Tilman Santarius · Hans Jakob Walnum
Carlo Aall *Editors*

Rethinking Climate and Energy Policies

New Perspectives on the Rebound Phenomenon

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Preface

It has been a long 150 years since English economist William Stanley Jevons identified the potential rebound paradox created by technology advances that both improve resource efficiency and make uses of those technologies more economically. His impressive feat of systems thinking came to him already during the early stages of the fossil fuel age. He witnessed the onset of the current era through the emergence of the coal-fuelled Industrial Revolution. But his insight was mostly forgotten during the era of fossil fuel.

The interest is reawakening just at the onset of a new era ushered into being December 12, 2015 in Paris, where more than 190 countries joined together to commit to “aggregate[ing] emission pathways consistent with holding the increase in the global average temperature to well below 2 °C above preindustrial levels and [the need to pursue] efforts to limit the temperature increase to 1.5 °C.” This astonishing landmark means that this book is not only incredibly timely, but very necessary. It is about time indeed we lay out fully the issues that amplify, or moderate, the coupling of energy consumption and economic performance.

What does the Paris goal of staying well below 2 °C mean? Translating temperature into carbon speak is pretty straightforward. According to IPCC reports, holding the increase in the global average temperature to well below 2 °C above preindustrial levels means that there is only little carbon left to emit. In other words, it acknowledges the need to move out of the fossil fuel economy. To be specific starting from December 2015 until eternity, there are a maximum of 800 gigatonnes of carbon net emissions left, and possibly much less if we want to reach the goal with a high level of certainty. Currently we, the people living on this planet, emit more than 35 gigatonnes of carbon a year.

Now, to put this in perspective, if you were on vacation with just 800 Euros left in your pocket, and you knew you needed to spend 35 Euros a day to pay for food and board, how many more days could your vacation last until you have to return home? Obviously the analogy has its limitations. On the carbon front, in contrast to vacations, we want to phase out carbon softly to avoid disruption and chaos. If we are careful, we could wean ourselves over the next 35 years and make the transition manageable. We would need to get net emissions down to zero before 2050, all the while making sure that the journey does not compromise the rest of the biosphere as we are looking for alternative energies to power us. And more food and amenities, because I hear the world population is still expanding.

In this context, the design challenge before us is undoubtedly formidable. We need the best tools available to figure out, and walk, the path. Simplistic and naïve energy efficiency strategies are just not going to cut it. Only by understanding the dynamics of our interventions reasonably well can we can discover effective pathways that secure human wellbeing while allowing us to grow rapidly out of our fossil fuel dependence. This is the reason why this book edited by Tilman Santarius, Hans Jakob Walnum and Carlo Aall is essential.

If indeed we want to succeed with decoupling energy use and economic prosperity, and to live within the resource and carbon budget that our one planet provides, thoughtful and innovative ways forward are required. An essential step toward a sustainable world is for decision makers to recognize the possibilities of rebound effects in order to design public policies and initiatives that are truly effective. As this book reminds us very well, the challenge doesn't stop at climate and energy policy, but affects transportation, urban planning, the Internet, tourism, even labour-market policy and more. In fact, rethinking sustainability policies in order to make them impactful requires identifying—and eventually containing—rebound effect risks in virtually all fields of policy-making.

This book marks the long overdue beginning of a new chapter in the history of mankind. It provides insights we so dearly need if we truly want to succeed. Emancipating ourselves from fossil fuels while learning to prosper within the resource budget of our planet is worth the effort of every waking moment. Simply said, *Rethinking Climate and Energy Policies—New Perspectives on the Rebound Phenomenon* points the way.

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Contents

Abstract

This volume suggests rethinking current climate, energy and sustainability policy-making by presenting new insights into the rebound phenomenon; i.e. driving forces, mechanisms and extent of rebound effects and possible ways to mitigate these effects. It pursues an innovative and novel approach to the political and scientific rebound discourse and, hence, supplements the current state of knowledge discussed in the field of energy economics and recent reports by the Intergovernmental Panel on Climate Change. Building on the realm of rebound publications from the past four decades, this volume contributes in three particular ways: Part I offers new aspects in rebound economics by presenting insights into issues that have so far not been satisfactorily researched, such as rebounds in countries of the Global South, rebounds at the producer side, as well as rebounds from sufficiency behaviour (as opposed to rebounds from technical efficiency improvements). Part II goes beyond the conventional economic rebound research and explores multidisciplinary perspectives on the phenomenon, in particular from psychology and sociology. Advancing such multidisciplinary perspectives delivers a more comprehensive understanding of rebound driving forces, mechanisms and policy options. Part III puts rebounds into praxis and presents several policy cases and sector-specific approaches, including labour markets, urban planning, tourism, information and communication technologies, and transport. The volume finally embeds the issue into a larger debate on decoupling, green growth and degrowth, and sketches out lessons learned for sustainable development strategies and policies at large. Employing such widespread and in-depth analysis, this volume makes an essential contribution to the discussion of the overall question: Can resource use, energy use and greenhouse gas emissions be substantially reduced without challenging economic growth?

Chapter 1
Introduction: Rebound Research in a Warming World

Tilman Santarius, Hans Jakob Walnum and Carlo Aall

In December 2015, at the UN conference on climate change in Paris (COP21), 195 governments accomplished a momentous agreement to diminish humanities' dangerous interference with the climate system, and to support actions and investments towards a low carbon, resilient and sustainable future. The parties agreed to stick to —and even strengthen—the goal agreed on in Copenhagen (COP15) in 2009; that is to "*holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels*" (UNFCCC 2015).

Throughout science, civil society and the media, the Paris Agreement is widely considered as again another strong political signal to cut greenhouse gas (GHG) emissions to sustainable levels and basically end fossil fuel use within the coming decades. However, 2015 came with a dramatic drop in the global prices on fossil fuels, whereas a number of commentators in the climate debate call for the opposite to happen. Global emissions of carbon dioxide related to energy use were flat in 2014, compared with the previous year according to the International Energy Agency (IEA), but are expected to increase again in 2015 due to falling oil prices.

As an explicit step to show action in the aftermath of the Paris climate conference, several countries have announced to increase their energy efficiency. Most notably, five days past the Paris talks, the US Department of Energy tabled a new energy efficiency policy, which it called "*the largest energy-saving standard in history*" (US DoE 2015). According to the US government, this policy intends to

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save the sheer amount of 885 million tons of carbon dioxide emissions until 2030 by way of making space heating and cooling devices more efficient. In the process, US businesses are expected to save 167 billion US dollars. Many other countries, from Ethiopia to Kazakhstan, are now also planning to invest in energy efficiency. And in the European Union, debate is heating to significantly increase the EU's 2030 energy efficiency target (e.g. to 40 %), as many consider the current 27 % target as too low on ambition for meeting the goal to limit global warming. So the idea in all these efforts is that a reduction in energy use per unit of consumption will reduce the total GHG emissions. The problem with this reasoning is that very little attention is given to the intermediate factor; namely, the level of energy consumption. Few—if any—countries have adopted a goal of reducing its absolute level of energy consumption, and few countries have integrated its climate and energy policies; in most countries, these are separate policy areas aiming at different overall goals—namely, that of securing the national energy demand compared to that of reducing national GHG emissions.

The authors of this volume appreciate any action to address the challenge to mitigate climate change, and to adapt to its unavoidable consequences. We assume that a significant portion of this effort will have to include energy use. However, we depart from the evidence that many efforts did already increase the energy efficiency of nations throughout past decades, but that all too often such honest endeavours have been partly or fully neutralized by newly increased energy demand (Sorrell 2015). Global data indeed suggests that over the long run, energy efficiency has steadily increased in most countries; i.e. energy use per unit of consumption or per dollar of gross domestic product has declined (IPCC 2014; IEA 2014). But at the same time, absolute energy consumption has increased in most nations or at best remained stable in very few countries—apart from certain phases of absolute reductions that could clearly be attributed to economic breakdowns (such as in the countries of Eastern Europe and the former Soviet Union during the 1990s, or globally during the financial crisis in 2008/2009).[1]

While this paradox can have many reasons, one of them has been found in the *systemic relationship between efficiency and expansion*; notably, that it is the efficiency improvement as such that enables, or even causes, an increase in demand. This phenomenon is termed the '*rebound effect*'. It raises doubts whether straightforward efficiency policies, such as the new US standard for heating and cooling devices, the tightening of the 2030 EU energy efficiency target, or others, can live up to their promises of producing substantial reductions in GHG emissions unless they are embedded in more comprehensive policy designs that address potential rebound effects at the same time. And with the Paris Agreement now even striving towards the aspiring goal of limiting climate change towards 1.5 °C warming, any size of global rebound effect will have to be considered in the calculation of policy effects and, as far as possible, be contained.

[1]This fact appears all the more sobering when consumption-based data—instead of territorial statistics—are considered (see e.g., Bruckner et al. 2012; Peters et al. 2012).

This volume, which is dedicated to interrogate the nature and relevance of the rebound phenomenon for the purpose of contributing to improve climate as well as energy policy, is guided by several overarching questions: How can it be explained that energy efficiency improvements often do not translate into adequate absolute reductions of energy service demand? With what kind of scientific disciplines, theories, and empirical models can the rebound phenomenon, and its various different forms be investigated? What are specific conditions under which rebound effects tend to emerge in certain real-world sectoral- and policy-contexts? And finally, what kind of policies, measures and other solutions (individual, systemic) should be considered in order to contain rebound effects and take care that global energy and resource demand can be reduced to sustainable levels?

1.1 Reducing Energy and Resource Demand for Sustainability

The debate on the relationship between energy use and climate change, and the possible need to reduce energy use in order to avoid unacceptable global climate change, adheres to a continuous scientific discourse, initiated in the early 1970s by contributions from scholars like Georgescu-Roegen (1971), Daly (1973) and Mishan (1977). Embedded in this early discourse was a strong critique of economic growth as a superior goal for the development of nations and the formulation of physical limits of growth (Meadows et al. 1972). The 1987 Report by the World Commission on Environment and Development ‘Our Common Future’ renewed impetus to the discourses from the 1970s (WCED 1987). Energy use and consumption were key issues in the report, and the need to fundamentally change patterns of production and consumption in rich countries was very much emphasized.

Since the 1990s efforts were made to pick up on the critiques of economic growth and its implications under the heading of sustainable consumption (Schor 1991; Cross 2000; Princen et al. 2002). A basic element in the sustainable consumption debate was the issue of global justice and the idea that people in the rich north can ‘live better by consuming less’ (Jackson 2006) and the debate on the potential for decoupling environmental impacts from economic growth (Jackson 2009). In these debates, three perspectives on how society should achieve more sustainable consumption emerged (see Sachs and Santarius 2007): (1) **Efficiency**: increase efficiency in energy and resource use by making production processes as well as end-use products and services more efficient (e.g. improve fuel economy of cars), in most cases through technological innovations. (2) **Consistency**: change the resource base of production and consumption in order to make them less environmentally harmful (e.g. shift from fossil fuels to renewable energy carriers). (3) **Sufficiency**: reduce the volume of products and services (e.g. reduce kilometres driven, or resource inputs) and change structural patterns (and habits) of production and consumption (e.g. shift from private cars to public transportation).

The sustainable consumption discourse soon focussed on transforming production to become more efficient in terms of resource use rather than pressing for radical changes in consumption. This strategy, coined 'eco-efficiency' in 1992 by the World Business Council for Sustainable Development (Schmidheiny 1992), originates from a more general idea of how society could be transformed in order to solve environmental problems: the reform-oriented school of ecological modernization, which emerged in Europe during the early 1980s (Spaargaren et al. 2000; Mol 2001). A basic assumption of ecological modernization and eco-efficiency is the idea of environmental re-adaptation of economic growth and industrial development by means of increasing the marginal environmental efficiency of industrial production measured, e.g. in the form of energy per unit of production or per unit price. The final and total output received less attention; that is, whether applying a strategy of ecological modernization or eco-efficiency has actually reduced the total environmental pressure on society, or just literally moved the pressure to other regions or related economic activities, often referred to as either leaking or rebound effects (Hertwich 2005).

The debate on the relationship between consumption, energy use and climate change has recently been further developed under the heading of 'degrowth' (Latouche 2009; Schneider et al. 2010; D'Alisa et al. 2015). In these works, it is argued that degrowth should not be treated as a negative event affecting the present global economy—thus being met with strategies to boost the economy back onto the growth track. It should instead be treated as a strategy for economic restructuring in rich industrialized countries in order to achieve two goals: a more just distribution of economic welfare between rich and poor countries, and a substantial absolute reduction of environmental pressure.

Increasing the efficient use of energy and material resources is widely considered a key strategy for achieving such absolute reduction of environmental pressure, most notably human-induced climate change (Weizsäcker et al. 1998; UNEP 2011; OECD 2012; IEA 2014). Yet, while new technologies and environmental policies have indeed led to significant improvements in energy and resource efficiency per unit of consumption or output, progress in the total reduction of environmental impacts has been less than expected. What has rebound research so far delivered to explain this paradox?

1.2 A Brief History of Rebound Research

Already in 1865, William Stanley Jevons has precisely described the relationship between the increase in energy efficiency and the increase in demand in his famous book 'The Coal Question' (Jevons 1906). It appears that just as today, so too did at Jevons time obviously circulate the idea that efficiencies could save nations from an increasing shortage in the supply of energy carriers. For Jevons recites: "*It is very* *commonly urged, that the failing supply of coal will be met by new modes of using it efficiently and economically. The amount of useful work got out of coal may be made to increase manifold, while the amount of coal consumed is stationary or diminishing. We have thus, it is supposed, the means of completely neutralizing the evils of scarce and costly fuel.*" (Ibid, p. 102) But Jevons strongly opposed this view and instead postulated the core of the mechanism that today is termed a rebound effect: "*It is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to a diminished consumption. The very contrary is the truth.*" (Ibid, p. 103) Apparently, however, the (seeming) paradox described by Jevons has been forgotten for more than 100 years. Only since the 1980s, it has experienced a renaissance. The history of modern rebound research can roughly be divided into four distinctive, though partly overlapping phases:

Phase 1—Theoretical Exploration: Daniel Khazzoom published the first microeconomic explanation of the paradox (Khazzoom 1980, 1987)—although he did not yet mention Jevons nor called this a rebound effect. Around the same time, yet disconnected from Khazzoom, did Leonard Brookes formulate a number of hypotheses, which suggest a rebound effect at the macroeconomic level (Brookes 1978, 1990). Both publications sparked an intensive debate among energy economists, but it was not before Harry Saunders' publication in 1992 that the two strains of discussion—the Khazzoom and the Brooks discussion—had been merged as the 'Khazzoom-Brookes-Postulate' (Saunders 1992, 2000).

Phase 2—Empirical Foundation: The 1990s witnessed a large number of publications that theoretically and empirically investigated and substantiated Khazzoom's, Brookes' and Saunders' hypotheses (for an overview, see e.g. Alcott 2005). Dozens of microeconomic empirical investigations appeared. In addition, first macroeconomic rebound effects have been modelled (see Sorrell et al. 2009). In 1998, Greening and Greene presented the first meta-analysis of the rebound literature (Greening and Greene 1998; Greening et al. 2000). A special issue of Energy Policy was devoted to the issue in 2000, which contained a number of seminal articles (e.g. Berkhout et al. 2000; Birol and Keppler 2000; Brookes 2000; Saunders 2000; Schipper and Grubb 2000). Shortly thereafter, Binswanger (2001) and Jalas (2002) introduced the factor of time to rebound research and thus opened a new strand of debate. Another milestone is the multi-year research project at the UK Energy and Resource Centre under the direction of Steve Sorrell, which gave birth to several comprehensive reports (Sorrell 2007; Allan et al. 2007; Broadstock et al. 2007; Sorrell and Dimitropoulos 2007, 2008). Moreover, two edited volumes on the rebound effect have been published in the late 2000s (Polimeni et al. 2008; Sorrell and Herring 2009), on which this volume heavily draws and which it intends to update, advance and diversify.

Phase 3—Political Evaluation: As public critique on resource-intensive economic growth re-emerged with the financial and economic crisis in 2008/2009, this popularized the rebound issue in civil society and policy debates (e.g. Jackson 2009). Apart from the controversial popular book by Owen (2011), several Internet posts as well as occasional articles in daily and weekly newspapers have been published (e.g. Barret 2010; Burns 2011; Afsah 2012). To address policy-makers, further meta-studies were conducted and a number of policy-oriented reports as well as popular scientific articles appeared (e.g. Jenkins et al. 2011; Maxwell et al. 2011; Azevedo et al. 2012; Michaels 2012). Around the 'Rio+20' UN conference in 2012, the issue played a crucial role in the discussion of concepts such as green growth and green economy (Santarius 2012; International Resource Panel 2011, 2014). Besides, during this phase and until today, manifold further publications strengthened the empirical and theoretical foundations of the rebound effect.

Phase 4—Multidisciplinary Extension: In recent years, rebound research has shifted from solely to be discussed within energy economics towards an interdisciplinary field based on several disciplines and methodologies (Giampietro and Mayumi 2008; Schneider 2008; Girod and de Haan 2009; Peters et al. 2012a; Walnum et al. 2014; Otto et al. 2014; Santarius 2014, 2015a). Thus, a new chapter was opened in the history of rebound research, with the phenomenon being grasped through explanations that go beyond income and substitution effects. This implies that structures (physical infrastructures, economic and political systems, mental mechanisms) as well as other factors (e.g. habits, lifestyles, change of attitudes and norms) despite 'saved money' can generate rebound effects.

1.3 Terminology and State of Research

Energy economists usually distinguish at least three types of rebound effects: direct, indirect, and economy-wide rebound effects (Sorrell 2007). At the microeconomic, consumer-side level, for example, expected reductions in fuel consumption from making cars more fuel efficient may lead to cost savings, and these cost-savings can partly be used by car owners to drive more kilometres than before. This is called a 'direct rebound effect'. It might also be the case that car owners use the savings to spend them on other activities, e.g. on new household gadgets or long-distance flights. This is called an 'indirect rebound effect'. In certain cases, these effects can even lead to a net increase in energy use, which is dubbed 'backfire'. Rebound effects can be generated not only at the level of (end-use) consumers, but also in the process of production. Such effects could be considered as 'mesoeconomic rebound effects'. They can be generated through direct and indirect rebound effects from companies, but may also stem from energy price effects at industry branch or market level. Finally, making economies more energy efficient fosters overall economic output. This can generate additional demand for energy, thus multiplying micro- and mesoeconomic rebounds at consumer and industry level. Such efficiency-induced economic growth effects at the aggregate level have been researched as 'macroeconomic rebound effects'. All effects together sum up to the 'economy-wide rebound effect'.

As of microeconomic direct rebound effects generated through income and substitution effects, there is broad agreement on the overall functioning of these effects. Controversy remains on the actual scale of direct rebounds in various sectors and countries, although several recent meta-analyses suggest somewhat reliable average trends (see Greening et al. 2000; Sorrell 2007; Maxwell et al. 2011; Jenkins et al. 2011; Madlener and Alcott 2011; Azevedo et al. 2012). However, indirect rebound effects have only been partly researched so far (see for instance, Druckmann et al. 2011; Chitnis et al. 2013, 2014; Azevedo and Thomas 2013; Lin and Liu 2015). This volume draws on more than three decades of microeconomic rebound research, outlines remaining open questions, and provides some fresh research on some aspects of microeconomic rebound research that have not yet been treated satisfactorily. At the same time, it exposes the rather narrow economic approach on consumer-side rebounds to theories from other disciplines, namely from environmental psychology.

As of 'mesoeconomic rebound effects', only few studies acknowledge the importance of production-side rebounds as a separate and identifiable factor and area of research. Greening et al. (2000) are the first to mention rebounds by "firms" and point out two distinct rebound mechanisms, namely 'output effects' and 'factor substitution', yet without further investigating these effects (likewise Sorrell 2007; Sorrell et al. 2009; Jenkins et al. 2011). The limited number of other publications that offer a theoretical perspective on production-side rebound effects (e.g. Michaels 2012; Borenstein 2013; Turner 2013) mention the same linkages that occur in the case of macroeconomic effects—namely, the fact that the interaction of labour, capital and energy as factors of production changes throughout the economy, which can lead to overall economic growth. Only few empirical studies start calculating producer-side rebounds at the aggregated level of industry sectors (Bentzen 2004; Safarzynska 2012; Saunders 2013), while a handful of studies are available on freight and air transportation (Santarius 2015b). This volume takes stock of the limited existing research and further develops the research agenda for producer-side rebound effects.

As of macroeconomic rebound effects, much controversy remains, such as on the scope of the output elasticity of energy (namely, how energy as a factor of production leverages overall economic growth), the degree of substitutability of all factors of production or the relationship between efficiency increases and product/service innovation (Sorrell 2007; Madlener and Alcott 2009; Turner 2013). It is difficult to prove or disprove how the dynamics between energy efficiency and growth work, based on macroeconomic growth models. The results of the models much depend on underlying assumptions (Santarius 2014). This suggests that investigating efficiency-induced economic growth effects should be carried out not only through the lens of economics but also through other scientific disciplines, which might help to better grasp the complex matter and shed new light on the relationship between energy efficiency and output growth. This volume intends to foster such a debate.

Although the rebound phenomenon has provoked many reports and dozens of peer-reviewed articles, it still appears greatly under-researched. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change, which mentions it in several chapters and reviews key findings of existing rebound research (e.g. IPCC 2014, pp. 98, 249, 390, 707, 1168), concludes that the research base is still far from delivering a robust understanding—let alone a reliable quantification of the various forms of rebound effects. Not merely empirical research is needed, but even more so sound theoretical explanations of how and under which conditions rebound effects emerge (see also Turner 2013; Santarius 2015a).

At the same time, strong controversy upon the phenomenon prevails. Some scientists claim that rebound effects are limited, due to demand saturation or negligible energy costs, and therefore are of minor importance (e.g. Lovins 1988, 2011; Schipper and Grubb 2000). Others conclude that rebound effects are at least of some importance, but do not indicate that energy efficiency polices are substantially ineffective (e.g. Sorrell 2007; Gillingham et al. 2013). Again others state that the rebound effect is very significant and challenges the belief that improving the efficiency of energy use is an effective policy for reducing energy demand and GHG emissions to sustainable levels (Saunders 2000, 2013; Ayres and Warr 2009). However, in part, these obviously contradictory conclusions may stem from applying different definitions of what is meant by rebound effects, applying different system boundaries in rebound analysis, and investigating the rebound phenomenon through different models, theories and disciplinary lenses. Throughout the chapters of this volume, and by summarizing common findings in the editor's conclusions, this volume hopes to provide more clarity on the nature and scope of the rebound phenomenon, as well as on the limits of rebound research.

1.4 Structure and Content of This Volume

This volume is structured into three parts. Part I is dedicated to rebound economics, part II advances multidisciplinary approaches to the phenomenon, and part III applies the rebound concept to a variety of sectors and policy cases.

Part I departs from the large existing body of economic rebound research, adds new qualitative and quantitative findings and poses still-open research needs. In Chap. 2, Reinhard Madlener and Karen Turner review the plethora of past publications and illuminate perspectives on how to look at economic dimensions of the rebound effect. This chapter attempts to synthesize existing rebound taxonomies, address the lack of clarity and understanding in how analysis can bridge the gap between micro- and macro-level effects and finally pays particular attention to what policy makers can do with rebound analysis and findings. Against this introductory background, the following chapters of part I present some fresh insights on aspects that have so far not been sufficiently researched in rebound economics. In Chap. 3, Johannes Buhl and José Acosta ask the question, to what extent sufficiency strategies are prone to rebound effects? The authors analyze re-spending effects along income elasticities from a national survey on income and expenditures in Germany. In doing so, they shed light on methodological shortcomings and rethink microeconomic demand functions. Chapter 4 takes the reader to India in order to contribute to the discussion about rebound effects in the Global South. On the basis of empirical evidence from private automotive transport in urban India, Debalina Chakravarty and Joyashree Roy question the common assumption that rebounds tend to be larger in the South than in the global North. Part I of this volume closes with Chap. 5 on 'meso-economic' rebound effects. Tilman Santarius reviews the scarcely available literature on company-caused rebounds, discusses potential sector-level- and market price-effects and finally analyzes potential new rebounds that may evolve from feedbacks between the micro- and the macro level.

Part II intends to go beyond conventional rebound economics and advance and diversify the multidisciplinary approach to the phenomenon. Chapters 6, 7, and 8 dive into micro-level, consumer-side rebounds from the perspective of environmental psychology; afterwards, Chap. 9 takes macro-level effects into account from the perspective of sociology. In Chap. 6, Anja Peters and Elisabeth Dütschke identify possible psychological drivers to explain rebound effects, including attitudes, personal and social norms and response efficacy, and then expose those to qualitative results from an empirical focus group study. Based on these insights, Tilman Santarius and Martin Soland develop a theoretical rebound model based on behavioural science theories and advance a typology of 'motivational rebound effects' in Chap. 7. Then in Chap. 8, Christine Suffolk and Wouter Poortinga round up this discussion by exposing psychological rebound explanations to empirical data from residential energy-efficiency improvements in Wales. Turning from micro- to macro-level effects, Chap. 9 begins by briefly reviewing pitfalls and shortcomings of macroeconomic rebound research. Tilman Santarius then tilts new ground by grasping macro-level rebounds through perspectives from sociology, namely by considering the impacts of efficiency improvements on social acceleration and the economy of time.

Part III is dedicated to discuss the implications of rebounds for various cases and fields of applied policy-making. These include such diverse areas as labour market policy (Chap. 10), urban planning (Chap. 11), adaptation and mitigation in the tourism sector (Chap. 12), ICT and cloud computing (Chap. 13), and freight transportation (Chap. 14). As will be seen, the chapters not only discuss the implications of efficiency-generated rebounds for policy-making. In a much broader perspective, they also apply the basic mechanisms behind rebound effects to consider blind spots, unexpected side effects and second-order feedback mechanisms that endanger the effectiveness of climate and energy policies to significantly cut energy use and greenhouse gases. This gives way to developments of more resilient policies and measures, which balance efficiency, consistency and sufficiency strategies and embed them into smarter and more comprehensive policy designs.

In Chap. 10, Johannes Buhl and José Acosta discuss implications of working time reduction to reduce consumption levels. Challenging the long-hoped hypothesis that more spare time would inevitably reduce resource consumption, they find out that time savings do trigger relevant rebound effects, but at the same time lead to increased voluntary social engagement and greater life satisfaction. Petter Naess in Chap. 11 projects the rebound phenomenon on matters of urban planning. Along data on the relationship between residential location and leisure travel in three Nordic cities, he identifies new forms of rebound effects in the form of resource-consuming side effects of otherwise resource-saving residential locations. Although the scope of these effects seems to remain modest, Naess' findings allow conclusions for both city planners and communal policy makers as well as individuals who aim to rethink their personal lifestyles.

Chapter 12 takes tourism to task. Carlo Aall, Michael Hall and Kyrre Groven transfer the concept of rebound from the energy to the climate field of research and policy making and demonstrate its application on aspects of both mitigation and adaptation for the case of skiing and winter tourism. This approach allows them to explain forms of mal-mitigation and mal-adaptation in this sector and to suggest a more solid policy agenda to avoid those. Hans Jakob Walnum and Anders Andrae look at rebound effects from cloud computing in Chap. 13. As cloud computing is said to deliver breakthrough efficiency improvements in the ICT sector, it serves as a prime example to discuss direct and indirect rebound effects from digital energy usage. However, Walnum and Andrae conclude the enabling effect of cloud computing, i.e. that it gives rise to new product and service innovations, will likely be larger than the rebound effect.

From the digital era back into the analogue world, Chap. 14 is devoted to identify possible rebound effects in road freight transportation that stem from technology changes as well as climate change mitigation policies. On this basis, Hans Jakob Walnum and Carlo Aall try to grasp how policies must be designed to achieve major GHG emissions reduction in that sector. With Chap. 15, part III sums up this volume's policy-oriented discussions by asking what implications the rebound phenomenon has for the quest of decoupling energy demand from economic growth. To profoundly illuminate the polarized debate between 'green growth' and 'degrowth', Jørgen Nørgård and Jin Xue systematically analyse the interrelationship between technological efficiency improvements, demographic developments and affluence levels of consumption. They discuss various policy options, including work sharing, reversed obsolescence and a progressive population policy, to sketch out viable pathways that may achieve a just reduction of global economic scale and a long-term sustainable economy.

In the conclusions (Chap. 16) to this volume, we will once again embed the rebound debate into the larger perspective of climate, energy and sustainability politics. We will summarize key findings, point out observations when comparing this book's various rebound approaches, argue that a new 'phase 5' of rebound research should carry the discourse one step further, but also highlight some weaknesses and general limits to rebound analysis.

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Part I
New Aspects in Economic Rebound Research

Chapter 2
After 35 Years of Rebound Research in Economics: Where Do We Stand?

Reinhard Madlener and Karen Turner

Abstract The phenomenon of rebound effects has sparked considerable academic, policy and press debate over the effectiveness of energy efficiency policy. In recent years, a plethora of theoretical and empirical rebound studies have been published, fueling the discussion but also raising further issues and unanswered questions. At the same time, it seems that there is a lack of understanding of how to treat and measure central aspects such as potential energy savings expected and the energy services impacted by an efficiency increase. Moreover, there is a lack of clarity and understanding in how we move from micro- to macrolevels of analysis and reporting. In terms of policy understanding, the crux of the problem is that there is no such thing as a simple formula for all aspects of rebound. The aim of this chapter is to clarify the correct perspective on how to look at economic dimensions of rebound, with particular attention to what policy-makers can do with rebound analysis and findings. Further, we attempt to synthesize existing rebound taxonomies and to provide, in a concise manner, the economic rebound mechanisms at work. We then approach the rebound theme from both micro- and macroperspectives, before bringing the two angles together. Overall, we argue that both policy-makers and researchers need to be aware that rebound is an issue that ought to be tackled at multiple levels and that there are policy trade-offs, especially between economic growth and ecological sustainability. This may be resolved at least to a certain extent by welfare considerations.

Keywords Energy economics · Economic rebound mechanisms · Rebound taxonomy · Economy-wide rebound

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Increasing energy efficiency by implementation of new technology is still seen by many as a kind of ‘silver bullet’ for energy and climate policy in terms of its cost-effectiveness and many other benefits stemming from technological innovation. An intensive debate was triggered by Brookes and Khazzoom in the early 1980s on the remaining energy efficiency potentials in the presence of rebound. Rebound is triggered by the reduced cost of delivering or receiving an energy service when increased efficiency reduces physical energy input required. However, beyond this basic ‘trigger’, there has been debate in terms of how different types (and mechanisms) of the ‘rebound effect’ should be named, measured and reported. This debate has been partly between engineers and economists but also among economists and other social scientists. Over the last 35 years or so, critical minds have continually warned that rebound effects undermine the potential benefits to be reaped in terms of resource savings and make efficiency policies less attractive cost-wise (i.e. in terms of the physical energy savings delivered per monetary unit invested).

However, at the same time, it is important to note that rebound is driven by processes that also deliver economic benefits such as increased incomes, improved competitiveness, better quality of services etc. Thus, others have then joined the discussion by arguing that the energy-saving perspective is just one out of many that will be taken into account by policy-makers working in a context of multiple objectives. In this context, hence, there is a need for analyses to consider a careful balancing of the manifold and often delicate policy trade-offs involved. These tradeoffs, as well as the heterogeneity of energy efficiency and rebound impacts throughout the economy, require a better and sound understanding of the complex mechanisms at work. Besides, in more recent research in economics (e.g. Gillingham et al. 2016; Borenstein 2015; Turner 2013) rebound is considered less in terms of being exclusively a negative factor to be minimized (as ecologists would argue). Rather, many economists would argue that rebound minimization may or may not be the welfare-optimal outcome (due to opportunity costs of forfeiting the utility of energy services and related indirect benefits).

***What is the right perspective to look at rebound*?**

Some of the existing rebound research has been very narrowly focused, for example by estimating direct rebounds—the intensified use of a durable good that has become more energy efficient, thus lowering the marginal cost of using the energy service in question. Other rebound studies have been extremely broad in focus, trying to attribute many or all increases in the energy use of society to rebound effects. That is, not just those stemming from technical efficiency improvements (thereby lowering the cost of providing an energy service), but extending, for example in Druckman et al. (2011), to those that stem from lifestyle changes (and simply involve a change in the level of use of an energy service with no change in cost). Van den Bergh (2011) also extends the concept of rebound to conservation activity, where the price of the resource (rather than the service delivered) will trigger an economic response. This raises questions in terms of what different authors mean when they refer to rebound, questions regarding the ‘trigger’ for rebound (and any economic benefits sharing that trigger), as well as what we regard as the potential or anticipated energy 'engineering' savings that any economic rebound response is measured against. This raises issues as to whether malfunctioning of new and energy-efficient hardware or a poor match between the technological capabilities of the hardware and the ability of the user to learn how to exploit these, is actually part of the rebound effect measured. Moreover, consideration of the trade-off between energy-use minimization and economic benefits raises questions such as whether energy *sufficiency* (i.e. voluntarily consuming less energy than one can afford) can be considered a viable option to combat rebound.

***What can policy-makers do*?**

There has been a tendency in the rebound literature to regard rebound as 'bad' that policy-makers should attempt to minimize it in order to maximize reductions in energy use if energy efficiency policies are to be regarded as effective. Rebound has also been presented as something of an additive process, with the effect multiplying as consideration of the impacts on energy use extends beyond that of the user whose efficiency is the target of policy. A central objective of this chapter is to highlight contributions to date, and encourage greater focus in the future on the range of reasons why the rebound 'problem' is not so simple in its nature or implications as many believe, make believe, or hope for. At the most fundamental level, we raise issues regarding how policy expectations regarding 'potential energy savings' may be framed and determined in practice relative to how they are considered in different academic studies. That is, do policy-makers start from the perspective of a pure engineering saving so that zero rebound implies no response to energy efficiency improvements beyond the pure energy savings expected from engineering calculations? Transparency is required in rebound research regarding the perspective taken, on just what type of responses are analyzed, the nature of trade-offs involved, as well as the extent to which rebound mechanisms can be considered purely in economic terms.

We attempt to focus attention on developments in rebound research that can be of immediate practical use to policy-makers. For example, we highlight consideration of embodied energy 'multipliers' to assess the impacts of switching expenditures between more and less energy-intensive goods and services, and how impacts may vary at local, regional, national and (where there is concern over issues of pollution leakage/displacement or 'carbon footprints') global levels.

2.1 The Rebound Architecture

2.1.1 Another Taxonomy of Rebound Effects?

A common categorization of energy efficiency rebound is the one in direct, indirect and economy-wide rebound effects (cf. Turner 2013, Sect. 2). The complex nature of rebound, however, raises the need for introducing more layers, for instance in terms of source of efficiency improvement and whether this is on household (consumption) or the industry (production) side of the economy (of course the emerging notion of the “energy prosumer” blurs the division line between producer and consumer). However, we also have to consider the type of energy use concerned, as well as what share of the difference between potential/expected and actual energy savings is due to rebound and what is due to technical performance or human learning problems, or changes in lifestyles/preferences, that prevent the full efficiency improvement being realized. This lack of consensus and clarity in the rebound taxonomy—after 35 years of intensive rebound research and a burgeoning literature—is an issue on the micro-, meso-, and macrolevels, but relates especially to the indirect and economy-wide effects.

An important field of controversy concerns the issue of what is, or should be, called “rebound” and what is due to other effects. In this respect, studies that measure rebound need to be able to separate all other effects on energy use from those that are caused by energy service cost reductions due to an increase in technical energy efficiency. Another discussion is on what should be counted as an “energy service” in order to assign energy rebound effects.

Figure 2.1 summarizes the taxonomy of rebound. It shows that two very central distinctions are those between direct and indirect rebound effects on the one hand side, and between private household and firm rebound on the other hand. From the microlevel, which can be thought of either as the individual or firm/household level (cf. Fig. 2.2), the level of analysis can be widened by moving to the sectoral (meso)

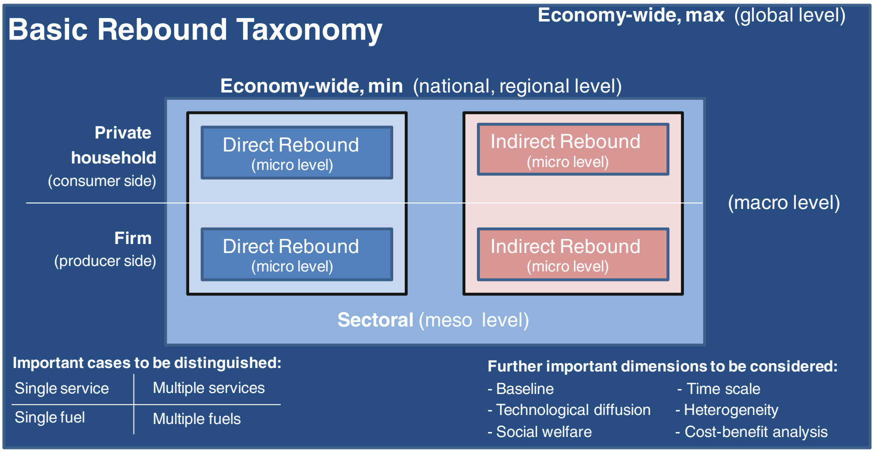

Fig. 2.1 Basic rebound taxonomy. The rebound literature is full of taxonomies, and taxonomy discussions, so that the reader is sometimes overwhelmed (at best) and often confused (at worst) by the many different versions. The present one is intended to be useful by being relatively simple and yet comprehensive

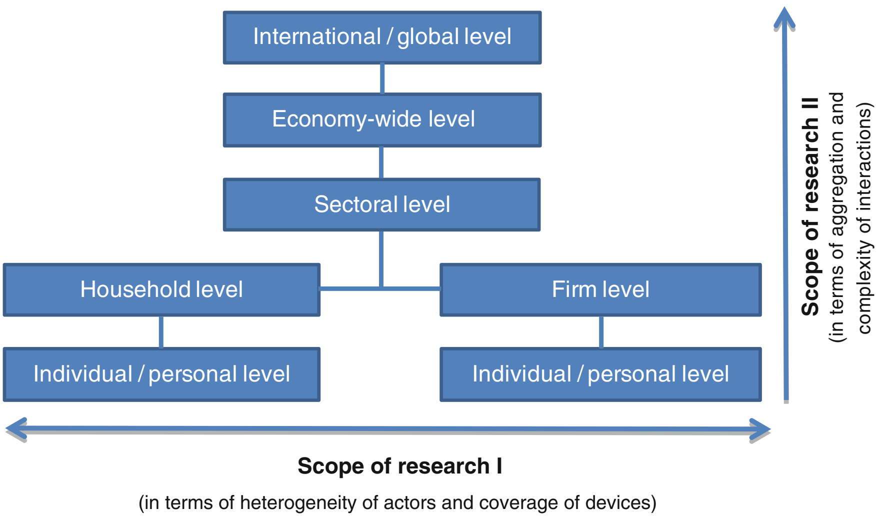

Fig. 2.2 Levels of rebound effects. Rebound can be analysed at different levels and by means of different methodologies/approaches. Dynamics and interdependencies remain hard to tackle, as do new kinds of energy services on which data may not yet be available

level of analysis, and on to a more macroeconomic, i.e. regional (province/state, urban/rural), national or global perspective. Further, the analyst needs to be clear about whether to study a single or multiple fuel energy rebound and whether a single service or multiple services are involved. The latter has to do with fuels such as electricity, which can be used for providing a multitude of energy services. Finally, the choice of an appropriate baseline, the time frame and dynamics of rebound, heterogeneity of consumers and firms, and social welfare considerations are important additional dimensions to deal with.

2.1.2 Rebound Mechanisms

Besides definitions of rebound and terminology, the mechanisms at work also need to be clearly identified. So far the probably most comprehensive collection of rebound mechanisms ("types of rebound pathways") is provided by van den Bergh (2011). The 14 mechanisms identified comprise the following: (1) direct rebound (price effect); (2) adoption of larger units or such with more functions/services; (3) respending (income effect); (4) extra demand for energy-intensive goods (composition effects); (5) changes in the processes of one phase of the product chain or life-cycle on a later phase/later phases; (6) change in factor input mix; (7) increase in total factor productivity and production output; (8) energy efficiency induced relative price changes rippling through the economy (general equilibrium or macroeconomic effect); (9) international trade and relocation effects; (10) capital investment and accumulation effects; (11) technological innovation and diffusion effects; (12) changes in preferences; (13) indirect energy use effects due to investment in new technology (embodied energy effect) and (14) time savings (time rebound effect). It becomes clear that some mechanisms overlap with the definitions of certain types of rebound (e.g. direct, indirect, economy-wide and macroeconomic rebound). Additional mechanisms that can lead to rebound effects are identified in later chapters of this volume (most notably, in part II).

Note that a useful analysis is likely to involve more than simply attempting to aggregate over the different rebound effects that can be investigated along these rebound pathways or mechanisms to arrive at a single overall rebound effect. Rather, they all take a different perspective of how induced technical energy efficiency improvements ripple through the economy and, thus, need to be understood individually. Further below we will discuss that some rebound categories impact each other (i.e. if the direct rebound is large, indirect rebound from re-spending can, under specific circumstances, be expected to be small) and that some rebound effects have a negative sign, thus compensating positive rebound effects elsewhere in the system.

Figure 2.2 makes the two dimensions more explicit that complicate matters in rebound research. One dimension is the scope of research in terms of the aggregate investigated (from the household and firm that are both composed of individual actors or decision-makers all the way from sectoral-, economy-wide- to the international and global level of analysis). This impacts the complexity of interactions that need to be tackled. The other dimension has to do with the heterogeneity of actors considered, the heterogeneity of devices and energy services involved, and the multi-tasking increasingly enabled by software agents and automation.

In terms of type of research and analysis, we move up from very micro, partial equilibrium analysis (at the household and firm level) through micro-/meso-level but still partial (sectoral level) analysis to the analysis of inter-sectoral effects. Such inter-sectoral impacts (supply chain interdependencies; see below) can most easily be addressed by studying multiplier effects—even where prices are assumed to be fixed. When prices are flexible, changes in demand and impacts on revenues matter, rather than just the required capacity, while macroimpacts may be limited. On this basis, one may decide to potentially link meso-level and economy-wide rebound analysis. Note that at the level of inter-sectoral analysis, we have a combination of still partial effects (prices may still be fixed) but working with meso-level or economy-wide input-output (I-O) analysis, e.g. for the computation of multiplier effects or, alternatively, general equilibrium impacts (to capture inter-sectoral effects while also allowing for the price changes involved). Finally, for international/global analysis of rebound, I-O multiplier analysis is still relevant in terms of partial analytics, although economy-wide analysis (e.g. by means of computable general equilibrium, CGE, modelling) could extend up to the inter-country global level where changes in relative prices and terms of trade are likely to be important.