2008).

I approach carbon reductions in offsets as a dynamic, two-way relationship of mutual influence and adjustment between social systems and material nature (Castree 2005: 155; 2003b; 2005: 160; Boyd et al. 2001; Bakker & Bridge 2006; Bäckstrand & Lövbrand 2006; Goodman 2001; FitzSimmons 1989). The material and discursive aspects of carbon commodification are interwoven (Bridge & Smith 2003), thus this analysis aims to show how dialectical socionatural relations influence offsets in the evolution of the new carbon economy more generally (Bumpus & Liverman 2008; Lohmann 2006; Baldwin 2009; Boykoff et al. 2009; Redclift 2009; Escobar 1996; Bäckstrand & Lövbrand 2006; Oels 2005; Redclift 2009; Braun & Castree 1998). As others have shown, the significance of the biophysical world in nature-based industries has to be balanced with embracing aspects of nature's social production (Goodman 2001; Castree 1995; Bakker & Bridge 2006; Le Billon 2001; Boyd et al. 2001; Prudham 2003): capital metabolises nature into exchangeable values affecting spaces, environments and social relations across place and scale (Swyngedouw 1999; Sneddon 2007; Blaikie & Brookfield 1987; Bryant & S. Bailey 1997; Bryant & Goodman 2004). Others have shown how the biophysical properties of the non-human world also often resist these processes of commodification (cf. Bakker 2005; Bakker & Bridge 2006); firms must adapt given the technologies available, their ability to mobilise resources and local socio-ecological relations that allow nature's articulation within capitalist processes (Bakker 2003; Castree 2008b: 145). In carbon offsets, broader regulatory systems, governing mechanisms, institutions and 'tactics' are all present to manage the conflicts and contradictions in the commodification of carbon (Bakker 2009; Callon 2009; Lohmann 2009; Lovell & Liverman 2010: 3; MacKenzie 2009).

I focus here on the calculability of tCO_2e through an examination of the major material dimensions of offset technology deployment (Le Billon 2001); its specific local social relations, and the role of tools to govern reductions through carbon standards (Lohmann

2009; MacKenzie 2009). The analysis concerns the material interaction of the different *technology* types with local socionatural conditions and the calculation activities for offsetting that encourage the material and discursive components of the commodification of carbon. Rather than aiming for an *integration* of structural Marxist approaches with post-structural accounts (cf. Castree 2002), I aim to provide an account of carbon offsets that finds a more epistemological middle ground that realises the importance of complementary lenses to the problem through dialectical understanding (Sneddon 2007: 170). By better understanding the material dimensions of how carbon offset technologies interact with the environment and local social relations (cf. Lovell & Liverman 2010), we are better able to understand the linkages between the political economies and evolution of the international carbon markets, and local development implications (Bumpus 2009); important critical and practical components for the emerging carbon economy (MacKenzie 2009).

Two case studies of energy-based carbon offsets in Honduras add empirical depth to the paper, which focuses on the creation of tCO_2e for project-based (i.e. not sectoral or programmatic) offsets: a renewable energy project (small-scale hydroelectric facility), and a biomass efficiency project (improved cookstoves; ICS)[1]. As part of a broader study on the evolution of carbon offset markets, key informant interviews were conducted with carbon financiers, project developers, verifiers and communities associated with the projects. Document analysis of the case studies and direct observation triangulated the outcomes and conclusions presented here.

This analysis has two principal aims:

i. To develop an analysis of the commodification of carbon in order to explain the socionatural processes of creating a tonne of carbon dioxide equivalent (tCO_2e);
ii. To open up the dialectical tension between the international carbon market and local socionatural relations, mediated by technology type, drawing links between governance of international carbon mechanisms and 'local development' through the application of specific offset technology.

Following an explanation of my approach to the analysis, I provide a technical description of 'what carbon' is to be commodified in carbon offsets and an outline of the relationship between fundamental concepts of offsetting and project types. I then delve deeper into the processes of commodification used to create carbon reduction credits in order to develop both the theoretical and practical issues for understanding tCO_2e. Drawing on two different carbon offset case studies, I illustrate the major dimensions of materiality that affect their commodification of carbon reductions, and how such materiality links international carbon market evolution to local socionatural conditions. I conclude with the theoretical and policy insights that can be drawn from the analysis.

Making carbon reductions

Commodity status is not intrinsic, but "is the result of conscious and unconscious actions of people in specific circumstances" (Castree 2003b: 283): global capitalist processes shape

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[1] The case studies are based on doctoral research undertaken at the University of Oxford (2005-2009) and through extensive fieldwork on carbon offset case studies in Honduras. My aim here is to use the case studies as illustrative of the processes and general tendencies inherent in carbon offsets, rather than applying a critique of their specific carbon accounting per se. or an extrapolation of conclusions to all offset project types and manifestations.

localities and the transformation of nature into commodities. At the same time the specific features of the raw materials themselves affect how these processes are undertaken and reworked at multiple scales (cf. Barham & Coomes 1994; Swyngedouw 1999). This broad conceptualisation is useful for analysis of carbon reductions in offsets given the broader evolution of the carbon markets and political economy of offset governance (Bumpus & Liverman 2008), and the local material specificities, and social relations, of technology deployment that allow carbon reductions to be created (Lovell & Liverman 2010).

Carbon offsets rely on "baseline-and-credit" trading systems that "create" assets: tonnes of carbon dioxide equivalent (tCO_2e; Figure 1). These assets (carbon credits) represent the additional carbon reductions from a baseline of emissions through the investment in emission reduction projects that would not have otherwise taken place (Yamin 2005: 30). This is the fundamental notion of environmental "additionality" that differentiates the emissions produced by an offset project from the "business-as-usual" scenario of baseline emissions without the project (Michaelowa 2005). These counterfactual scenarios are determined through analyses of the socio-political economic situations in which the offset project is taking place, and the construction of hypothetical future baseline emissions scenarios.

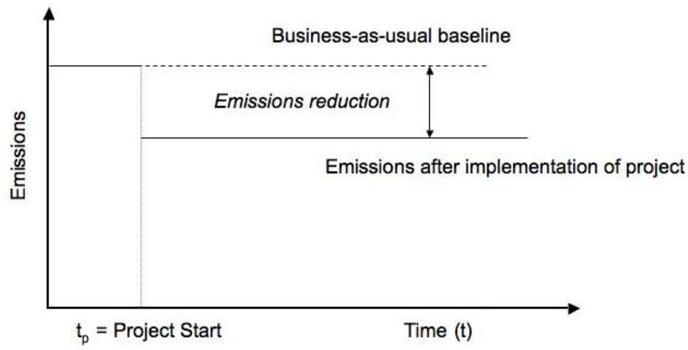

Figure 1: Principles of the baseline determination and the calculation of carbon credits (adapted from Michaelova 2005; Bumpus & Liverman 2008).

The creation of tCO_2e relies on the implementation of project activities and the processes of calculating, justifying and verifying emissions reductions. The materiality of the carbon, and the real world context in which it is reduced, must be kept in tension with the institutional requirements – such as carbon standards – that exist specifically to assert that a reduction has taken place against the baseline scenario. For energy-based offsets, additionality, baselines and methodologies are developed through the relationship between the demands in the carbon market and the differential calculability of certain technologies to reduce carbon emissions.

The material nature of the technology's engagement with the atmosphere, therefore, plays a crucial role in the effective commodification of the tCO_2e and its ability to be incorporated into carbon standards of differing levels of rigour. Industrial gas destruction of Hydrofluorocarbon-23 (HFC-23), for example, is materially much easier to measure and define compared to, for example, afforestation and reforestation (A&R) projects where baselines of tree growth, permanence of carbon sequestered and monitoring requirements are more difficult to assert. As a result industrial gas destruction has been easily incorporated into the legal requirements of the Kyoto Protocol's Clean Development

Mechanism (CDM) and is, therefore, subject to rigorous accountability. On the other hand A&R have historically been incorporated into voluntary carbon offset (VCO) markets[2] where, because of the voluntary, (i.e. not legally-binding) nature of the market, less rigorous carbon reductions are balanced by, for example, public demands for forest projects (Bayon et al. 2007; Hamilton et al. 2008; UNEP-Risoe 2010; Liverman & Boyd 2008).

Carbon offsets have some very specific attributes associated with their commodification that contrast them to commodification in other ‘natures’. The most important of which is that, in contrast to commodifying a unit of nature in order to govern its existence, like timber, carbon offsets create a commodity and value out of a piece of nature – carbon dioxide in the atmosphere – that, if achieved properly, *does not exist*. Carbon offsets in their entirety can, therefore, be considered to consist of four interrelated ‘forms’ of carbon (see Table 1): the carbon that continues to be emitted by the offset credit buyer (Type 1); the carbon that would have been emitted if it had not been displaced by the project activity (Type 2); the lower emissions as a result of the project activity (Type 3); and the tCO_2e (Type 4) that is produced by the difference in emissions as a result of the project activity and the baseline. A simple equation describes the relationship between these types:

Type 2 – Type 3 = Type 4

And under ideal hypothetical conditions:

Type 1 = Type 4

Table 1: Description of the four types of carbon embodied in the case studies presented here[3].

Offset project Technology	Type 1 carbon: Carbon still emitted by buyer of tCO_2e	Type 2 carbon: Baseline emissions	Type 3 carbon: Displaced carbon	Type 4 carbon: tCO_2e produced by project activity
Grid-connected hydroelectricity project	Industrial emissions in Europe above a regulated target (i.e. incentive to buy offset credits)	Diesel; emissions from fossil fuel combustion that would have been emitted in the absence of the project	Emissions from fossil fuel burning after project implementation (i.e. lower emissions when hydroelectricity fed into grid)	Difference in emissions as a result of the project activity compared to the baseline. Hydroelectric output measured at source.
Decentralised Improved cookstoves	Emissions from clients buying offsets voluntarily for public relations/marketing[4]	Non-renewable biomass burnt in traditional 3-stone fire cookstoves	Reduction in use of non-renewable biomass through the use of more efficient cookstoves	Difference in emissions. Statistical sampling of fuelwood burnt by families with and without improved cookstoves.

[2] At time of writing 14 A&R projects exist in the CDM. However, they have not seen the success of industrial gas reduction, grid connected renewable energy and other centralised technological offset projects in the CDM.
[3] This is a heuristic interpretation to clearly show the relationships between different emissions associated with a project and does not account for baseline changes over time.
[4] Although the buyers of the offsets are doing so for different reasons – one is under legal obligation of the Kyoto Protocol and the others for marketing reasons –offsets are bought as under incentives for organisations to reduce their net carbon footprint and thus are still useful in this analysis.

The important point to note for this analysis is that the material conditions of all 'types' of carbon associated with an offset project must be considered. Given these conditions, which exist in multiple locations, over varying timeframes and with different actors, carbon reductions must be conceptualised relationally: it is only within the historical, material and social contexts in which it exists that we can understand 'what' is the carbon we are reducing, how is it being reduced (if at all), who stands to benefit from its commodification and with what consequences[5].

Creating the carbon commodity: processes of commodification and the international carbon economy

The process of creating a carbon commodity exists within a constant dialectical tension between the international carbon market and local socionatural relations. tCO_2e is commodified through socio-technical processes that govern the categorization of carbon reductions; a process that is strongly mediated by the type of technology used to displace emissions and create reductions.

The creation of tCO_2e is governed by the underpinning principles of offsets that aim to guarantee emissions reductions, and therefore their validity in a market for climate change mitigation. Generally accepted principles of carbon offsets are that they are real, additional, permanent and verifiable (Broekhoff & Zyla 2008). In order to materially attest these principles, carbon standards require documents and processes that define the carbon reductions in offsets. These processes are often dictated at a distance, created by actors outside of the local site of carbon reductions and are created to assist in the transformation of reductions into tradable credits. This section briefly sketches the commodification processes in carbon offsets in order to understand how these processes bind offsets to multiple actors and locations through technology. The section focuses on 'constructing the carbon commodity', drawing, where appropriate, on analyses of specifying commodity processes in nature (Boyd et al. 2001; Castree 2003; Robertson 2000; 2004; 2006). The analysis necessarily engages the role of carbon standards in defining a tCO_2e, it does not provide a comparison specific between standards and instead assumes that the principles of offset standards are a useful heuristic for understanding tCO_2e commodification. I show here that tensions exist between the ability to determine material reductions and the requirements of the market that govern processes of disciplining and holding emissions reductions in place to enable their commodification.

Privatisation in carbon offsets

Under market environmental modes of governance (cf. Liverman 2004), emissions reductions have to be assigned rights of ownership – the assignation of legal title to a named individual, group or institution – so that they can be traded as commodities allowing future exchange (Castree 2003b). For offsets to generate future carbon reductions, forward contracts are negotiated through Emissions Reduction Purchase Agreements (ERPAs; Yamin, 2005b), discursively and legally privatising the tCO_2e that the project is predicted to generate[6]. Following the creation of the project idea notes and preliminary feasibility

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[5] I am indebted to Prof. Margaret FitzSimmons for her personal time and valuable insight into these issues in the embryonic stages of this work carried out at the University of California, Santa Cruz in 2008.

[6] Carbon offset projects are also unilaterally developed and then sold into the market. However, forward contracts have been a principal way of financing new projects because of the need for up-front finance in project development.

studies, the ERPA begins a process of legally linking two (or more) actors together in carbon reductions and credit purchasing. As a minimum, an ERPA defines the property rights of a commodity's first exchange and trade from the organisation(s) generating the credit to the investor who lays claim to it[7]. The privatisation of the communal atmosphere through creating purchase agreements and quantifying carbon reductions arising from project activities thus provides control of the commodity to buyers (a potential "allowance to emit") and embodies the legal and discursive privatisation of carbon in the commodification process (cf. Castree 2003b).

Individuation and abstraction in carbon offsets

The carbon commodity created in offsets relies solely on its codification and categorization by experts as a result of analyses of project activities and baseline scenarios. This process of categorizing and separating out an entity or specific thing from its supporting context is known as 'individuation' Castree (2003b: 280). In project-based carbon offsets, carbon reductions are individuated and functionally abstracted through a representational and physical (discursive and practical) cut to create units of nature that are deemed socially useful (i.e. credits that represent a tonne of emissions reduction; Bakker 2005; Mansfield 2004; Robertson 2006). I use the notion of 'hemming in', defined as "to confine or be bound by an environment of any kind: to enclose, shut in, limit, restrain" (Oxford English Dictionary 2009), in order to represent the notion that the porosity or movement of the credit is restricted by the process that aims to define its existence (see Figure 2).

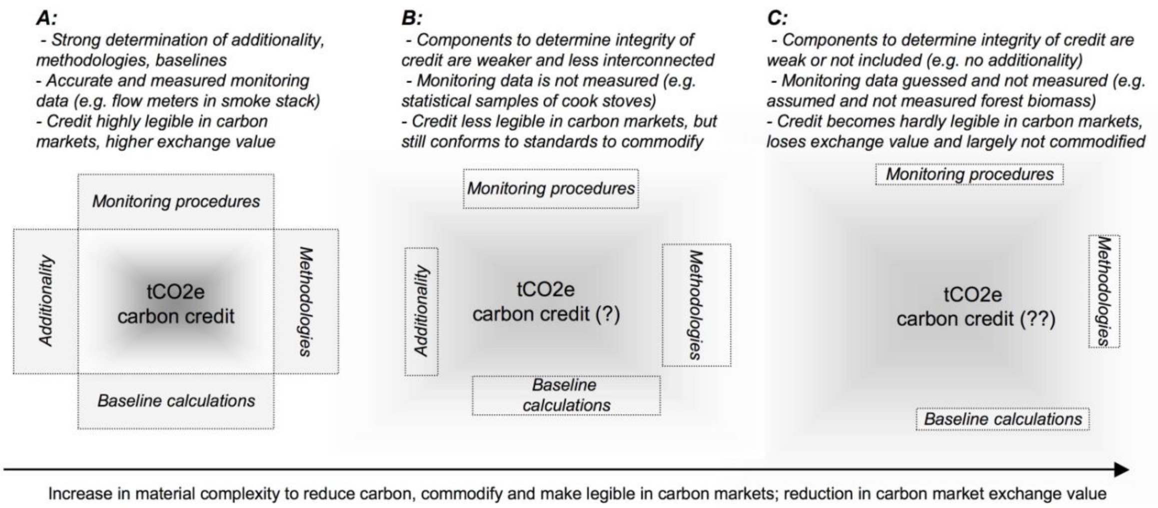

Figure 2: A conceptual diagram illustrating the 'hemming in' of carbon credits through the practices of determining project additionality, baseline calculations, methodologies and monitoring procedures. Carbon credits as tCO_2e are individuated from the atmosphere when these four practices determine the material reduction of a tonne of carbon from the atmosphere. Projects that have a material basis that allows these components to be easily defined create a more certain commodity (*A*). As projects become more complex and technologies less well-understood, accurate accounts of

[7] Of course the attraction of carbon trading to traders is that credits can continually be traded until they are finally retired from the system to create the actual offset. However the focus of this research is to understand the processes through which carbon reductions are created, and turned into commensurable commodities in the market - how that carbon is then traded with specific actors after this is the focus of future work in this area (also see Bailey 2007; Lovell & Liverman in press)

these four components can become weaker (moving from *A* to *C*). The commodification of the tonne of carbon dioxide equivalent becomes more difficult and finally the integrity of the carbon credit as a saleable commodity on the market becomes difficult to assure (*C*).

Individuation and projected functional abstraction in offsets is created through the a priori representational separation of a current emissions trajectory from a hypothetical one through calculations and assumptions that are necessarily complex (Lohmann 2009). In this way, energy-based offsets do not constitute a *reversal* in emissions; they simply slow the path of *potential* emissions. The Project Design Document (PDD), and its constituent components – methodologies for calculating baselines, proving additionality and the monitoring plan to ensure effective monitoring of future emissions reductions – are all present to constrain, define and individuate carbon reductions *before* they have been reduced. Baselines are, therefore, spatiotemporally context-dependent, specific and variable. This situation has serious ramifications for climate policy, where reduction commodity potential is easily *ex ante* created or destroyed based upon calculation of future baseline scenarios. In this way, the abstraction of carbon "ties the commodification of nature to systems of representation more broadly … as regimes of calculation and expertise that more generally make nature and territory 'legible' and governable" (Prudham 2009:130). These processes are the first step in materially creating a tCO_2e, which, given its non-existential nature, could be termed a piece of 'counterfactual material nature'[8]. Carbon reduction processes are therefore similar to specific other natures, such as the commodification of wetlands, and rely on an "act of reference" (Robertson 2000: 472) in order to convey them, albeit imperfectly, in a market.

The ability of carbon commodification processes to effectively 'hem in' the carbon reductions changes with the different specific material dimensions of reducing carbon: some projects contain more 'uncooperative carbon' (following Bakker 2005) than others, where hemming in is more difficult and commodification process harder to complete. The importance of this concept is that specific material dimensions of certain projects and technologies make some tCO_2e more tangible than others. For example, projects such as HFC-23 reduction, although criticised (Wara 2007), actually provide more clear additionality than others, have methodologies that are robust and calculable, and have carbon reductions that can be easily measured (i.e. case *A* in Figure 2). In contrast, a project, such as blended finance improved cookstoves, or already profitable renewable energy projects, that have more difficulty in defining additionality, variable methodological calculations and monitoring based on statistical analysis or assumptions, are more loosely defined (i.e. case *B* or even possibly *C* in Figure 2). The ability to successfully individuate and functionally abstract carbon reductions is, therefore, both a function of the material dimensions in which reductions are created and the ability for practices and documents to effectively assert those reductions.

All offset projects necessarily can, therefore, be seen as existing on a spectrum of 'more' or 'less' uncooperative carbon. An example of this is the bottleneck and difficulties in passing

[8] Lohmann (2005) invokes 'counterfactual' scenarios in the commodification of carbon in offsets and uses the term to illustrate that emissions reductions are not really created in offsets (see also Byrne et al. 2001), whilst others use 'counterfactual scenarios' as a technical term to outline various baseline scenarios that would happen in the absence of the offset project (e.g. Pfaff et al. 2000). I invoke the term here to represent the fact that offsets do create questionable carbon reductions in some cases, but that the 'material' nature we are dealing with in carbon offsets consists of a 'nature' (CO_2) that does not exist (i.e. counterfactual) yet is still materially bound up in socionatural-technical processes that turn a piece of nature into a commodity through its reduction.

methodologies under the CDM and the problem of defining emissions reductions from different projects to a standardised level (Sterk & Wittneben 2006; World Bank 2006a). As Morgan Robertson points out, there is a "problem of measurement" (2004: 367), which, in this case, is highly determined by the technology implemented and the socionatural context in which it is used. This affects the extent to which carbon can be 'hemmed-in' in an increasingly cognizant carbon market that requires certainty that carbon reductions are real (Gunther 2008).

This tighter hemming-in has meant that capital accumulation in carbon offsets has been closely tied to firms' differential ability to work with a specific technology, create new forms of governance for reductions, and more accurately determine carbon reductions. It has also been responsible for the call for serious reform of the CDM because of the inherent difficulties with understanding the material application of methodologies and additionality, promoting more sectoral reductions which rely less on such hemming in on a project-by-project basis (Figueres 2004; Sterk & Wittneben 2006; Olsen & Fenhann 2008a; Wara & Victor 2008).

Monitoring and verification: actual and spatial abstraction

Carbon reductions are spatially abstracted as information in order to continue their commodification and placement into wider systems of exchange. Robertson (2000) notes that spatial abstraction essentially involves treating an individualised thing in one place as essentially the same as any apparently similar thing located elsewhere. This process across space belies subtle, and unavoidable, differences in commodities and the contexts in which they were produced. Spatial abstraction in offsets allows credits to flow from the place of carbon reduction to the place of carbon emissions (the fundamental rationale of using offsets)[9] and allows them to be commensurable with both emissions (Type 1) and other credits in the same system produced under different local socionatural conditions.

The material abstraction in the carbon reduction takes place once the project has been implemented through the execution of the monitoring plan associated with the technology use, and the *ex-post* verification of the reductions by third party organisations. Verification therefore attempts to hem in the credit based on calculating *ex-post* reductions to assert that a material reduction has taken place. Information about the amount of carbon reductions that have been achieved is spatially abstracted when it is conveyed, as data, from the local project site(s), to a third party verifier and then on to registries or emissions reduction accounts of the carbon offset investor, project developer or entity that owns the rights to the tCO_2e.

Through individuation and abstraction, information about a climatic service (cf. Thornes & Randalls 2007) is used to justify the creation of a product that can then be sold on and/or used to justify domestic emissions. Without the ability to be spatially abstracted, carbon reduced through offset projects in the global South can never be fungible with the carbon emissions they are supposed to balance in the North: offsets rely on spatial abstraction because the carbon dioxide reduced in one place must be 'seen' to be the same as carbon

[9] This is especially true of offsets examined here that span North (developed) and South (developing countries). The difference in marginal abatement costs between the North and South are a key driver for the inclusion of offsets (Bumpus & Liverman 2008), although North-North offsets also exist in the form of voluntary offsets in countries without binding emissions targets (e.g. USA) and in Kyoto's developed country offset mechanism, Joint Implementation.

dioxide that is emitted in another. This process allows carbon reductions to be "abstracted from their place specificity" (Robertson 2000: 478) and to be displaced into wider systems of exchange; ultimately leading to the credit's retirement, creating the moment when a tonne emitted is actually offset.

Displacement and exchange in carbon offsets

The principal aim of carbon offsets is to provide cheaper emissions reductions across space (Böhringer 2003). Carbon reductions created through the CDM, for example, are used for compliance under the Kyoto Protocol or the European Union Emissions Trading Scheme (EU ETS) and therefore represent a generic licence to emit[10]. This point represents a key tenet of the commodification: the displacement of nature, and its severance from sites of production and specificity.

Displacement can be seen to occur in carbon offsets as credits are abstracted across space as pieces of information, and issued to project proponents from regulatory schemes and voluntary offset buyers. Displacement may obscure the social conditions of its generation where credits are used purely for legal compliance where the local material conditions of reduction are of low importance. This 'generic carbon' forms one of Castree's (2003b) sextet of commodification and can easily be seen in the 'secondary CDM' market where spot trading of CERs that have already been commodified and issued through the CDM process, are subsequently traded on carbon exchanges. The movement of credits across virtual accounts, through the International Transaction Log of the CDM, 'tracks' the credits and aims to avoid double counting (the same tCO_2e being counted more than once by different actors). On the other hand, local conditions may be emphasised in order to gain higher prices in specialist, 'boutique carbon' markets (Capoor & Ambrosi 2009), driven in the North in times of excess credits or for buyers looking for development stories for public relations activities in addition to carbon reductions (Hamilton et al. 2009; Taiyab 2006). In both cases the carbon market can create demand for specific forms of the carbon commodity, 'generic carbon' or 'high sustainable development carbon' (Hamilton et al. 2009), and uses documentation to describe basic reductions or additional requirements, such as a 'sustainable development matrix' in the CDM Gold Standard to cater for market needs. Displacement occurs in all offsets, but is differential, contingent on the of the carbon markets demanding it.

As a commodity, carbon can then be exchanged and dealt with similar to any other commodity listed on exchanges (as the secondary CDM market shows) and can be retired to compensate for emissions under legal systems, such as the EU ETS (Jepma 2003). Their commodity status affords them a valuation at higher prices than forward contract credits; driven largely by supply/demand and emerging regulatory factors in the carbon market, such as post-Kyoto negotiations and EU legislation on carbon trading (Bailey 2007; Yamin 2005). Offset credits are then finally retired and taken out of exchange circulation in order that the tonne emitted is balanced by the retirement of the tonne reduced (in credit form). In the CDM, the Kyoto Protocol mandates that countries retire credits through official registries to record each tCO_2e. In the VCO market retirement is much more disparately governed, although new registries are emerging to centralise this process and to avoid double counting of emissions (Kollmuss et al. 2008; Gillenwater et al. 2007). It is at the

[10] There are some specific project types, like large-scale hydroelectricity and afforestation and reforestation projects, that are not eligible under the EU ETS illustrating that carbon is not completely generic within the system although the variety of projects that do supply the ETS from the CDM are considered as such.

point of retirement that the materiality of the commodification of the credit is realised and the final substitution of the tonne emitted with the tonne reduced is rendered materially commensurable (e.g. Type 1 = Type 4). Retirement of the credit also acts to “re-veil” the carbon commodity from a ‘far flung’ place (Smith 2007; Hartwick 1998) reaffirming its displacement through consumption (Lovell et al. 2009).

Global-local linkages and offset technologies

We can see that carbon offsets undergo a complex process of defining emissions reductions in order to create tCO_2e as a tradable commodity. Offsets create a ‘counterfactual material nature’ in order to place carbon reductions into wider systems of commodity exchange. As I show here, the complicated, contested nature of creating baselines and justifying additionality makes carbon more or less uncooperative: the actual emissions reductions gained from different projects vary according to the process of disciplining carbon reductions. These complex relational processes create a constant tension between the international carbon market and local socionatural relations that is strongly mediated by the type of technology used to displace emissions and create reductions. Table 2 outlines the principal components of each of the case studies, illustrating that although both attempt to produce tCO_2e, they do so via very different material engagements with the atmosphere and processes of defining emissions.

Table 2: A table outlining the principal components of two case study projects in Honduras and their relative material dimensions.

Component	CASE STUDY A: Hydroelectricity Project	CASE STUDY B: Improved Cookstove (ICS) Project
Project type/overview		
	Run of river, daily containment hydroelectric dam. 13.5MW Large centralised discrete (1 site) capital project (~$15million).	Improved cookstoves, Up-scaling of existing cookstove project (~$50,000) with 1,600 stoves (multiple sites)
Creating carbon reductions		
Actual reduction	Displaces diesel electricity generation in national grid (national scale reductions)	Replaces traditional wood burning stoves with more efficient stoves that burn less non-renewable biomass (household/community scale reductions)
Documentation supporting commodification	Documents show: legal title over the emissions reductions, baseline of emissions, methodologies to calculate carbon reductions (Relies on grid that would have been burning diesel in place of hydro dam. Energy mix in Honduras high level of diesel generators, barriers to investment for hydro facilities), verification and monitoring of emissions reductions and movement of 'credits' across space. Documents officially sanctioned by UN system and credits transferred through official registries.	Documents follow UN process (in small scale CDM), but not officially sanctioned. No existing documents for methodologies because of complexity of emissions reductions and lack of UN-sanctioned official support for improved cookstove projects at start of project (2005). New documents created by verifiers to produce methodology for calculation and monitoring of emissions reductions. Carbon finance up-scaled operations to allow more stoves to be produced.
Monitoring carbon reductions	Centralised project with well-understood technology and material carbon reductions led to clear methodologies and guidance on associated emissions reductions for international market.	No clear guidance or mandatory governance structures because of difficulty in methodologies and calculations for improved cookstove projects. This has changed over time as lessons learned about the material difficulties of projects are fed into governing standards.
Link to international markets	Credits flow into regulated markets to comply with European Union and Kyoto emissions reduction requirements.	Credits used in offset company offering voluntary emissions reductions for consumers/companies outside of the Kyoto Process.
Biophysical properties for carbon reductions		
Opportunities as result of biophysical constitution	Situated in mountainous region: elevation and water availability. River highly polluted, little opposition or opportunity cost for water, communities amenable to reforesting hillsides. Honduras generating most electricity from diesel therefore opportunity to reduce emissions.	Situated in peri-urban areas of capital city in shanty towns: demand for wood high, prices high therefore more uptake more likely (because of increased economic efficiency and lack of available wood to cut and collect by household).
Physical in situ obstacles as a result of biophysical constitution	Needs rainfall. Needs national power company to maintain grid infrastructure otherwise hydro plant cannot feed power into the grid. Need to have cooperation from local communities to ensure reforestation of watershed (therefore efficient running of dam).	Stoves degenerate over time (difficult to calculate efficiency); variation in stove-use between households and over time. Possible use of different, untested, biomass in combustion. Monitoring of carbon difficult because decentralised, dispersed sites of reduction (household kitchens).
Institutional obstacles as a result of biophysical constitution	Officially none, although questions of additionality remain and future demand for energy which is not outstripped by 'clean' hydro.	At time of implementation, no approved methodologies under UN system; project developer had to create own systems. Lack of registration to standard affects exchange value of credit.

Major material dimensions of the projects affect the ease with which they are incorporated into carbon markets (cf. Le Billon 2001). Consequently, there are actions that carbon project developers take to adapt to and manage these uncooperative components of projects in order to fit material conditions into the governance structures, institutional requirements and technical capabilities (Bakker 2009) that carbon markets require (Table 3).

Table 3: Major material dimensions and responses for the case study carbon offsets. Sources: UNFCCC (2005); Atmosfair (2008); Gold Standard (2008; 2009).

Material Dimensions	Hydro	Cookstoves
Measurability of emissions reduction activity (Type 3 carbon)	High; measured at source	Low; estimated from statistical samples[11]
Distribution of reductions	Centralised	Decentralised
Measurability of displaced carbon (Type 2 carbon)	High; switching off bunker fuels in real time as hydro comes online	Low; fraction of NRB difficult to assert, statistical sampling of stove use within different user communities
Inclusion possibilities in carbon markets	Able to be included in compliance markets; material calculations assisted in project being one of the first to be registered	Mostly included in voluntary market, with more recently recognised methodologies incorporated into more rigorous carbon standards
Local responses to deal with material basis of uncooperative carbon	Relatively simple: Some technological implementation; restoring watershed.	More complicated: improving local governance for monitoring; attends to local understanding of carbon component of project in order to improve information provision.

Commodifying credits from hydroelectricity

The carbon credits generated by the hydroelectric project were registered under the CDM and used in Europe for compliance under the EU ETS. Legally, a tCO_2e from the project is considered to be fully commensurable with a tonne emitted by a facility covered by the ETS. However, although these form commodities that are used for legal compliance, their creation was not without contestation and obstacles. The material dimensions of additionality exemplify the 'political life' that abiotic natures (such as carbon) can imbue (cf. Bakker & Bridge 2006). Project developers in Honduras noted that low amounts of up-front carbon finance, and variable carbon prices, did not provide sufficient incentives to invest in capital-intensive projects, such as a hydroelectricity dam. Indeed, the project developers had to argue for *and* against the project's additionality to different investors in order to gain finance for the project. Defining the project's additionality, therefore, relied on the process of justification and negotiation between interested parties. Similar to the creation of other new economic systems through practices of calculation (cf. Mitchell 2008), different carbon offset actors introduce different calculations to persuade others that they are superior to rival models and additionality scenarios. In addition to the production of technical

[11] Current methodologies rely on statistical sampling, however there are emerging digital sensor technologies which can be applied to monitor stoves on a continual basis (TWP 2010).

documents, the a priori creation of carbon reductions, therefore, also exists through a discursive exercise of power and argument. In this way, the material nature of the dam's expense provided both an opportunity to argue for carbon finance because it was considered rhetorically additional, and an obstacle to creating *actual* material carbon reductions because, in reality, the project may very likely have gone ahead anyway. Despite these difficulties, CDM regulatory bodies easily accepted the additionality of the project, even though the material nature of implementing a multi-million dollar hydro dam project meant that it had to be financially stable with and without carbon finance (for other examples, see Lohmann 2009).

In contrast to potential difficulties in defining additionality, calculating future carbon reductions was relatively simple to justify for the hydro facility because of the nature of the project: electricity generation from water flow replaces fossil fuel used for generation in the grid. The centralised nature of the project meant that predicted energy outputs, and therefore displacement of fossil fuels, could be predicted and then monitored and measured easily, thereby allowing easier individuation and spatial abstraction of the credits produced. This situation existed even though biophysical phenomena, such as excess rain, which caused a generator to explode, or insufficient rain, which meant the generators couldn't run, affected the overall energy output and carbon credit production. Dealing with these obstacles posed by the project's material dimensions, however, was relatively easy: clutches were installed on generators to avoid over spinning, and a comprehensive local reforestation plan was enacted in order to improve the watershed for the facility. Moreover, these material obstacles were not barriers to the project's ability to generate carbon credits; indeed the reforestation activities were actually used as an opportunity to describe positive local effects, assisting the project in selling to high sustainable development carbon markets (World Bank 2006b; 2008; Atmosfair 2008). The 'socionatural-technical complexes' that create carbon credits in this situation are, therefore, at once both material and discursive in nature (cf. Escobar 1999; Mitchell 2008), and dynamically connect local conditions in the South to broader narratives and demands of the carbon market in the North (Bumpus & Cole, forthcoming).

Reworking commodification in cookstoves

Due in large part to material constraints of including cookstove projects as carbon offsets[12], carbon finance systems have only recently been recognized in formal systems such as the CDM and Gold Standard (GTZ 2010; Mann 2007). Indeed, obstacles to inclusion in carbon finance existed by virtue of individual stoves' physical interrelation with the environment, and the calculability requirements for bringing stoves into carbon offset mechanisms. For example, additionality was difficult to assert in some of the stoves associated with case study B because of multiple funding avenues to local project implementers from both carbon and non-carbon sources. In addition, the decentralised and widely distributed sites of carbon reductions created obstacles to effective monitoring and understanding accurately over time the amount of carbon reductions achieved. As a manager of the project noted, "we watered down the monitoring requirements because it was a small project and we were running out of time due to [verifier's] other commitments". These difficulties and lower carbon qualifications are not surprising given the project's pilot status and early inclusion in the carbon markets when voluntary projects shifted from relying more on consumer-offset

[12] Cookstoves were excluded from the CDM until 2008 for both methodological and categorical reasons that defined improved efficiency of stoves as avoided deforestation, rather than energy efficiency. Despite re-attending to these components of its commodification, difficulties still remain in passing stoves projects in the CDM, with only one having passed registration by May 2010, indicating their difficult incorporation into compliance markets as fully commensurable with other emissions reductions

connections (Lovell et al. 2009) to the requirements of calculating standards (Hamilton et al. 2008).

Although these limited methodological processes can be partly explained by the projects' pilot status, the *inherent* difficulties can be explained through the relationship between the technology's specific engagement with the atmosphere and the inadequate (but evolving) ability of socio-technical systems to define the carbon reductions that delineate the extent to which carbon credits can be effectively commodified. In this case, the carbon reductions were difficult to 'disentangle' from their broader socionatural context (Lohmann 2009: 509). Two material factors complicated individuation in cookstoves: firstly, the methodologies for the project cannot *measure* the use of technology that leads to emissions reductions (i.e. Type 3 carbon), but must be made on estimates of samples of stove use that attempt to allow extrapolation to the heterogeneous communities they represent. Secondly, difficulty in calculating the fraction of non-renewable biomass (fNRB; i.e. Type 2 carbon) used in cooking – a crucial factor in determining emissions reductions – also adds another layer of complexity to the accuracy of methodologies (see Table 1) (cf. KR Smith et al. 2000: 758; Harvey 2009; Masera et al. 2006; Edwards et al. 2004)[13]. This early work to calculate stove carbon reductions, however, did lay the foundations for the development of methodologies and their registration under the Gold Standard (Gold Standard 2009).

In the absence of wide-scale digital monitoring of emissions from individual stoves, improved local inclusion has become important for cookstove offset projects (Harvey 2009; Gold Standard 2009; Climate Care 2009). MacKenzie (2009: 451) notes that the evolution of the carbon markets over time may have exposed inconsistencies and flaws, allowing the creation of tCO_2e to consolidate in news forms. Similarly, the evolution of accounting for 'uncooperative carbon' has meant that the practices of calculation have also had to evolve. For stoves, this has included increased participation of local actors in both the disciplining of carbon reductions and the evolution of accounting techniques. The difficulty of monitoring has also led to a possible renegotiation of the privatisation of the carbon credits themselves, and the *need* for improved engagement with local institutions to understand the constraints, and possibilities, that carbon commodification places on the project (Bumpus 2009).

Based on the analysis here, and at the risk of over simplification, Figure 3 provides a basic heuristic interpretation of the dialectical tensions between the carbon market requirements, local material dimensions of reductions and the commodification process as it relates to project type and local socionatural processes. The point to note is that, like other commodified 'natures', tCO_2e is created through a constant tension between the processes that aim to define and discipline it and that the possible uncooperative nature creates obstacles and opens up opportunities to multiple actors (cf. Boyd et al. 2001; Mitchell 2008). Further research is required to understand how this heuristic is altered for other forms of socionatural technical interactions in other carbon offset types, but serves to illustrate the important tensions that form in the complexes required for the commodification of tCO_2e.

[13] Stoves that use renewable biomass are considered to be 'carbon neutral' because the emissions from wood burning are assumed to be sequestered over time through the re-planting of the wood source.

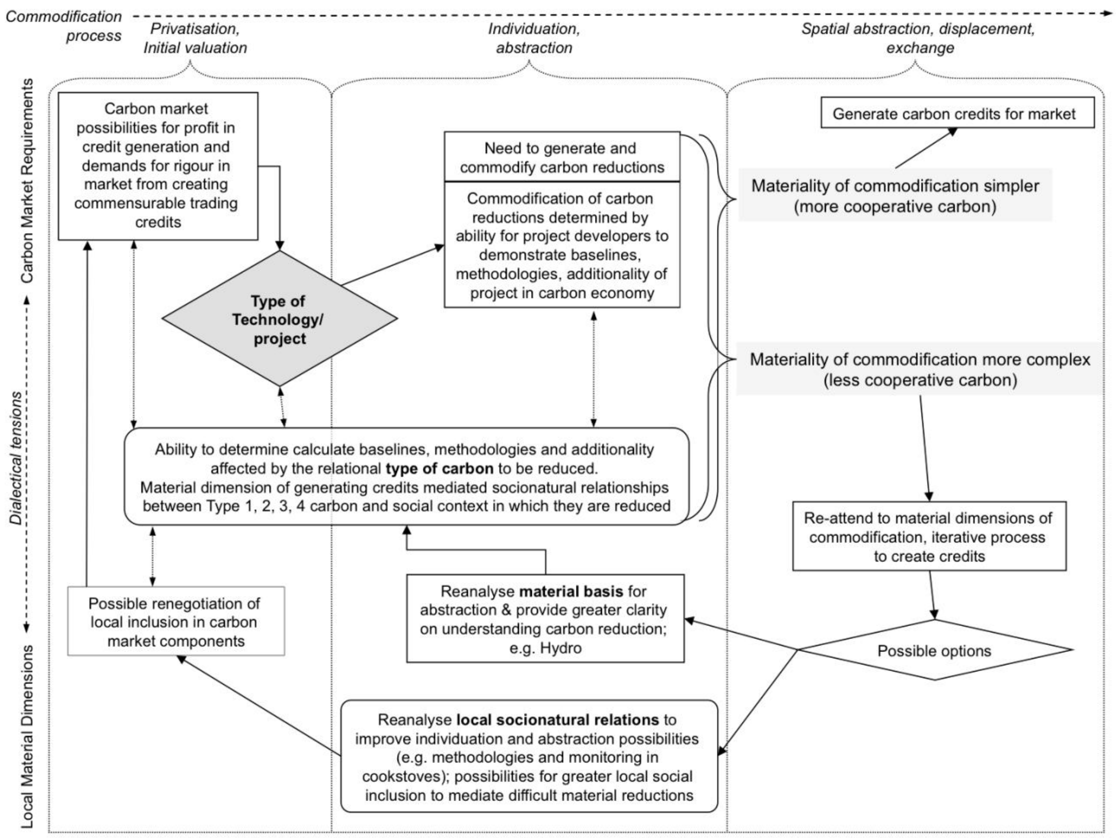

Figure 3: A graphical heuristic to illustrate the dialectical tensions between the materiality of reducing carbon in offset projects and their relations to the global carbon economy through the processes of commodification. In a necessarily simplified process, flow of process starts in the top left corner with carbon market possibilities. Double sided arrows represent dialectical tensions between issues (in boxes) and more generally between the evolution of the carbon economy (upper) and the difficulty/importance of the materialities of carbon reductions (lower).

Tentatively, then, complex local socionatural material conditions (where project technologies do not have simple technical solutions to calculate carbon reductions) may allow improved local involvement, and possible benefits from carbon finance. This situation, however, does not inherently attend to the power and bargaining positions between Northern carbon capitalists and Southern NGOs or groups in need of finance for their development projects (cf. Newell et al. 2009), and relative benefits accrued from the project. Continued political ecological research that attends to the political and discursive aspects of carbon credit generation in offsets is required to elaborate on these points.

Conclusion

This piece provides a specific example of socionatural articulations and capital's engagement with the 'natural' world. Through offsets, "capitalism produces specific natural environments but these environments are, in turn, both enabling and constraining... *in specific relation* to the social relations they are imbricated within" (Castree 1995: 24; emphasis in original). The material nature of carbon reductions and the social relations in which these are governed, argued, negotiated and enacted are dialectically related to the broader requirements of the new and evolving carbon economy. Offsets are produced through 'socionatural-technical complexes': they are at once both material and discursive, relying on the actions and agency of a number of actors and components of 'nature' in order to construct emissions reductions and turn them into tradable commodities. Ultimately the commodification of carbon becomes a political economic, socionatural relational process across a wide range of literal and figurative distances (Pryke et al. 2003; Lohmann 2009).

The process of commodification of carbon differs in material difficulty according to the engineered technology in question, and the ability for carbon standards to effectively hem in carbon; a process that is inherently difficult. Carbon reductions in offsets, then, are not solely scientifically verifiable material ‘removals’ of carbon from the atmosphere. Instead, behind each carbon credit is a process of commodification that relies on a dialectical relationship between the requirements of the evolving carbon economy, local socionatural-technical complexes, and the relational aspects of connected carbon emissions and reductions (Types 1 – 4).

The limited analysis of case studies here points to the need for more studies that aim to bridge the ontological ground between material and discursive approaches to the creation of the new carbon economy (cf. Mitchell 2008). Although carbon offsets can be governed at a distance through “codes of knowledge representing the human interface with the biophysical world” (Baldwin 2009: 419), local material dimensions of offsets can redefine the extent to which these techniques are possible. The theoretical analysis here has, therefore, shown that despite the fact that expert advisors in the carbon economy play an “authoritative role in the construction of … eco-knowledges”, the material difficulties of some technologies, and the specific requirements of markets, may in some circumstances open up possibilities for self-reflection and inclusion of multiple voices in such constructions (cf. Bäckstrand & Lövbrand 2006: 54-55). As Lovell and Liverman (2010) note, it is crucial to pay close attention to the material world and the role of technologies, which form a vital part of the ‘plethora of actors’ that make up the broader political economy of carbon offsets. Building on this, I have shown that the commodification *process* intimately connects international governance of carbon finance (and carbon finance mechanisms) with the socio-natural relations in specific places.

Carbon offset technology, therefore, plays a significant role in connecting local processes to global markets and, as such, is a crucial consideration in related debates concerning sustainable development through carbon finance (cf. Olsen & Fenhann 2008b) and project-based offset reform more generally. The article has opened up avenues on constructing the carbon commodity as a segue to further understanding geographic interpretations of how carbon offset project locales are wired-in (cf. Massey 1994; Castree 2003a) to broader political economies and spheres of influence (cf. Simon 2008).

In sum, as tools to mitigate climate change through tangible project activities, offsets sit at junctures between the material properties of reducing carbon emissions, the construction of markets to govern reductions and the social relations that enable offset production. Analysis of the specific connections in these socionatural-technical complexes are important to both the theorisation of socionatures under contemporary and future environmental governance regimes, and policy debates about shaping global environmental change and North/South sustainable development in the 21st Century.

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