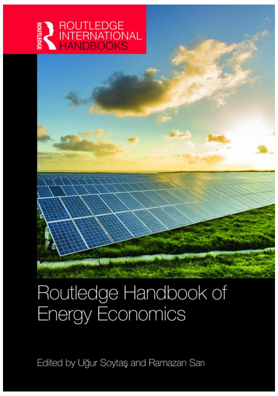

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Uur Soyta, Ramazan Sar

Energy efficiency and economy-wide rebound

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Lisa Ryan, Karen Turner, Nina Campbell
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Energy efficiency and economy-wide rebound

Realizing a net gain to society?

Lisa Ryan, Karen Turner, and Nina Campbell

1 Introduction

Improvements in energy efficiency have historically been promoted as a cost-effective and efficient way to reduce energy demand and greenhouse gas emissions (IEA, 2015; UNEP, 2014; European Council, 2014). Energy efficiency measures play a key role in many countries' strategies to mitigate climate change, while improving the security of energy supply by reducing pressure on the demand for energy. However, the benefits are not limited to energy and greenhouse gas emission savings. There is a wider set of potential benefits from improving energy efficiency that are now being coined 'the multiple benefits of energy efficiency' (IEA, 2014; ACEEE, 2015; Kerr et al., 2017). These benefits extend from individual level to national and regional level and across economic, social, and environmental contexts. Notwithstanding this, the merit of energy efficiency as a mitigation measure is regularly called into question in both academic and popular press with allusions to 'the rebound effect' (e.g. see Revkin, 2014; Gillingham et al., 2013; Shellenberger and Nordhaus, 2014). Rebound occurs when the realized reduction in energy demand is less than the engineering estimates would predict because of a range of economic responses triggered by the initial reduction in energy service price faced by the more efficient user.

There is an inherent tension in considering rebound as an indicator of the success, or not, of energy efficiency policy while adopting a multiple benefits prism. The measurement of rebound generally focuses on the ratio between actual and potential energy savings, where the latter is given by pure engineering savings that are technically possible. To have zero rebound in this setting would imply the absence of *any* economic response to a change in efficiency. This would seem to be a perspective peculiar to the energy efficiency rebound literature and not one that would enter consideration of increased efficiency in, for example, the use of capital or labor. The multiple benefits prism, on the other hand views the desired energy demand reduction as but one vector of many outcomes of energy efficiency policy measures (albeit the primary and thus potentially most heavily weighted objective).

In this chapter we examine the nature of economy-wide impacts of energy efficiency improvements more closely and the relationship with rebound effects. We argue that it is necessary to consider whether rebound in an economy-wide perspective reflects an outcome that delivers net socioeconomic gains from a societal perspective or whether rebound implies outcomes that are sufficiently negative (in terms of lost energy savings) to either deter from energy efficiency improvements or to warrant 'rebound mitigation' policy actions. However, we then go a step further, considering whether it might be possible to reduce economy-wide rebound effects (increasing energy savings) while retaining the socioeconomic gains of energy efficiency improvements, without resorting to mitigation tactics (such as additional tax burden associated with energy use) that may both constrain expansion and exacerbate inefficiencies/distortions in the economic system. We do so by considering the hypothesis that it may be possible to reduce rebound by focusing energy efficiency improvements on activities that are substitutes for more energy and/or carbon intensive competitors in delivering energy-using services such as transport, electricity generation, and heating. This introduces a different focus in terms of the types of substitution possibilities that have played such an important role in the rebound literature, traditionally with relatively high substitution possibilities between different types of fuel/energy uses and between energy and non-energy goods being associated with large rebound effects. Rather our argument relies on increasing substitution probabilities between different means of delivering the *services* produced to favor less energy and/or carbon intensive options.

This chapter is structured as follows. Section 2 considers the policy context for concerns over rebound effects. Section 3 then aims to clarify the different types of expansionary processes associated with energy efficiency improvements that give rise to economy-wide rebound and the traditional consideration of substitution possibilities in this respect. Section 4 then focuses on enhancing the relationship between economy-wide rebound effects and socioeconomic benefits delivered by increased energy efficiency. Finally, we conclude in Section 5 with some implications for policy makers and considerations for future research.

2 Why are we concerned about rebound effects from energy efficiency improvements?

A basic economic definition of an energy efficiency improvement would be enabling the use of less physical energy (e.g. gas) to provide the same service output (e.g. hours of heating at a given temperature) and, consequently, at a lower cost. This is the trigger for economic rebound at various (direct, indirect, and economy-wide) levels.

It is useful to begin by examining the objectives of energy efficiency policy and an overview of the recent academic literature on rebound in order to better understand how rebound effects impact the achievement of these objectives.

Many improvements in energy efficiency are designed as cost-effective measures to reduce energy consumption while addressing energy security, environmental, and economic challenges. Improvements in energy efficiency can also lead to a reduction in the need for investment in energy infrastructure and fuel costs as well as increased competitiveness and increased real household income and expenditure. Energy efficiency is widely considered a key tool and is promoted by many governments through policy measures, particularly in addressing climate change. This is illustrated, for example, in IEA models where it is estimated that energy efficiency would need to account for approximately 40% of the total emissions reductions needed to reduce CO_2 emissions by half by 2050 (IEA, 2015).

However, an academic literature on rebound effects in energy use that act to erode savings in energy and CO_2 emissions has been growing over the last 40 years. This was triggered by the contributions of Brookes (1978) and Khazzoom (1980) building on much earlier foundations laid by Jevons (1865). In recent years, perhaps prompted by policy attention to the potential implications of rebound (e.g. UK House of Lords, 2005; Maxwell et al., 2011) and well-known review works, such as the UKERC study edited by Sorrell (2007) and the Breakthrough report of Jenkins et al. (2011), the rebound debate seemed to explode for a decade or so. Attention has extended from basic direct rebound measures (the response of an energy user to the reduction in cost of an energy service when the efficiency of its delivery improves) to economy-wide rebound. The latter is broadly defined in terms of changes in all types of energy use across the whole economy triggered by the chain of economic reactions to a specific energy efficiency improvement in a given sector of the economy, set against the potential energy savings associated with that efficiency improvement.

The rebound literature can be divided into studies (1) reporting empirical measurements of mainly direct (e.g. Saunders, 2014, 2015; Small and van Dender, 2007) and more recently indirect (Zhang and Lawell, 2017; Lecca et al., 2014) rebound effects; (2) reviews of rebound effect estimates (Sorrell et al., 2009; Greening et al., 2000; Gillingham et al., 2014); (3) discussions of theoretical frameworks for rebound (e.g. Saunders, 2014; Howarth, 1997); and (4) categorizing different types of rebound effects (van den Bergh, 2011; Turner, 2013; Borenstein, 2015). However, one key problem for policy and wider understanding of the rebound issue is a lack of transparency in and common ground across many studies in how rebound is actually measured (at all levels, but particularly beyond the direct level).

While the basic definition of rebound as one minus the ratio of actual energy savings to potential energy savings (converted to percentage terms) is widely accepted, there is less clarity in terms of how actual and potential energy savings are actually measured in different studies. In particular, there is often a lack of clarity in terms of whether the focus is on impacts of the pure efficiency improvement alone or includes other 'baseline' scenario considerations, such as quantity adjustments in the energy supply chain directly serving more efficient users (see Guerra and Sancho, 2010; Turner, 2013).

However, a more fundamental problem may lie with the inherent perspective in the rebound literature – and, crucially, how it is interpreted – that anything less than a full realization of potential technical/engineering savings in energy use implicitly raises questions in terms of the effectiveness of energy efficiency enhancing instruments. This is a questionable perspective. For example, we do not expect or want labor efficiency improvements to lead to an erosion of employment. Rather, we expect economic responses to lead to an (efficient) expansion of (more productive) economic activity. Why then would we expect (or desire) economic actors to be unresponsive to the stimuli produced by an improvement in efficiency in energy use? The key difference in the context of the labor efficiency comparator would seem to be that public and politicians alike would welcome large rebound, ideally backfire[1] effects in employment. Indeed, this is likely to be a primary aim of economic policy built around labor efficiency improvements. On the other hand, any energy efficiency policy action that results in a net increase in energy use may be viewed as somewhat counterproductive (though empirical evidence suggesting likelihood of such a 'backfire' even at the economy-wide level in the case of energy efficiency is limited).

It may also be argued that the definition, measurement, and focus on of a single 'rebound' measure risk becoming a distraction from actually understanding and explaining how energy efficiency improvements work and impact on a full range of activities and agents in the wider economy in different case study and policy contexts (Turner, 2013). It would seem more important for policy purposes to clearly report and explain a full range of both increases and decreases in energy use in different sectors of the economy. Moreover, this should be considered in the context of both economic and social benefits (e.g. increased income in low-income households) and costs (including, as well as rebound, contractions in activity and employment in energy/fuel supply activities) that accompany (or are accompanied by) changes in energy use. Perhaps more crucially, analysis of different rebound pressures must be presented and explained in such a way as to permit policy makers to consider how/if they need to address 'the problem'. This perspective is aligned with the assertion by Gillingham et al. (2014, p. 26):

> Rather than consider the rebound effect as a deterrent from passing energy efficiency policies, policymakers should include [these] welfare gains in the tally of benefits of a policy. The mistake of designing policies to 'mitigate' the rebound effect stems from a focus on minimising energy use, rather than the broader objective of maximising economic efficiency.

Put simply, the success of energy efficiency improvements in delivering energy savings should be considered in the context of the full range of multiple benefits or indicators that are of interest to government as representing the interests of society. These include energy prices, security, and poverty, along with GHG emissions, a range of macroeconomic indicators such as GDP, employment and public budgets, as well as 'health and well-being'. The energy efficiency literature provides numerous examples where one or more of these parameters have been estimated and found to be positive and significant (ACEEE, 2014; Copenhagen Economics, 2012; Diefenbach et al., 2015; Howden-Chapman et al., 2009; Janssen and Staniaszek, 2012; Kuckshinrichs et al., 2013; Lehr et al., 2013; Liddell and Guiney, 2014; Worrell et al., 2003). Nonetheless, rarely are they comprehensively included in government policy evaluation.

The relatively narrow frame of assessment employed in evaluating policies in many countries can attribute undue importance to rebound effects in physical energy use and related emissions by underestimating the benefits of the energy efficiency measure (Ryan and Campbell, 2012; IEA, 2014). It is thus important to understand the wider non-energy impacts of an energy efficiency measure and the relationship with a consequent change in energy consumption (i.e. the rebound effect) in order to be able to assess the full value of energy efficiency measures. The rest of this chapter focuses on one category of these multiple benefits, namely the economy-wide or macroeconomic impacts of energy efficiency improvements. A key question from a policy standpoint is likely to be whether economic well-being can be further maximized while reducing (or at least not increasing) economy-wide rebound.

3 The macroeconomic impacts of improvements in energy efficiency

The multiple benefits of energy efficiency improvements include macroeconomic impacts as reflected in changes to key variables such as GDP, incomes, employment and trade.[2] The IEA (2014) identifies two distinct stages that trigger impacts at the macroeconomic levels: (1) investment in efficiency-enhancing technology and (2) the realization of efficiency improvements resulting in energy bill savings, although in practice the two steps may occur almost simultaneously with interacting effects.

Let's take these in turn. In many cases the first action taken as part of an energy efficiency measure is to invest in energy-efficient goods and/or services.[3] Investment spending, as well as enabling efficiency improvements, introduces additional demand along supply chains servicing this spending, which will lead to expansion involving energy use in different parts of the economy. However, as with any demand-led expansion, where there are constraints on supply this may impact prices and potentially 'crowd out' other activities. Moreover, given that the investment expenditure will take place in a given time frame only, the positive economic impacts are likely to erode after the initial demand boost delivered by investment spending. On the other hand, if a sustained program of investment in energy efficiency is put in place, this is likely to continue to deliver returns. Generally, there has been little work on the economy-wide impacts in enabling increased energy efficiency, with the literature tending to focus instead on the impacts of it being realized. See Figus et al. (2017) for one example of a study that considers the impacts over time of short-term government support to improve efficiency in household energy use.

The 'second step' arises in that when a more energy efficient technology is used, and the physical energy use required per unit of production of consumption activity falls, then more efficient users should enjoy reduced costs in delivery of the energy service in question. At this point, individuals or businesses will achieve real income increases and make decisions on reallocating savings from energy bills. However, as argued by Turner (2013) and Lecca et al. (2014), the nature of the subsequent wider economic expansion is likely to differ depending on the broad type of use where efficiency improves, of which we identify at least two cases.

First, where efficiency occurs in household energy use (i.e. the final consumption side of the economy), the increase in household disposable income is the source of a reallocation of demand away from energy spending towards spending on other goods and services. This translates to demand-driven expansion in economic activity. Again, the net direction and magnitude of the impact of this demand boost on macroeconomic indicators will depend on the nature of spending, supply and fiscal conditions and the impacts on prices and competitiveness. Similarly, the qualitative and quantitative nature of indirect or economy-wide rebound effects will vary, particularly where reduced energy demand leads to contraction in capacity and activity in energy supply chains (Turner, 2009, 2013).

In the second case, where an efficiency improvement takes place on the production side of the economy the successful implementation of energy efficiency enhancing technology will trigger a productivity-led, or cost-push expansion where a clearer path to net positive impacts on key macroeconomic indicators may be more unambiguously anticipated. While the extent and dynamics of expansion (and related energy use) will depend on the specific nature of the efficiency improvement and what type of activity it occurs in, as well as capacity and conditions particularly in labor and capital markets, the *net* impact on all components of GDP has a clearer potential to be positive. However, even where net positive impacts are likely to occur at a macro level, the *gross* impacts at the individual sectoral level may not all be positive. In particular, in energy supply sectors there may be a contraction in activity and capacity arising from a decrease in energy consumption. More generally, labor and capital supply conditions, as well as the strength of and demand response to positive competitiveness effects, will govern the extent to which different sectors are able to expand. The greatest pressure for expansion is likely to occur in sectors that are impacted (directly or indirectly) by the initial efficiency improvement (through supply chain linkages). However, these will not necessarily be sectors that produce the most value-added for the economy or employ the most people/provide the most income from employment, and may also be more or less energy and/or carbon intensive sectors. In short, the outcome of any energy efficiency enhancement cannot be predicted on a theoretical basis alone.

Rather, a review of applied case studies is required to answer the question of what magnitude of economy-wide rebound effects can be expected in either of these two (broad) cases. In the major UKERC review of rebound evidence reported in Sorrell (2007), economy-wide rebound estimates, mainly from studies using CGE modeling techniques, took on a wide range of values. A key conclusion was that economy-wide rebound is dependent on the nature and location of the energy efficiency improvement and the economic conditions prevailing in the economy under study. The findings of more recent CGE studies (e.g. Figus et al., 2017; Lecca et al., 2014; Broberg et al., 2015) continue to support this conclusion. Case-specific conditions include a range of factors, particularly the costs of introducing efficiency improvements, energy intensity of the sector where efficiency improves, and how the labor market functions.

However, Turner (2009) – and the sensitivity analyses of many CGE modeling studies – demonstrates that the assumed or estimated values assigned to key substitution elasticities play a key role in governing the extent of *both* economic expansion *and* economy-wide rebound. This is particularly (but not exclusively) in the production/consumption functions of sectors where energy efficiency improves and/or where more efficiency outputs are used. Rebound researchers (both CGE and more generally) have focused on the importance of the importance of (1) inter-fuel substitution elasticities; (2) elasticities of substitution between energy and materials/non-energy goods (in consumption and production), energy, capital and labor (just production); and (3) trade elasticities for energy and energy-using goods and services. All other things held constant, the higher these elasticities are, the greater will be both any expansion and the economy-wide rebound effects triggered by an efficiency improvement.

Consequently, rebound mitigation propositions have tended to focus on constraining substitution effects in favor of energy, in particular by countering the initial decrease in the effective price of a particular energy type following the efficiency improvement itself and/or the consequent energy demand reduction through economic instruments such as carbon taxes. However, such actions would be likely to also constrain the expansionary process itself, which will have wider implications in terms of lost economic opportunities from energy efficiency policies.

Moreover, to date the rebound literature has not addressed the question of whether economic expansion and economy-wide rebound need be so negatively tied following an energy efficiency improvement. This is an important gap. If it can be filled, well-informed policy analysts may look to target energy efficiency improvements so that they facilitate (rather than constrain) consequent expansionary processes in areas of the economy where such processes give rise to benefits (e.g. increased employment) and have lower carbon intensity. Moreover, where this may involve efficiency-induced stimuli favoring lower energy/carbon-intensive activities that are competitors for more energy/carbon-intensive ones in delivering services, well-aimed policy action may involve acting to enhance rather than constrain substitution possibilities.

4 Connecting economy-wide rebound effects and socioeconomic gains

A central question considered in this chapter is how to enhance the relationship between energy efficiency policy, economy-wide rebound effects and socioeconomic gains. More specifically, we focus on the question of whether it may be possible to consolidate economy-wide gains while limiting the energy rebound (or maximizing energy savings). In this context, we focus on economic prosperity but note that policy makers will also identify societal values associated with health and well-being, environment and climate change mitigation, employment, and social equality – that is, the basic interpretation of the term 'multiple benefits' proposed in IEA (2014). We consider this perspective by examining first the link between socioeconomic value at economy-wide level from energy efficiency measures and rebound, and then how the factors that determine the size of the resulting economy-wide rebound can be increased to enhance socioeconomic benefits.

4.1 Rebound and socioeconomic gains from increased energy efficiency

There has been limited analysis of the relationship between energy efficiency, socioeconomic gains, and rebound in the academic or policy literature. Linked to this, there are few examples of explicit estimations of the welfare impacts from rebound effects. Several papers acknowledge that the energy efficiency rebound effect is likely to have positive welfare implications (Gillingham et al., 2014; Borenstein, 2015), but this assertion has not yet been explicitly examined in the context of economy-wide analysis in any detail.

Chan and Gillingham (2015) provide the first welfare-focused treatment of the rebound at the *microeconomic* level. They use a theoretical model of consumer utility to derive conditions when rebound is likely to generate overall welfare gains. It does not include the costs of investment in energy efficiency, nor the dynamics or behavioral anomalies of the decision process. They show that, when there are external costs present, an 'exogenous costless increase' in energy efficiency and the consequent direct and indirect rebound may increase or decrease welfare. The determining factor in the Chan/Gillingham model is the external costs associated with increased energy consumption. If these are lower than the benefits from increased energy use through the rebound effect, then the rebound effect is welfare enhancing. This approach implicitly assumes that we do not consider the sole objective of energy efficiency policy to be energy savings but rather to be overall economic efficiency and societal welfare, as is true in other areas such as labor and health policy making.

How do we move from this to consideration of the societal well-being implications of economic expansion accompanied by rebound at the economy-wide level? If we were to apply a similar approach as Chan and Gillingham (2015), a detailed analysis and good comprehension of *societal* costs and benefits arising via the economy-wide response would be needed. If the primary objective of energy efficiency policy is to reduce energy use, then this should be weighted accordingly in policy assessment among the broad set of potential policy outcomes.

4.2 Boosting the energy rebound/socioeconomic well-being relationship

In Section 3 we discussed how improvements in energy efficiency will drive demand-led or productivity-led (cost-push) expansions in economic activity, but with supply conditions determining whether this will involve crowding out and/or reallocation of labor and capital between different sectors. Depending on the nature of production in the sectors that benefit most in the expansionary process, increased activity in any one sector is likely to be accompanied by some increase in energy use/energy rebound with associated external costs in that sector and potentially elsewhere. On the other hand, particularly in more labor and/or wage-intensive expanding sectors, these costs will occur alongside increases in employment and income from employment. These are two economic variables that are generally considered to be welfare-enhancing at a societal level (e.g. see Whelan et al., 2015).

Thus, a first point of interest in assessing whether costs associated with energy rebound are likely to dominate benefits from economic expansion may be whether the expansionary process favors more or less energy-intensive sectors as against (and/or combined with) other characteristics such as labor and/or wage intensity. That is, considering the likely *composition* of increased economic activity and the extent to which it will deliver social benefits that may be set against the costs associated with accompanying economy-wide rebound effects.

However, a second question is whether it is possible to design and target energy efficiency policy in such a way that the delivery of socioeconomic benefits can be decoupled from economy-wide rebound effects. We put forward the following hypothesis. If energy efficiency improvements can be targeted at a means of delivering an energy-using service (e.g. public transport or renewably sourced heat) that is a substitute for a more energy-intensive competitor in delivering a given service (e.g. private transport or oil-based heating), and it is possible to make the less energy-intensive option more attractive to service users, then such a decoupling may be possible. In other words, we propose that energy (and potentially other types of) efficiency improvements be targeted in a way that exploits substitution possibilities between different means of delivering energy-using services so as to favor relatively low energy/carbon options, and thereby limiting the extent of energy rebound accompanying economic expansion.

Exploring this hypothesis would require a broadening of our attention from one of the mainstays of rebound research, namely the focus on rebound occurring through substitution effects that favor increased but more efficient energy use. Rather, the focus would need to shift to consider not just energy use itself but the inputs to the production of energy services (which will be more or less directly *and* indirectly energy intensive). Crucially, it would also involve focusing on how service users respond to changes in price and other determinants of demand in the competing options they may choose between. For example, in choosing between electric rather than gas-powered heating systems (assuming that electricity is delivered in a low carbon way), or between different modes of public transport relative to fuel use in private cars to deliver mobility.

This service-focused argument may not be an immediately intuitive one for policy making, where the most energy-intensive production and consumption processes have generally been the first targets of energy efficiency policies (i.e. heavy manufacturing, inefficient lighting, driving private cars; see IEA, 2011). Moreover, it is one that requires considerable research effort. As discussed above, the economic channels for the economy-wide impacts of energy efficiency and resulting rebound are strongly case specific. Similarly, empirical analysis of different case studies for different types of service delivery in different economic conditions would be required in order to establish the conditions for which our hypothesis might hold and to determine how it might be exploited to further enhance the net socioeconomic gains of energy efficiency measures.

5 Conclusions: implications for policy makers and future research

Economy-wide rebound effects are generally symptomatic of increased economic activity triggered by improved energy efficiency. Here we have argued that, in a similar manner to any other policy, assessment of an energy efficiency policy should be considered from a societal cost-benefit perspective. In this light, the realized energy savings are unlikely to be the only measure of success or otherwise of the policy, rather the economic impacts and increased societal well-being and economic prosperity may be an equal or higher priority for many regional and national policy makers and members of the public.

We argue that a key question is not one of how to mitigate rebound. Rather it is one of recognizing the macroeconomic benefits that share the same trigger as rebound (the initial reduction in the relative price of energy services in the sector/activity where efficiency improves) and seeking to retain these, while identifying and understanding the distributional implications (across different industries and households). Where there is a binding constraint underlying the need to reduce energy use (e.g. climate change commitments) and therefore mitigate rebound, taking a perspective that focuses on maximizing socioeconomic gains implies that this should be treated in a similar way to any other macro-level constraints (on government budget, balance of payments etc.).

Through consideration of the channels through which economy-wide rebound occurs, we conclude that the level of substitution in demand between different energy-using *service* options may be a key parameter in decoupling rebound and societal gains from energy efficiency rather than reducing the demand for the service as a whole. We consider the implications of targeting energy efficiency measures at the less energy and/or carbon-intensive service options for delivering services that are commonly associated with relatively high energy use (e.g. mobility and using public rather than private transport option(s) for a given for journey). We hypothesize that this may involve improving the attractiveness of lower carbon/less energy-intensive options through price and/or other characteristics relative to more fuel-intensive competitors (e.g. using a private car for the same journey). Such developments may then lead to a decoupling the rebound from any economic expansion that may be triggered by improved efficiency.

Several policy implications arise. First, there should be more attention to identifying and considering service options that may be the target of energy (and possibly other) efficiency policies with a view to enhancing their competitiveness with higher energy/carbon alternatives. This involves a change away from the focus in current policy thinking that prioritizes energy efficiency improvements mainly in energy-intensive activities. In terms of the academic rebound debate, a shift of attention is required from focusing mainly on inter-fuel and energy/non-energy substitution possibilities in favor of considering how users substitute between competing means of delivering energy and energy-using services. This is also likely to require more attention to how various energy types and particularly durable/investment goods interact in both delivering different heating and transport services and in delivering efficiency improvements in these services and their underlying energy uses. Interdisciplinary research in energy use and diffusion of energy services would be useful that may involve combining behavioral models and societal issues with macroeconomic modeling.

However, as discussed above, and already accepted as the case in considering causal mechanisms that deliver economy-wide and macroeconomic effects of energy efficiency measures, this issue will ultimately need to be considered on a case-by-case basis. Initial research activity may involve theoretical analysis of the conditions under which more efficient and competitive low carbon energy service delivery is likely to translate to a decoupling of economic expansion and economy-wide rebound. However, as argued above, the outcome of any specific case study will be an applied question.

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Notes

1 Backfire occurs when the rebound effect is greater than 100%.

2 The term 'macroeconomic' in this paper is used to cover economy-wide effects that occur at national, regional and international level. It is concerned with the aggregate effects of energy efficiency measures which may be considered as comprising (1) the sum of the individual microeconomic effects and (2) the impacts of the whole economy resulting from non-linear complex interactions throughout the economy.

3 Energy efficiency improvements can also be undertaken without involving investment if we assume energy efficiency improvements are delivered as a public good, in which case only the energy cost reduction effects apply in this discussion. However, for large-scale improvements in energy efficiency globally, both behavioral change and investment – as well as financing systems that encourage behavioral change – will be needed. Therefore the investment effect will apply for most governments seeking to estimate the macroeconomic effects of energy efficiency measures.

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