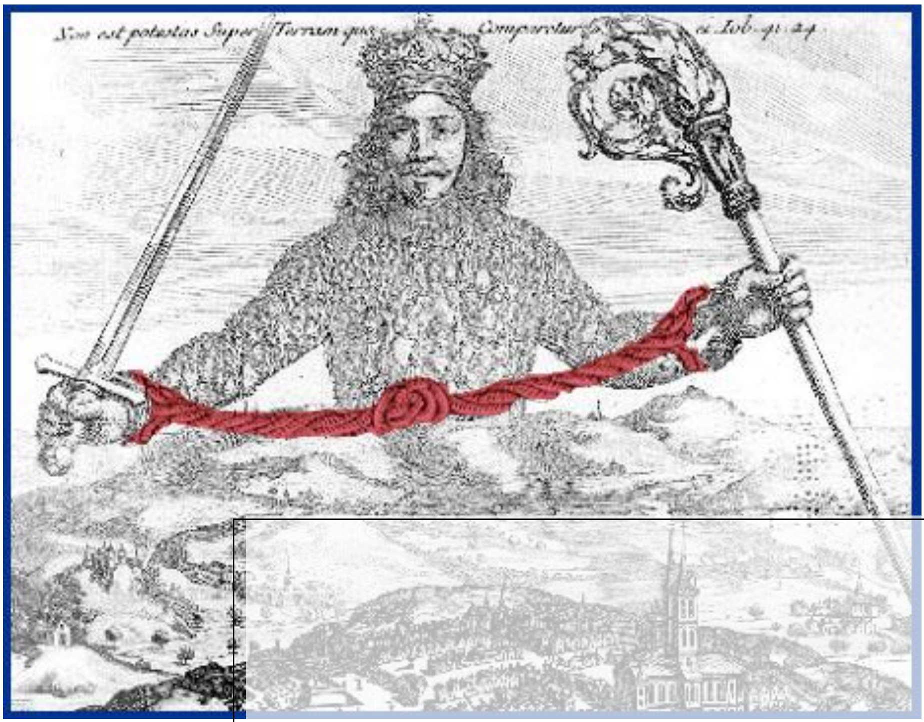

Constitutional
Economics
Network

Working Paper
Series
ISSN No. 2193-7214

CEN Paper
No. 05-2018

*On the evidence of rebound effects in the lighting sector: Implications for promoting LED lighting **

Bianca Blum [a]; Julian Hübner [b]; Adrian Milde [c];
Bernhard Neumärker [d]

* Developed first as a Thesis at the Department of Economic Policy & Constitutional Economic Theory.
[a, b, d] Department of Economic Policy & Constitutional Economic Theory, University of Freiburg, Germany.
[c] Student in Economics, University of Freiburg, Germany.

E-Mail: bianca.blum@vwl.uni-freiburg.de; julian.huebner@vwl.uni-freiburg.de; bernhard.neumaerker@vwl.uni-freiburg.de

10th, May, 2018

University of Freiburg
Institute for Economic Research
Department of Economic Policy and Constitutional Economic Theory
Platz der Alten Synagoge / KG II D-79085 Freiburg
www.wipo.uni-freiburg.de

Developed as part of the collaboration project between the University of Freiburg and the Leistungszentrum Nachhaltigkeit, as well as the partners of the project “Sustainable LED Lighting - Technologische Herausforderungen, Marktzugangshürden und politische Akzeptanz (SusLight)“.

LEISTUNGSZENTRUM NACHHALTIGKEIT FREIBURG

Albert-Ludwigs-Universität Freiburg

UNI FREIBURG

Table of Content

1. Introduction

With EU Regulation 244/2009, the EU was planning to switch from classic incandescent and halogen lamps to more efficient lighting technologies, such as compact fluorescent lamps and LEDs (see Verordnung (EG) Nr. 244/2009). The aim was to reduce energy consumption for lighting. After all, a light bulb consumes about six times as much power as a comparable LED holding the intensity of the light constant (see Mills and Schleich 2014). The EU promised about europe-wide electricity savings of up to 40 billion kWh. Savings in the order of 7.5 billion kWh were forecast for Germany, which corresponds to about 1.4% of total electricity consumption in Germany (539 billion kWh) in 2009 (see Frondel 2010). In addition, the EU Commission promised to avoid up to 15 million tonnes of carbon dioxide annually (see Frondel 2010).

The fact that consumers reacted to the prohibition of incandescent lamps with so-called "Hamsterkäufen" of light bulbs and that halogen lamps have gained a lot of market share since the prohibition of trade weaken the expected success of the Regulation (see Danish Energy Agency 2015). In addition, the purchase prices of LED fell faster than expected and their development was faster than predicted, which means that the market shares of LED are also higher than had been forecast (see Danish Energy Agency 2015). It is estimated that LEDs will account for 71% of global residential lighting by 2020 (De Almeida et. al.., 2014).

The English economist and philosopher William Stanley Jevons states in his 1865 book that the more efficient provision of a raw material leads to an increase in the consumption of this raw material (see Jevons 1865, cited from Clark and Foster 2001). Even today's economists, such as Borenstein (2013), draw attention to the fact that more energy-efficient goods are used more frequently than the less efficient predecessor models. This phenomenon is known as the Jevons Paradox or rebound effect. The concept of Jevons was revived by economists Khazzoom and Brookes in the 1980s. Hertwich (2005) summarizes Brooke's approach in such a way that increasing energy efficiency triggers economic growth, which subsequently leads to a net increase in energy demand (see Hertwich 2005). Brookes sees the rebound effect as a macroeconomic phenomenon. If gross production increases due to more efficient use of fuel and fuel consumption increases because its effective prices are falling, then this is a sign of a rebound effect (Brookes 1978, cited from Greening, Green and Difiglio 2000). Khazzoom (1980) takes only one energy service into account and explores how the demand for it changes when real prices decrease due to an increase in efficiency (see Khazzoom 1980, cited from Hertwich 2005). Saunders (1992) then summarizes the two approaches in his paper "Khazzoom-Brookes Postulate" (see Saunders 1992, cited from Sorrell 2009). Today, "rebound" is understood when only a part of the energy saving potential is achieved due to rising demand (see Santarius 2015, p.42). This means that an improvement in efficiency of 1% results in a reduction in energy consumption that is less than 1% (see Binswanger 2001). How large the rebound effect is, is still controversial today. Some studies show that the rebound effect exists and can be of great relevance (see Binswanger 2001, Greening, Green and Difiglio 2000, Sorrell and Dimitropouls 2008). While others find that the rebound effect is of lesser importance for most energy services (see Schipper and Grubb 2000). It is crucial how the term is understood and defined.

The aim of this paper is to assess the evidence of rebound effects in the lighting sector through empirical studies and derive policy implications for promoting LED lighting. In the first section energy consumption for lighting in Germany is considered to estimate the relevance of possible rebound effects. Following on from a brief definition of the term rebound, empirical studies on rebound effects in the lighting sector will be considered and analyzed. This will provide insight into the potential relevance of rebound effects in the sector under consideration and provide the opportunity to derive policy implications for promoting energy efficient LED.

2. Germany and the energy consumption for lighting

Germany is pursuing ambitious targets for the energy turnaround; in 2020, for example, it intends to reduce gross electricity consumption by 10% compared to 2008, and by 2040 gross electricity consumption should even be 25% lower (see Destatis 2015, p.11).

In its report "Daten zur Umwelt", Destatis (2015) compares energy consumption by application in 2005 and 2015 (see Destatis 2015, p.34). It is found that the share of lighting in total energy consumption has increased over the years studied from 1.7% in 2005 to 1.9% in 2013. Electricity consumption for lighting also increased by 4.8%, from 12.4 billion kWh in 2005 to 13 billion kWh in 2013 (see Destatis 2015, p.40).

In a large-scale meta-study on energy efficiency in Germany, Bauernhansl and Sauer (2016) also conclude, that the energy requirements for lighting increased from 2003 to 2014. This increase in energy demand takes place despite the possibility of saving large amounts of energy through more energy-efficient lighting (see Bauernhansl and Sauer 2016, p.203). The reasons for the insufficient decrease in power requirements for lighting are various. In their study, the authors suspect that this might be due to the rebound effect.

Along with the increased consumption of light, the number of applications for lighting is steadily increasing. For example, data from the Federal Statistical Office show that the trend is currently towards more living space and an increase in single- and two-person households (see Destatis 2015 p.11). Thus, not only effectively more area is created, which is to be illuminated, but it also use fewer people the illuminated area. Another reason that seemed to prevent the expected savings from the light bulb ban was the relatively small switch to LED lighting. While the sales of halogen lamps in Europe increased by 477% between 2007 and 2013 (see Danish Energy Agency 2015), LEDs consumed comparatively slightly more. The main reasons for this seemed to be the high purchase price (see Leuser, Weiß and Britschke 2016).

There is obviously considerable potential in Germany to save energy in the lighting sector by using energy-efficient light sources such as LED. However, the relevance of rebound effects should be considered here. In the following, after a short definition of the term, empirical studies on the rebound effect in the lighting sector will be presented and discussed.

3. On the rebound effect of efficiency improvements in lighting

3.1. Definition of the Rebound effect

First of all, a short definition of the term rebound effect investigated in the context of this paper is to be made. It is also important to distinguish between energy efficiency, energy and energy services. Energy efficiency is defined as the relationship between output and input, in the case of lighting that would be the ratio of generated lumens (output) and wattage (input) required (see Sorrell and Dimitropoulos 2008). Energy is the input factor here, measured in wattage, as the required amount of electricity to provide an energy service. Following Sorrell and Dimitropoulos (2008), output is defined as an energy service. This can result in a rebound effect if the lighting intensity has increased, while the energy consumption remains constant.

Moreover, rebound does not necessarily mean that the same energy service has an increasing demand. It may also be possible, that the energy efficiency improvement of one good leads to an increase in the demand for another different energy service. It may happen that savings in the automotive sector are re-invested in an air travel. In this case, we speak of an indirect rebound effect (see Madlener and Alcott 2009). This paper is based on a definition of the direct rebound effect, which requires that energy efficiency improvement causes the increase in demand for energy services (see Santarius 2015, p.48).

Furthermore, when considering the rebound effect, the approaches examined here are predominantly addressed only to the consumer side, but not to the producer side, as is the case in other publications (see Berkhout, Muskens and Velthuijsen 2000, see Sorrell 2010).

Sorrel and Dimitropoulos (2008) explore in their study the different, microeconomic definitions of the rebound effect, as well as their weaknesses and strengths. The rebound effect is usually determined by elasticities, such as price, income, or substitution elasticities. In addition, it is assumed that the efficiency improvement is exogenous and therefore costless (see Gillingham, Rapsony and Wagner 2016). All relationships between an increase in efficiency and demand can therefore be described as elasticities (see Madlener and Alcott 2011, pp. 19f.). Madlener and Alcott (2011) write in their report "Wachstum, Wohlstand, Lebensqualität " of the German Bundestag that science cannot even agree on a rough estimate for the rebound effect, which shows how diverse the definition and measurement of the rebound effects exit. It should be therefore remarked, that calculations of rebound effects have not necessarily been compiled using the same methodology. A comparison of different studies of rebound effects in the lighting sector should give better insights of the relevance of the effect for the lighting sector.

3.2. Empirical evidence on rebound effects in the lighting sector

Table 1 gives an overview of the different studies on the rebound effects in the lighting sector, which were considered in this paper. There are several approaches to approximately determine or prove the rebound effect for lighting. Borenstein (2013) tries to quantify this by means of the price elasticity and the substitution effect for lighting. While others use household surveys (see Mills and Schleich 2013, Schleich, Mills and Dütschke, 2014) or historical data (see Fouquet and Pearson 2006, Fouquet and Pearson 2011) to investigate the rebound effect.

Fouquet and Pearson (2006) use historical data from the United Kingdom to try to approximate the rebound effect in the lighting sector. They analyzed the change in demand for lighting in the United Kingdom (UK) over the past seven centuries, from 1300 to 2000, depending on the different light sources (candlelight, whale oil lamp, natural gas lamp, light bulb). In addition, they controlled for wealth and development of the economy.

Table 1: Overview of rebound studies in the lighting sector

Authors	Study	Kind of Study
Fouquet und Pearson (2006)	*Seven Centuries of Energy Services: The price and the use of light in the United Kingdom (1300-2000)*	empirical
Fouquet und Pearson (2011)	*The Long Run Demand for Lighting: Elasticities and Rebound Effects in Different Phases of Economic Development*	empirical
Greening, Green und Difiglio (2000)	*Energy efficiency and consumption – the rebound effect – a survey*	literatur review
Schleich, Mills, Dütschke (2014)	*A brighter future? Quantifying the rebound effect in energy efficient lighting*	empirical
Mills und Schleich (2014)	*Household transitions to energy efficient lighting*	empirical
Tsao und Waide (2010)	*The World's Appetite for Light: Empirical Data and Trends Spanning Three Centuries and Six Continents*	empirical
Tsao et. al. (2010)	*Solid-state lighting: an energy-economics perspective*	empirical
Borenstein (2013)	*A Microeconomic Framework for Evaluating Energy Efficiency Rebound And Some Implications*	theoretical framework
Berkhout, Muskens und Velthuijsen (2000)	*Defining the rebound effect*	literatur review

Reference 1: Own illustration.

The authors examined how the energy price, energy efficiency, the price of lighting, per capita light consumption, light consumption in general and real GDP per capita have changed. For example, lighting in 2000 was a thousand times more efficient than in 1800 and light consumption in 2000 was more than 25,000 times 1800 or light consumption per capita increased by a factor of 6566 compared to 1800 (Fouquet and Pearson 2006). It is also noticeable in the study that per capita light consumption in the years under review rose much more than the real GDP per capita. Frondel (2012) attributes this to the dramatic price reduction for lighting during this period. With GDP 15 times higher in 2000 compared to GDP in 1800, it is also important to look at the rise in UK living standards and falling real prices for lighting. The living space was also larger and households could afford more lighting. Fouquet and Pearson (2006) were able to show what influence decreasing energy prices and increasing efficiency have on lighting.

In a recent study, Fouquet and Pearson (2011) calculated price and income elasticities in demand for lighting in the UK. The price elasticity allows to estimate the magnitude of the rebound effect.

Fouquet and Pearson (2011) found out that by the mid-19th century, the income elasticity was about 0.7 and the price elasticity was about -1.2. A price elasticity of less than -1 means that the rebound effect was over 100%, resulting in a so-called backfire. Backfire is a disproportionate increase in energy consumption as a result of energy efficiency improvement. From 1840 to 1890, income and price elasticities rose again dramatically. At that time, a 1% price reduction or an efficiency improvement led to a 1.7% increase in lighting consumption. An increase in per-capita income by 10% to 35% also led to an increased demand for lighting. From this it can be deduced that both the introduction of more efficient lighting and the access to it due to increasing prosperity in the past must have increased the rebound effect.

In general, these historically considered rebound effects should not be over-interpreted. Unlike the period around 1900, lighting is no longer considered as a luxury good today (see Fouquet and Pearson 2011). Fouquet and Pearson (2011) find that income elasticity has fallen below 1.0 since 1960 and between 0.3 and 0.2 over the period 1980-2000. Price elasticity for lighting has been in the range of -0.7 to -0.4 since 1910 (see Fouquet and Pearson 2011). The authors conclude that these elasticities are high as long as an economy grows strongly and has not yet reached its saturation level. However, when a certain level of wealth is reached, the elasticity decreases again. For this reason, the authors also suggest that the EU ban on incandescent lamps in the UK could actually lead to low energy savings (see Fouquet and Pearson 2011).

A much-cited study on rebound effects comes from Greening, Green and Difiglio (2000). In their survey study, they summarize a large number of empirical studies to give an overview of the magnitude of the direct rebound effect in different energy service sectors. In doing so, they deal with research on the rebound effect of private households, as well as with studies on the rebound effect of companies, as well as with essays on the macroeconomic rebound effect. They subdivide into different energy services, e.g. Space heating, lighting, etc., in private households and companies and then give details of their rebound effect and its height (see Greening, Green and Difiglio 2000). In addition, they point out that there are few empirical studies on lighting, compared to other energy services sectors. They estimate that household lighting can achieve 80% -95% of potential savings. As a result, they come to a direct rebound effect for residential lighting of 5-12% (see Greening, Green and Difiglio 2000).

Schleich, Mills and Dütschke (2014) determined the direct rebound effect by exploring a large survey in German households. The rebound effect is measured as efficiency elasticity of demand. In addition, they investigate the proportion of the rebound effect that can be attributed to both the increased burning time of the lamp and the increased luminosity (see Schleich, Mills and Dütschke 2014). They find that in 90% of the cases, when changing from an incandescent lamp to a more efficient luminaire, the illumination duration and / or the brightness has changed in lumens. If, for example, a light bulb is replaced by a more efficient light, it is 24% brighter than the light bulb. The burning time increased on average by 8 minutes per day. Schleich, Mills and Dütschke (2014) calculate a rebound effect of 6%. The higher luminosity in lumens accounted for almost 60% of the rebound effect.

Tsao and Waide (2010), and Tsao et. al. (2010), investigate medium to long-term rebound effects in the lighting sector. The study by Tsao and Waide (2010), which analyzes light per capita consumption relative to GDP per capita and the cost of lighting based on historical data, has provided insights into the long-term rebound. They asked whether demand for light was independent of energy efficiency and thus independent of the cost of lighting. This would mean that technological advances would not lead to an increase in the demand for lighting, but to a decrease in (input) energy and thus there would be no rebound effect. In contrast to most of the other studies on the rebound effect in lighting, the authors deal with the question of the medium to long-term rebound effect. They take into account that it often takes decades before new application possibilities for useful energy emerge, which can then dramatically impact the demand. Using other empirical studies, including that of Fouquet and Pearson (2006), they could gather data from 3 centuries (1700-2000), 6 continents (Africa, Asia, Europe, Australia, North and South America) and 5 different species each Evaluate fuels and lighting technologies. They conclude that per capita consumption of light is approximately linearly proportional to the ratio of per capita income to the cost of light (see Tsao and Waide 2010). Taso and Waide (2010) So they conclude that both the price and income elasticity of demand for lighting is around 1. They also find that a similar proportion of global GDP per capita is spent on light, suggesting a relatively high rebound effect.

Tsao et. al. (2010) forecasts for lighting consumption in 2030, based on the findings from Tsao and Waide (2010). They assume that LED will be the dominant lighting technology of the future and that this technology will be even more efficient and cheaper by the year 2030 (see Tsao et. al., 2010). Assuming that demand for light does not saturate, they expect the share of 0.72% of global GDP per capita to remain unchanged for lighting. In addition to the global number of many poorly lit or poorly lit areas, as well as new application possibilities for LED could also drive demand for LED further (see Tsao et. al., 2010).

Saunders and Tsao (2012) comment on the results of the previous study by Taso et. al. (2010). They confirm that the introduction and market penetration of more efficient lighting techniques will not result in any overall energy savings in lighting. Saunders and Tsao (2012) estimate a rebound effect of just over 100%, concluding that the global energy intensity of lighting, that is, the energy consumption of lighting relative to global GDP, has not changed over the past 30 years and will not change in the future (see Saunders and Tsao 2012).

4. Implications for the promotion of LED lighting

To ensure that growth does not come at the cost of more energy use, the energy efficiency improvement must be stronger than the increase in demand for energy for lighting. According to recent findings of this paper, the direct and short-term rebound effect in residential lighting seems to be just above zero to about 10% (see Berkhout, Muskens and Velthuijsen 2000, Greening, Green and Difiglio 2000). However, the rebound effect in the lighting sector not only entails the danger that energy savings will not be achieved, but also that there will be more and more lighting overall. For example, Schleich and Mills (2013) have shown that luminous intensity increases dramatically when a light bulb is replaced by a more efficient luminaire. Animals and humans are already suffering from light pollution and this issue could pose an even more serious threat to the health of living beings in the future (see Borchers and Schomerus 2015). It is therefore necessary to implement a suitable rebound management in the promotion of energy-efficient light sources, such as the LED, in order to counteract the negative effects of increasing energy efficiency in the long term. In addition to the effectiveness of the measure, it is necessary to find an instrument of economic policy which, on the one hand, is suitable for promoting energy efficiency but, on the other hand, is also able to prevent rebound effects. Blum et. al. (2018) find in their study on the influencing factors of rebound effects that they can be both economical and psychological and do not necessarily occur separately from each other. They advocate the use of fiscal instruments, such as taxation mechanisms, to compensate for the savings gained by decrease the cost of energy services, thus preventing a rebound effect. This would also be conceivable for the promotion of LED technology, as Blum (2018) has shown in a theoretical approach to promote LED lighting via taxation policy. Here, the use of a unit tax for all bulbs leads to a so-called quality switch and consequently to an increase in the average quality in the market. The advantage of this approach is that the tax is levied equally to all bulbs. Thus the LED in comparison to the other bulbs is indeed cheaper in its relative price, but an additionally purchased unit of this bulb is provided with the same tax amount. Blum et. al. (2018) further suggest that a potential rebound policy must address the fact that consumers have unsaturated needs that can now be met through energy efficiency improvements. Following this idea, rebound management would limit the welfare maximization of individuals. This study has shown that historically rebound effects often also go hand in hand with unsatisfied needs and remain unaffected by them. Thus, observing a rebound effect in consumption is not necessarily an expression of inefficiency, which would call for economic policy to intervene in the market, but may be rational in the context of utility maximization. Therefore, when choosing rebound management, care should be taken to ensure that lower income groups are not disadvantaged by the policy measure (see Blum et. al. (2018)). Blum et. al. (2018) also name the relevance of social and personal norms in connection with rebound behavior. Again, this may be relevant to the lighting as well. Often, rebound behavior is evoked based on insufficient information about the impact of the energy efficiency decision, so that an observed rebound effect has often been unconsciously triggered by the consumer (see Blum et. al. (2018)). Ultimately, it seems to make sense to consider various factors that can trigger rebound effects when choosing the policy measure. We have shown that rebound management would be appropriate for the lighting sector, as historical data and empirical observations have demonstrated the relevance of rebound in this area. Furthermore, it seems to be expected that the demand for light will continue to increase and thus energy efficiency improvements in lighting technology do not necessarily produce the desired effect. An appropriate policy measure to support LED promotion must therefore be found to make the development of light use efficient and sustainable.

5. References

Bauernhansl, T., Sauer, A. (2016): Energieeffizienz in Deutschland – eine Metastudie, 2. Auflage, Stuttgart.

Berkhout, P., Muskens J. C., Velthuijsen, J. (2000): Defining the rebound effect, Energy Policy, Vol 28, p.425-432.

Binswanger, M. (2001): Technological progress and sustainable development: what about the rebound effect?, Ecological Economics, Vol 36, p. 119–132.

Blum, B. (2018): Ausgestaltung einer Steuerpolitik zur Förderung von LED-Beleuchtung, The Constitutional Economics Network Working Papers (ISSN 2193-7214, No.01-2018), Albert-Ludwigs-Universität Freiburg.

Blum, B.; Hübner, J.; Müller, S.; Neumärker, K.J.B. (2018): Challenges for sustainable environmental policy - Influencing factors of the rebound effect in energy efficiency improvements, The Constitutional Economics Network Working Papers (ISSN 2193-7214, No.02-2018), Albert-Ludwigs-Universität Freiburg.

Borchers K.C.; Schomerus, T. (2015): Umweltverschmutzung durch Licht – die Ausweisung von Lichtschutzgebieten als Instrument zur Reduktion von Lichtimmissionen, T. NuR, Nb 37, p. 614-621, available online: https://doi.org/10.1007/s10357-015-2885-7 .

Borenstein, S. (2013): A Microeconomic Framework for Evaluating Energy Efficiency Rebound And Some Implications, NBER Working Paper Nb 19044, available online: http://www.nber.org/papers/w19044 .

Brookes, L. G. (1978): Energy policy, the energy price fallacy and the role of nuclear energy in the UK. Energy Policy Vol 6, Nb 2, p. 94–106.

Clark, B.; Foster, J.B. (2001): William Stanley Jevons and the coal question, Organization & Environment, Vol 14, Nb 1, p. 93-98.

Danish Energy Agency (2015): European LED Market Evolution and Policy Impacts, available online: https://www.energimyndigheten.se/globalassets/energieffektivisering/produkter-med-krav/belysning-hem/dea---clasp-report-on-european-led-market_final.pdf.

De Almeida, A.; Santos, B.; Paolo, B.; Quicheron, M. (2014): Solid state lighting review – Potential and challenges in Europe, Renewable and Sustainable Energy Reviews, Vol 34, p. 30–48.

Destatis (2015): Umwelt, Haushalte, Konsum, Daten zur Umwelt, Ausgabe 2015, Statistisches Bundesamt , Umweltbundesamt.

Fouquet, R., Pearson J.G. (2006): Seven Centuries of Energy Services: The price and the use of light in the United Kingdom (1300-2000), The Energy Journal Vol 27, Nb 1, p. 139-177.

Fouquet, R., Pearson J.G. (2011): The Long Run Demand for Lighting: Elasticities and Rebound Effects in Different Phases of Economic Development, BC3 Working Paper Series 2011-06.

Frondel, M. (2012): Der Rebound-Effekt von Energieeffizienz-Verbesserungen, ENERGIEWIRTSCHAFTLICHE TAGESFRAGEN Vol 62, Nb 8, p. 12-16.

Frondel, M., Lohmann, S. (2010): Das Glühbirnendekret der EU – ein unnötiges Verbot, Zeitschrift für Energiewirtschaft, Vol 34, p. 247–253.

Gillingham K., Rapson D., Wagner G. (2016): The Rebound Effect and Energy Efficiency Policy, Review of Environmental Economics and Policy, Vol 10, Issue 1, p. 68–88.

Greening, L., Green, D., Difiglio, D. (2000): Energy efficiency and consumption – the rebound effect – a survey, Energy Policy, Vol 28, p. 389-401.

Hertwich, G. (2005): Consumption and Rebound Effect, Journal of Industrial Ecology, Vol 9, Issue 1-2, p. 85-98.

Jevons, W. S. (1865): The Coal Question: An Inquiry Concerning the Progress of the Nation on the Probable Exhaustion of Coal, London, Macmillan.

Khazzoom, J. D. (1980): Economic implications of mandated efficiency in standards for household appliances. Energy Journal Vol, 1, Nb 4, p. 21–40.

Leuser, L., Weiß, U., Brischke, Lars-A. (2016): Beleuchtung: Auswirkungen von Rebound- Effekten und gesellschaftlichen Trends auf den Energieverbrauch sowie Möglichkeiten der Adressierung durch politische Instrumente, Ifeu (Institut für Energie- und Umweltforschung Heidelberg), Berlin.

Madlener, R., Alcott, B. (2009): Energy rebound and economic growth: A review of the main issues and research needs, Energy, Vol 34, p. 370–376.

Madlener, R., Alcott, B. (2011): Herausforderungen für eine technisch-ökonomische Entkopplung von Naturverbrauch und Wirtschaftswachstum unter besonderer Berücksichtigung der Systematisierung von Rebound-Effekten und Problemverschiebungen, Bericht an die Enquete Kommission Wachstum, Wohlstand, Lebensqualität, Berlin: Deutscher Bundestag.

Mills, B., Schleich, J. (2014): Household transitions to energy efficient lighting, Energy Economics, Vol 46, p. 151–160.

Santarius, T. (2015): Der Rebound-Effekt: Ökonomische, psychische und soziale Herausforderungen für die Entkopplung von Wirtschaftswachstum und Energieverbrauch. Weimar (Lahn), Metropolis.

Saunders, H. D. (1992): The Khazzoom-Brookes postulate and neoclassical growth, Energy Journal Vol 13, Nb 4, p.131-148.

Saunders, H.D., Tsao J. (2012): Rebound effects for lighting, Energy Policy, Vol 49, p. 477–478.

Schipper, L., Grubb, M. (2000): On the rebound? Feedback between energy intensities and energy uses in IEA countries, Energy Policy, Vol 28, p. 367-388.

Schleich, J., Mills, B., Dütschke, E., (2014): A brighter future? Quantifying the rebound effect in energy efficient lighting, Energy Policy, Vol 72, p. 35–42.

Sorrell, S. (2009): Jevons' Paradox revisited: The evidence for back fire from improved energy efficiency, Energy Policy, Vol 37, p. 1456–1469.

Sorrell, S. (2010): Mapping rebound effects from sustainable behaviours Key Concepts and Literature Review, Sustainable Lifestyles Research Group (SLRG), available online: http://www.sustainablelifestyles.ac.uk/sites/default/files/projectdocs/slrg_working_paper_01-10.pdf .

Sorrell, S., Dimitropoulos, J. (2008): The rebound effect: Microeconomic definitions, limitations and extensions, Ecological Economics, Vol 65, p. 636-649.

Tsao, J., Saunders, H.D., Creighton, J.R., Coltrin, M.E., Simmons, J.A. (2010): Solid-state lighting: an energy-economics perspective, Journal of Physics D: Applied Physics, Vol 43, Nb 35, p.259-281.

Tsao, J., Waide, P. (2010): The World's Appetite for Light: Empirical Data and Trends Spanning Three Centuries and Six Continents, Leukos, Vol 6, Nb 4, p. 259-281.

VERORDNUNG (EG) Nr. 244/2009 DER KOMMISSION vom 18. März 2009 zur Durchführung der Richtlinie 2005/32/EG des Europäischen Parlaments und des Rates im Hinblick auf die Festlegung von Anforderungen an die umweltgerechte Gestaltung von Haushaltslampen mit ungebündeltem Licht, available online: http://eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=CELEX:32009R0244&from=EN .