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What is wrong with energy efficiency?

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ABSTRACT
At first sight the purpose of energy efficiency is plain: it is to reduce the amount of energy used and the carbon emissions associated with the design and operation of things like buildings, domestic appliances, and heating and cooling technologies, or with the organization of bureaucratic, business or industrial processes. National and international responses to climate change are dominated by policies that promote energy efficiency and by people who take this to be a self-evidently important thing to do. Established criticisms, including those which focus on problems of rebound, draw attention to the unintended consequences of such strategies, but rarely challenge the conceptual foundations of 'efficiency' as a topic in its own right. This paper uses Bruno Latour's *We Have Never Been Modern* (1993) notion of purification and Ian Hodder's *Entangled: An Archaeology of the Relationships Between Humans and Things* (2012) ideas about entanglement to develop a more fundamental critique and to argue that, far from being a solution, efficiency, as currently constituted, undermines that which it is expected to achieve. It is concluded that if carbon emissions are to be reduced on any significant scale, then it is essential to consider the meanings and levels of service and the types of consumption and demand that efficiency policies support and perpetuate.

KEYWORDS
buildings; energy demand; energy efficiency; low-carbon society; policy measures; rebound effect; social practices; social theory

Introduction

According to the UK's Committee on Climate Change, there are two principal ways of reducing carbon emissions, one of which is energy efficiency (the other is decarbonizing supply).[1] The European Commission's 2030 climate and energy framework outlines targets in three areas, and again one of these is to increase 'energy efficiency' by 27% compared with the 'business-as-usual' scenario (2014).[2] The European Council for an Energy Efficient Economy is committed to keeping 'energy efficiency first' in the line of responses to climate change,[3] and the International Energy Agency (IEA) asserts that 'Energy efficiency is key to ensuring a safe, reliable, affordable and sustainable energy system for the future', also suggesting that 'It is the one energy resource that every country possesses in abundance and is the quickest and least costly way of addressing energy security, environmental and economic challenges.'[4] In 2009, Stephen Chu, then US Secretary of Energy, concluded that 'energy efficiency is not just low hanging fruit; it is fruit that is lying on the ground' (The Times, 2009). So what is wrong with energy efficiency?

This paper argues that far from being an effective response to climate change, the headlong pursuit of energy efficiency is positively counter-productive. There are two main reasons for this. First, that efficiency strategies reproduce specific understandings of 'service' (including ideas about comfort, lighting, mobility, convenience *etc.*), not all of which are sustainable in the longer run. Second, that concepts and measures of efficiency depend on 'purifying' and abstracting energy from the situations in which it is used and transformed. Both tendencies obscure longer-term trends in demand and societal shifts in what energy is for, and both exemplify a particular moment in the history of energy–society relations. Ideas drawn from social studies of scientific knowledge inform an account of the building blocks on which programmes and discourses of energy efficiency depend, and of how such approaches perpetuate narrow but highly influential understanding of legitimate and possible responses. In detailing the contradictions of efficiency as a policy ambition and as a research agenda, the aim is to encourage climate change policy-makers, energy and building researchers,

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designers, engineers, and social scientists to take stock: to reflect on the consequences of their work and to develop strategies and solutions that challenge rather than reproduce increasingly problematic assumptions about present and future ways of life.

This essentially conceptual contribution proceeds as follows. The first step is to describe how notions of efficiency are used in different settings and what they have in common (the next section: features of efficiency). The next is to outline the work involved in constituting forms of equivalence and in establishing efficiency as a meaningful topic for building and engineering research and policy (the third section: constituting efficiency). This is work that can be usefully characterized with reference to Bruno Latour's concept of 'purification' (Latour, 1993), a term he coins to explain the importance of separating nature from culture within 'modern' society, and Ian Hodder's ideas about entanglement (Hodder, 2012). The fourth (purification versus entanglement) and fifth (purification as entanglement) sections elaborate on these ideas and their relevance for an analysis of efficiency as a policy priority. In essence, they argue that concepts of efficiency depend on carving definitions of both energy and service out of the complex interpenetration of everyday technologies and practices.

The suggestion that efficiency discourses obscure fundamental questions about what energy is for and how demand is made resonates with renewed interest in notions of sufficiency (Thomas et al., 2015; Toulouse et al., 2017), with longstanding concerns about the limits of technological fixes, including efficiency gains (Rees, 2009), and with an anxiety that energy-efficiency measures are unlikely to be enough to meet the challenge of radical carbon reduction. As US President Barack Obama emphasized at the 2016 United Nations Framework Convention on Climate Change in Paris, at some point 'more' will be needed.

A further and in many ways more important contention is that that current ways of thinking about energy efficiency are 'performative' – they have become embodied in technologies, policies and built environments, and in how the challenge of carbon reduction is defined and tackled. Accordingly, it is not just that 'more' will be needed: the point is that efficiency is itself part of the problem. In this context, the concluding section asks whether the downsides of the efficiency agenda can be avoided, and, if so, how?

Common features of energy efficiency

The term 'efficiency' is widely used not only in engineering, building design or product development but also in management, organization, economics and policy-making of all kinds. Across this range, some interpretations of efficiency are extremely precise (as when measuring the coefficient of performance of heat pump water heaters; Willem, Lin, & Lekov, 2017), others, like the World Bank's advice on energy-efficient cities,[5] are exceptionally broad. In business contexts, breakthrough innovations are contrasted with subsequent incremental improvements in efficiency. In the energy world, efficiency is treated as a 'fuel' (IEA, 2013). Political scientists write about national and European Union (EU) efficiency policy, and the need for a mix of such strategies (Kern, Kivimaa, & Martiskainen, 2017; Rosenow et al., 2016). Meanwhile, social scientists such as Dietz (2010) and Sovacool (2014) endeavour to explain why households and professionals do and do not adopt efficient solutions, and why there is a gap between what measures like those of additional insulation, better controls, and more efficient heating and cooling systems could and do achieve.

Despite this diversity and although the substantive topics of efficiency change as technologies and organizational forms emerge and disappear, discourses of efficiency have some features in common. One is a characteristically positive aspect. In relation to buildings and building technologies, more efficient solutions are expected to perform as well if not better than those they replace. More broadly, and as Mallaburn and Eyre's review of UK efficiency programmes demonstrates, such initiatives are politically attractive, being simultaneously good for the economy, for consumers, for manufacturers and producers, and for reducing carbon emissions (Mallaburn & Eyre, 2014). A related feature is that actual and anticipated benefits can be quantified and modelled. For example, the IEA produces regular estimates of 'avoided energy', *i.e.* of the resources not used because of increases in efficiency (IEA, 2013).

Calculations like these depend on resolving endemic issues about how improvements in efficiency are specified and known. A second shared feature is that judgements of efficiency depend on where and how system boundaries are defined and drawn. As is widely recognized, money saved through the adoption of more energy-efficient technologies (a car or central heating boiler) can be used in ways that have negative consequences for energy demand in the 'system' or society as a whole, *e.g.* enabling more travel, or the construction of larger homes (Rees, 2009, p. 304). Similarly, people with better insulated properties might take back 'comfort' (higher temperatures) rather than reducing the energy they consume (Hamilton et al., 2016).

So far, enthusiasm for policies to promote energy efficiency has not been diminished by the Jevons paradox, named after William Stanley Jevons, an economist who

made the link between increased technological efficiency (in his case, regarding the use of coal) and consumption, or by the conclusion:

> that the effect of improving the efficiency of a factor of production, like energy, is to lower its implicit price and hence make its use more affordable, thus leading to greater use.
>
> (Herring, 2006, p. 10)[6]

Instead, there are concerted efforts to establish the extent to which forms of rebound, take back or backfire undercut anticipated benefits (Sorrell, 2015), and to accommodate the fact that that efficiency savings relating to one activity or technology can be spent in other entirely unrelated areas of daily life (Binswanger, 2001). Like the calculations of efficiency they critique, such efforts typically treat energy as a resource that is spent and saved by variously rational actors.

Whilst there are differences of opinion about the scale of rebound effects and ongoing arguments about the macro and micro and the longer- and shorter-term consequences of efficiency (Herring, 2006, p. 10), interest in the topic is driven by the goal of *improving* rather than totally overhauling or abandoning efficiency policy.[7]

A third commonality is that efforts to enhance energy efficiency in buildings and in other contexts persistently 'reproduce the status quo by other means' (Rees, 2009, p. 304). This is not surprising in that energy efficiency is defined as a matter of delivering 'more services for the same energy input, or the same services for less energy input'.[8] However, the consequences are far reaching. It is not just that efficiency measures fail to stem, let alone engage with, societal transformations that lead to increases in demand (Thomas et al., 2015), instead, and as outlined below, the work involved in constituting energy efficiency, whether as a topic for research or as a goal for policy, is work that unwittingly binds us to an unsustainable future.

Constituting energy efficiency

Since efficiency is about delivering 'more services for the same energy input, or the same services for less energy input',[9] identifying improvements depends on specifying 'service' and on quantifying the amount of energy involved. Starting with a discussion of (1) *measurement* (how is 'less energy' known) and (2) *equivalence* (what counts as the 'same' or more service), this section explains how units of service are established (what it is that is efficient) in relation to other objects and entities, and over time. These themes are addressed in subsections on (3) *specifying*, (4) *framing* the *objects* of efficiency and (5) establishing *when* attributions of efficiency begin and end. In each case, the purpose is to catalogue the steps involved and to set the scene for a more theoretical discussion of the forms of abstraction entailed.

Measuring energy

Over the last few centuries, units like joules, kWh or million tonnes of oil equivalent (Mtoe) have taken the place of previously diverse, contextually situated methods of knowing energy in terms of horsepower, manpower or candle power (Shove, 2017). This is an important development in that generic measures make it possible to aggregate and compare energy use and to characterize the efficiencies of very different commodities and entities in the same terms. In detail, the choice of measures matters. For example, the terms in which efficiencies are compared, such as kWh/m^2/year (for buildings) or energy consumption divided by volume (for appliances such as freezers), can work in favour of larger, rather than smaller, devices and structures (Bertoldi, 2017; Calwell, 2010). However, the more fundamental point is that as well as enabling multiple forms of aggregation, including wide-ranging reviews of progress 'towards' efficiency across Europe,[10] contemporary metrics reproduce understandings of energy as an all-purpose resource, rather than as something which is generated and consumed in ways that are highly contingent, variable and historically specific.

Establishing equivalence

Efficiency is about delivering the same or more service for less energy, so how and by whom are meanings and measures of service defined? This is complicated. There are many ways to describe the services provided by a home, a room or an appliance, but judgements of relative efficiency can only be made if the meaning of 'service' is captured and standardized. When compact fluorescent light bulbs (CFLs) were first introduced, they were said to be 'equivalent' to incandescent light bulbs – and they were, but only with reference to their light output, as measured in lumens. Focusing on this one quality and defining equivalence in these terms radically simplified the task of producing a more efficient bulb (Diamond & Shove, 2015). This approach inevitably left other aspects, such as the quality of light as measured by the colour rendition index (CRI), out of the efficiency equation. This is relevant in that technological developments that improve performance on one dimension often have consequences for other features, meaning that more efficient solutions are almost always *different* (in some respects) from those with which they are compared. For example, low-e windows are thermally more efficient, but typically reduce the transmission of

daylight and of sound, and the fading of fabrics, meaning that rooms also appear darker. Since buildings are complex systems, modifying one aspect, such as adding insulation, can reduce the energy used for heating in winter, but create new demands, perhaps leading to air-conditioning to combat overheating in summer (Lomas & Porritt, 2017).

Whatever the outcome, establishing equivalence depends on foregrounding certain characteristics over others, and fixing these as indicators of service in relation to which relative efficiencies are compared. Chosen benchmarks are assumed to capture aspects of service that are both important and stable over time. Whilst expectations and standards clearly do evolve, such changes are usually attributed to market trends over which efficiency policy is thought to have little or no influence. Rather than having a hand in making 'needs', programmes of efficiency focus on meeting consumers' expectations, but with less energy. From this point of view, the challenge is to keep pace with innovation by producing standards with which to assess novel products (such as outdoor patio heaters), or by revising methods of assessment to take account of changes in how buildings and appliances are used.[11]

Programmes of energy efficiency are politically uncontroversial precisely because they take current interpretations of 'service' for granted. But in normalizing specific definitions of service, methods of evaluating efficiency carry normative assumptions about 'need' forward, invisibly bedding them into future programmes of research and development.

Bounding the objects of efficiency

The next step is to think about how the entities that are described in terms of efficiency are defined and bounded. The recent history of home heating illustrates a number of possibilities.

UK central heating systems have become much more efficient with the current labelling system distinguishing between those that are below 70% to above 90% efficient.[12] In the 2013 UK housing energy fact file, Palmer and Cooper discuss improvements in the energy efficiency of the UK housing stock, as indicated by the government's Standard Assessment Procedure (SAP).[13] They attribute these improvements partly 'to the better efficiency of new homes, but mainly to upgrades to existing homes – either from improved insulation or more efficient heating systems' (Palmer & Cooper, 2013, p. 41).

Taken as isolated objects, boilers have become more efficient. New versions use less energy to produce a given amount of heat than those they have replaced. The efficiency of the home has also increased, but by how much? As Palmer and Cooper report, 'average internal temperatures of UK homes in winter seems to have gone up by 4°C since 1970' (p. 59). This is, in part, related to the trend to use more rooms and to heat the total volume of space, rather than just the living room or kitchen (Kuijer & Watson, 2017). The SAP calculations used in evaluating the efficiency of UK homes suppose that all rooms are heated to 18°C, other than the living room, which is at 21°C.[14] But what if modern boilers were used to heat just one room? And what if they were used to maintain a temperature of 16°C rather than 19°C, as considered by Humphreys, Nicol, and Roaf (2011) or Van Marken Lichtenbelt, Hanssen, Pallubinsky, Kingma, and Schellen (2017)?

In some respects, it is easy to calculate the 'avoided' energy that should be ascribed to more efficient heating systems. But does it make sense to do so without recognizing that central heating has, in part, led to more heating overall? There are different ways of thinking about these questions, but the point is that as well as specifying (or assuming) equivalent service, claims about efficiency depend on analytically extracting the objects of those claims and treating them as independent entities (*e.g.* the home versus the heating system).

Framing objects of efficiency

Methods of increasing the energy efficiency of a home (*e.g.* by reducing heat loss) have effect within and as part of an existing structure, the systemic qualities of which matter for the impact (or otherwise) of each additional measure. As is well understood, the efficiency gains and anticipated cost savings of insulating a loft do not simply depend on the thermal performance of each m^2 of the insulation used: they also relate to the characteristics of the building as a whole. For this reason, multiple factors are taken into account when estimating 'energy efficiency' and when figuring out how much energy is required to maintain a certain indoor temperature.

But if the focus is shifted just a little to consider the amount of energy used in *keeping people warm*, many more considerations come into view (Brager, Zhang, & Arens, 2015). One obvious example is clothing. Wearing insulation close to the body is an exceptionally effective method of reducing heat loss, making better use of the body's own energy and thus requiring less additional input for the same 'warm' service. So why is it that some technologies (insulation, heating systems) figure so prominently in evaluations of efficiency while others, including clothing, chairs, carpets, slippers and curtains, do not? Part of the answer has to do with the specification of service. In most cases, the focus is on room

temperature, not on keeping warm. This in turn relates to the need to simplify and stabilize an 'equivalent' unit of analysis. Since people dress in very different ways, and since home furnishings are also taken to be matters of personal taste, it makes sense (from an engineering perspective) to take these elements out of the equation, and in the same move build them back in by making standardized assumptions about the thermal properties of curtains, carpets and clothing.

One consequence of this approach is that a range of potentially efficient strategies like heating the body rather than the room are rendered invisible and routinely excluded from priority setting in building-related efficiency policy. In short, legitimate objects of efficiency are crafted and constituted in very particular ways, foregrounding features of interest to designers and engineers and taking only some aspects of energy demand into account. What counts and what is excluded also reflects an interest in the fuels and resources used in powering society. As a result, human labour is usually disregarded. Again, this perhaps makes sense given the importance of 'equivalent service'. For example, the convenience of drilling holes with a power tool means that this activity cannot be compared with that of drilling by hand. And yet the 'result' – namely a series of holes – *is* arguably similar. So which is the more energy-efficient method? The answer partly depends on which kinds of energy figure in calculations of efficiency and which do not. In the longer run, the tendency to marginalize human effort along with various forms of renewable energy (the sun, the wind) reproduces a tendency to create a separate realm to which efficiency discourses apply.

When does efficiency begin and end?

The IEA's 2015 energy efficiency market report claims that 'Cumulatively, investments since 1990 have generated 256 EJ (6 120 Mtoe) of avoided consumption, with reductions in electricity and natural gas use dominating' (IEA, 2015, p. 17).[15] This does not mean that 1990 is in some absolute sense the dawn of efficiency. But it does mean that previous, also cumulative, histories of socio-technical change are out of range. Instead, the IEA's method is to identify 'investments' over a certain period, evaluate their impact with reference to some bounded object of efficiency and some baseline in time, and, holding to that baseline, calculate the quantity of avoided energy.

Picking another year, not 1990 but 1850, would obviously produce different results. But as this thought experiment suggests, setting 1850 as a reference point is implausible. First, and most obviously, the services delivered are not at all equivalent. Since 1850 there has been a massive expansion in the uses of energy and in the delegation of human to mechanical forms of power. What then is a meaningful time span over which to compare efficiencies? Pushing the notion of avoided energy to its limits but in another direction, could we imagine how much more energy would 'not be used' 200 years hence? How might supplies of 'avoided' energy be increased in future, and is there a chance that they might ever run out?

Discourses of efficiency are simultaneously time bound (they depend on comparison) but also timeless. What matters is the ratio of input to output, never mind when in history or in the future changes in that ratio might occur. In practice, policy analyses tend to focus on the short term, again partly because of the need to stabilize definitions of equivalent service and partly to demonstrate effect. This implicit and arguably inherent 'presentism' is worth highlighting in that increasing efficiency is frequently positioned as a response to exceptionally long-term challenges (Committee on Climate Change, 2015).

Purification versus entanglement

Constituting efficiency as a meaningful topic depends on treating energy as a generic, quantifiable resource and as something that has an ontological 'reality' of its own (Labanca, 2017). The discursive and methodological moves described above disentangle energy from the everyday practices and from the technologies and cultures in which it is enmeshed and help establish what Lutzenhiser describes as a parallel universe of engineering and policy, this being 'an exclusive and highly technical arena within which contests over resources, plans, power, and action agendas can be conducted' (Lutzenhiser, 2014, p. 147).

This is not an exceptional or unusual process. Though none has dealt with the topic of energy efficiency as such, studies in the history of science have repeatedly analysed the work involved in constructing boundaries and in generating methods and measures that make it possible to 'see' nature at work (Goodwin, 1997; Knorr-Cetina, 1981). What is known as the sociology of scientific knowledge (SSK) has its origins in the project of demonstrating that science is not independent of society and that seemingly 'pure' forms of method and enquiry are infused with politics, practical activity and social process (Latour & Woolgar, 1986; Mulkay, 1979). Partly situated within this tradition, Latour's now classic book *We Have Never Been Modern* (1993) deals with the rise of science and scientific method and with the work of 'purifying' and separating nature from culture.

In brief, Latour distinguishes between what he describes as pre-modern, modern and non-modern societies. Whereas pre-modern societies do not differentiate between nature and culture, this distinction is of utmost importance in the modern era, this being an era defined by the Enlightenment and by a commitment to scientific knowledge and the pursuit of truth founded on the systematic disentangling of culture from nature. The twist and the irony is that the work of 'purification' has the inevitable but unintended effect of producing and proliferating yet more complicated hybrid or 'quasi-objects' in which nature and culture intermingle. This leads Latour to conclude that despite appearances, modern societies also revolve around a particular amalgam of purification and translation. It is in this sense that 'we have never been modern'.

In this section and the next, Latour's complicated and subtle account of 'purification' and of the paradoxical impossibility of this endeavour is used in making sense both of the work of constituting 'energy efficiency' and of the dangers involved in framing it as a response to climate change.

Establishing energy efficiency as a meaningful topic requires a series of quite deliberate 'purifying' moves in which boundaries are constructed as a precondition for the construction of facts. As Latour puts it, 'we know the nature of facts because we have developed them under circumstances of our complete control' (Latour, 1993, p. 18). Sure enough, discourses of efficiency define their own terms: they specify what is to be included and what is left out. Filtering out 'extraneous' matters, which might range from the history of the service in question (*e.g.* the history of comfort) through to the possibility that such a service might be defined and experienced in multiple ways, is an essential precondition for the systematic analysis of relative efficiency. Calculations of efficiency are 'pure' and, in Latour's terms, 'modern' in the sense that their parameters are known. A more energy-efficient light bulb is thus one that delivers more lumens per watt than its rival. A more energy-efficient house is one that needs less energy to maintain the same temperature than the one next door.

Designers and policy-makers are now so used to thinking about efficiency in these terms that it is easy to forget the efforts (rehearsed above) involved in wresting energy and service out of the flow of daily life and making them amenable to calculation and measurement. As Lutzenhiser explains, the 'looking glass world' of efficiency policy is 'an abstract world, mostly without conflict and the messiness of ordinary affairs' (Lutzenhiser, 2014, p. 142). At the same time, the necessary work of 'purification' is a constant, and also unavoidable, source of tension. For example, it is because 'The realm of energy and efficiency is a technical world of physical forces and economic verities' that 'puzzlement abounds when reason fails to materialize' (Lutzenhiser, 2014, p. 142). As Lutzenhiser notes, many of the so-called 'non-technical barriers' that impede the otherwise logical development and uptake of more efficient solutions prove to be ordinary features of the social world that have been deliberately *excluded* in constituting objects of efficiency (see also Shove, 1998).

If efficiency measures are to be identified and if they are to 'work' in their own terms, they have to be specified and abstracted (purified) from the world in which they are expected to have effect. But as sociologists like Shove and colleagues have repeatedly argued, people do not use energy for its own sake, they use it as part of accomplishing social practices at home, at work and in moving around. From this point of view:

> understanding energy is first and foremost a matter of understanding the sets of practice that are enacted, reproduced and transformed in any one society, and of understanding how material arrangements, including forms of energy, constitute dimensions of practice.
>
> (Shove & Walker, 2014, p. 48)

For these authors, and for Labanca (2017), to discuss energy, let alone energy efficiency, in the abstract is to overlook the extent of these interdependencies, and to skate over the constraining and enabling forms of what Hodder (2014) refers to as human–material entanglement. The key idea here is that energy is inextricably woven into the infrastructures and appliances/devices that define, and are defined by, what people do. In Latour's terms, patterns of consumption, ideas of comfort, traditions of clothing, habits of heating and features of building design combine to form 'hybrid' – part human, part material – complexes that are mutually shaping and that in various important respects constitute each other.

In trying to tease generic aspects of energy performance out of such specific configurations, programmes and policies of energy efficiency necessarily miss what matters. In other words, they fail to stem long-term increases in consumption – as Obama puts it, they do not go 'far enough' – precisely because the efficiency 'arena' is so detached from the processes and dynamics through which energy demand is constituted.

One response, explored by Calwell in an unusually critical review of efficiency policy, is to suggest that the frame of reference be expanded and that as well as considering the efficiency of entire systems or societies, analysts also take a much longer-term perspective. In his view it is not that 'efficiency no longer serves a useful purpose, but rather … that it is not being framed

holistically enough nor given sufficient context' (Calwell, 2010, p. 34). In practice, it is difficult to say how much 'entanglement', here meaning overt recognition of inextricable interdependencies, the meaningful calculation of efficiency could bear. Taking a more historical approach, as Calwell proposes, introduces questions about how meanings of service evolve and, as already explained, these are questions that the efficiency paradigm does not and arguably cannot admit. All this is to imply that processes of purification are in some sense opposed to those of entanglement.

An alternative, also persuasive, conclusion is that it is not the fact (or fiction) of abstraction that is the limiting feature. Instead, the problem with efficiency policies is that they are much *too* effective, not in reducing demand but in reproducing and stabilizing essentially unsustainable concepts of service.

Purification *as* entanglement

Going further into Latour's work establishes the terms of a much more powerful argument against efficiency as it is currently understood. Latour has a lot to say about the forms of purification that characterize the 'modern' project (here the constitution of energy efficiency), but it is important to remember that his book is entitled 'We have *never been* modern'. By this he means that the work invested in purification is none other than a specific form of what he calls 'translation' or mediation.[16] In other words, the work of separating efficiency out as a meaningful topic is best understood as a form of mediation that *is itself* part of an ongoing history of entanglement. In Latour's words, purification is 'a particular case of the work of mediation' (Latour, 1993, p. 134).

This suggests that far from being somehow outside or apart from the everyday world of consumption and practice, the kinds of abstractions on which efficiency policies depend are integral to it. They help define and constitute the forms of human–material interdependence amidst which we live. To put it more directly, calculations of efficiency are always founded on some specification of equivalent service and it is through this that they perpetuate and stabilize contemporary, but often recently established, ideas, for instance about the meaning of comfort, the quality of light or the 'standards' that washing machines are expected to meet. Methods of defining and improving efficiency help hold these meanings in place, and in so doing they become part of the dynamic they deny.

Far from being purely 'technical' considerations, the purifying parameters on which judgements of efficiency depend are better understood as vectors, and as powerful forms of intervention through which social, cultural and political histories intersect. Whilst efficiency paradigms are founded on a stripped-down account of the relation between things and people, the reality is that all technologies, including those that count as efficient, figure in the interwoven co-evolution of material culture, consumption and practice.

In the realm of climate-change policy, efficiency therefore has a double, if not spiralling, role. As already explained, it acts as an invisible 'carrier' of quite specific interpretations of normal and appropriate service. In so doing, it reinforces the idea that such interpretations are non-negotiable, thereby justifying further emphasis on efficiency. In the UK, the government's commitment to delivering carbon reductions *without* compromising present standards of living means that efficiency appears to be only way forward. This sets in train certain lines of technological development and lays down what are likely to become path-dependent trajectories of innovation and investment.

What Hodder refers to as entanglement and what Latour represents as processes of 'translation' and 'mediation' through which human–non-human hybrids are intermingled are not exactly the same (Harman, 2014). Hodder is an archaeologist–anthropologist inspired by the tradition of actor–network theory and by the relational approaches that characterize Latour's work. But unlike Latour, he is interested in identifying forms of 'dependency' that give substance and direction to ongoing human–material relations. In writing about how asymmetrical dependencies arise and about the ways in which 'humans are caught up in the flows of matter, energy and information' (Hodder, 2016, p. 10) over the long term, and at scale, his aim is to reveal 'the dialectic of dependence and dependency between humans and things' (Hodder, 2012, p. 206).

It is not only that 'we have never been modern', as Latour suggests, but that the forms of material–human entanglement, which characterize all periods of history, have some kind of direction. Hodder's argument is that societies become 'entrapped' by the material relations of which they are a part, and that over time, forms of energy and resource dependency have become increasingly and perhaps irreversibly embedded. Hodder is not alone in recognizing that 'The 2015 Paris Agreement on climate change relies heavily on future technological advances and interventions' (Hodder, 2016, p. 25). But he is unusual in concluding that such a response is inherently counterproductive, and that the forms of human–material co-dependence involved lead 'ineluctably to dependency and more entanglement'. Although he does not make the connection in quite so many words, in reproducing and perpetuating resource-intensive interpretations of service, and the forms of dependency

associated with them, efficiency policies contribute to this deeply troublesome state of affairs (Hodder, 2014).

Conclusions

In conclusion, the *un-reflexive* pursuit of energy efficiency is problematic not because it does not work, or because the benefits are absorbed elsewhere, as the rebound argument suggests, but because it *does* work– via the necessary concept of equivalence of service – to sustain, perhaps escalate but never undermine, historically contingent but increasingly energy-intensive ways of life.

If this is what is wrong with energy efficiency, what should happen next? Are programmes of efficiency bound to have this double-binding effect? Does it make sense to take a stance *against* all forms of efficiency, or is there some alternative? Mirroring the position that Latour develops in *We Have Never Been Modern*, might there be ways of recovering a more positive but 'non-modern' role for energy efficiency by paying close attention to the question of what efficiency is for, and to the forms of material–human interaction it perpetuates?

One way of identifying such possibilities is to revisit the diagnosis of what is wrong. As summarized above, discourses and policies of efficiency and related programmes of research and development *do* depend on forms of purification. In that sense, they are part of the 'modern' tradition. But as Latour reminds us, these processes should not be taken at face value: instead, they should be interpreted as techniques that exemplify and constitute an historically and culturally specific moment in the ongoing configuration of human–material and energy-related entanglement. Energy-efficiency policies and the assumptions on which they depend are not outside these relations, but are integral to them. This turns out to be a problem in that contemporary assumptions embedded in efficiency policies are almost certainly not fostering and actively promoting ways of life that are compatible with radical carbon reduction.

This is not simply a matter of recognizing that efficiency is not the same as sufficiency, or that efficiency measures might rebound or backfire. The more important insight is that efficiency measures obscure the politics of the present. In preserving and perpetuating contemporary standards such policies disguise, and in the same move reinforce, their own role in making patterns of energy demand what they are today and in shaping those of the future as well. The solution is not to complicate or re-entangle the purifying work on which calculations of efficiency depend. That is both conceptually and practically impossible in that judgements of efficiency really do depend on abstraction. Instead, the challenge is to debate and extend meanings of service and explicitly engage with the ways in which these evolve. In effect, positioning energy efficiency as a useful rather than a counterproductive strategy depends on distinguishing between 'good' forms of efficiency, which have at their heart interpretations of service that are consistent with a radically lower carbon society and 'bad' forms which do not. This is clearly contested territory, but the ongoing commitment to 'present standards of service' is no less normative, and no less politically charged.

The prospect of designing energy-efficiency policies and strategies that are reflexive, historically aware and alert to the forms of service that they enable is intriguing, daunting and perhaps ultimately impossible. At a minimum, movement in this direction would require new ways of thinking about non-equivalence and about methods of folding these into a more rolling or dynamic mapping not only of how services are provided, but also of how they change *and* of the part that energy and energy-related technologies play in these processes.

More immediately, the conclusion that technologies, infrastructures and practices are interwoven suggests that there might be ways of crafting buildings and equipment that *do not* meet present needs, and that *do not* deliver equivalent levels of service, but that do enable and sustain much lower-carbon ways of life. This is not really a strategy of 'efficiency', not as understood by organizations like the IEA or the EU, but there is hopefully scope for fostering forms of design, manufacture and planning that actively unpick the types of embedded energy and carbon dependency that Hodder describes.

At a small scale there are some models and examples to follow. One is the method of providing homeowners and office workers with extended forms of 'adaptive opportunity'. This is not just a matter of enabling different ways of meeting established needs. Instead, and in relation to heating and cooling, the aim is to provide material arrangements and conditions that enable new (or old) interpretations of comfort to take hold (Humphreys, 1995). More prosaically, there are also things that can be done to ensure that existing low-carbon strategies persist, like guaranteeing at least the provision of a clothesline (Thomas et al., 2015). Enabling diversity is not the same as promoting energy efficiency, but at a stretch one can imagine future IEA reports that capture the 'avoided energy' generated by doing things differently, or by not doing them at all.

There is already plenty of research, policy and intervention around, alongside and sometimes in opposition to mainstream discourses and programmes of efficiency, and it is important to remember that not all strategies for

carbon reduction have efficiency (or decarbonizing supply) at their core. In addition, and since efficiency is a broad catch-all concept, not all the programmes and strategies that are labelled this way deliver on the promise of providing the same or more services for less energy. The rhetoric of efficiency is powerful and effective, but often vague enough to be used as 'cover' for a variety of other ambitions and goals. Whilst it would be a mistake to take references to efficiency at face value, it would also be wrong to underestimate how pervasive and how effective the efficiency paradigm is directing research, policy and investment.

Following Latour, one would expect the project and the ambition of energy efficiency to be multiply entangled. Sure enough, it is hardwired into methodologies and metrics, into the ways in which energy is understood, into future funding programmes, into policies at all scales, and into the terms in which responses to climate change figure on the political stage. In short, it is part of the contemporary landscape of knowing and doing. As such, it structures the kinds of expertise that counts and does so in ways that reproduce classically modernist splits between science and society.

In response, it is tempting to call for greater interdisciplinarity, and new ideas are definitely needed. However, as Daniels and Rose perceptively observed, it is no accident that the field of energy efficiency is 'devoid of any vision of history' (Daniels & Rose, 1982, p. 21). This is not something that can be fixed since it is an unavoidable consequence of how programmes of efficiency are conceptualized. In the end, it is impossible to imagine how organizations like the IEA, the EU or the UK Committee on Climate Change might come to recognize and explicitly evaluate their own role in making and shaping present and future 'needs'. At the same time, and as historians might well point out, the ambition of reproducing 'present' standards of living, now and in the years ahead, is doomed to fail. Although efficiency programmes certainly have an impact on the future, they cannot possibly contain or halt the shifting dynamics of energy demand or the changing complexes of practice on which that depends. On the one hand, the problem with efficiency is that it maintains the status quo, and in so doing helps perpetuate unsustainable ways of life. On the other hand, it cannot do so for long.

Although the preoccupation with efficiency stifles serious engagement with conundrums of this kind, and although it diverts attention away from the project of developing new, non-modern, configurations of nature and society, and of material culture and practice, there is still scope for critical debate and reflection and for re-evaluating the consequences and dangers of efficiency. This paper aims to contribute to that process.

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Notes

1. See https://www.theccc.org.uk/tackling-climate-change/reducing-carbon-emissions/what-can-be-done/.
2. See https://ec.europa.eu/clima/policies/strategies/2030_en/.
3. See http://www.eceee.org/about-eceee/governance/strategy/strategy-2016-2019/.
4. See http://www.iea.org/topics/energyefficiency/.
5. See, for example, the World Bank's guidance on making cities more energy efficient: http://www.worldbank.org/en/news/feature/2014/12/08/building-energy-efficient-cities-new-guidance-notes-for-mayors/.
6. Note the counter view that the very idea of 'rebound' is an outcome of an initially flawed understanding of energy and resource consumption. From this perspective, trying to trace 'trade-offs' between savings and consumption across different areas of daily life is a pointless exercise in that social activity is not organized this way. What people do is not separately evaluated in terms of money, time and forms of service. Instead, broader and more important questions are about how different social practices emerge, persist and change, and the forms of energy demand on which this evolving 'plenum' of practices depends.
7. Policy proposals designed to temper the effects of rebound typically argue for an energy or carbon tax, suggesting that this would help ensure that the benefits of efficiency are more comprehensively realized, and not diluted or squandered in ways that backfire.
8. See http://www.iea.org/topics/energyefficiency/. This is usually achieved either through technological innovation (developing, introducing and using appliances, buildings and infrastructures that consume less energy than those they replace), or by reducing 'waste'. That is, by eliminating uses of energy that do not deliver a useful service, *e.g.* turning off the lights in an empty room increases the efficiency with which energy is consumed in the building as a whole.
9. See http://www.iea.org/topics/energyefficiency/.
10. See https://www.eea.europa.eu/data-and-maps/indicators/progress-on-energy-efficiency-in-europe-2/assessment-2/.

11. See https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/571939/SAP_consultation_document__with_links_pdf/. There was a proposal – not adopted – to update assumptions within the UK Standard Assessment Procedure (SAP) regarding weekend heating periods to match the results of survey data (p. 8).
12. See http://www.homeheatingguide.co.uk/sedbuk-rating.html/.
13. SAP (Standard Assessment Procedure) is a method of evaluating the energy efficiency of homes that has been used since 1993 in the UK.
14. See https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/571939/SAP_consultation_document__with_links_pdf/.
15. See https://www.iea.org/publications/freepublications/publication/MediumTermEnergyefficiencyMarketReport2015.pdf/.
16. For both Hodder and Latour, these twin processes of purification and hybridization/entanglement are intimately connected. For example, Latour suggests that the more work that goes into separating nature from culture, or in his terms, the more we forbid ourselves to conceive of hybrids, the more possible their interbreeding becomes – such is the paradox of the moderns (Latour, 1993). This is a bit of a riddle, but the point is clear. As the extent of entanglement increases, and as its forms evolve through the multiplication of embedded social–technical arrangements (hybrids), including the lengthening of material and energy-related networks, so more work is needed to strip these 'complications' away. Meanwhile, these processes of purification create a 'world' in which the challenge of purification becomes ever more complex.

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