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The technology-evoked time use rebound effect and its impact on pro-environmental consumer behaviour in tourism

Abstract

The growing awareness of tourism's environmental impacts has facilitated energy efficiency improvements in all tourism sub-sectors, especially in tourist transport. Further technological improvements are envisaged to save travel time as well as to reduce travel costs. However, the time savings achieved can potentially trigger behavioural responses of tourists that are unexpected and can intensify consumption. Ultimately, this intensified consumption can negate the positive effect of energy efficiency improvements in tourism, the phenomenon known as the time use rebound effect. Existing literature fails to account for this effect as a driver of unsustainable consumer behaviour in tourism. This paper proposes a framework to conceptualise the potential time use rebound effect in tourism and discusses the importance of considering it for better understanding and management of pro-environmental tourist behaviour. The paper elaborates upon the implications of the time use rebound effect for sustainable tourism development.

Keywords: rebound effect; time; pro-environmental behaviour; tourist transport; technological efficiency improvement; greenhouse gas emissions

Introduction

Interest in tourism's energy efficiency has grown due to a steady increase in the industry's greenhouse gas (GHG) emissions (Scott, Gössling, Hall & Peeters, 2016). Technology is considered an important driver of energy efficiency improvements in tourism (Hall, Gössling & Scott, 2015) and policy interventions underpinned by technological solutions have been designed to reduce the carbon intensity of tourism (Peeters, 2010). These interventions are based on premises of economic rationality, assuming that the adoption of technology in tourism reduces its energy consumption without the need for behavioural change (Sorrell, 2015). However, technology-focused solutions tend to overestimate energy-saving potential and underestimate energy conservation costs (Binswanger, 2001) because they fail to sufficiently reflect upon how they might change tourist behaviour (Miller, Rathouse, Scarles, Holmes & Tribe, 2010).

Since energy efficiency improvements imply a cost reduction for energy services, corresponding behavioural responses may occur, often leading to increased consumption and offsetting anticipated savings, known as the rebound effect (RE) (Greening, Greene & Difiglio, 2000). The RE was first conceptualised and evidenced in the field of energy economics (see Brookes, 1990; Khazzoom, 1980; Saunders, 1992), but scientific debate on the RE outside energy economics in fields such as tourism is limited (Santarius, 2012).

Optimism about tourism's 'green' growth paradigm, based on technology-evoked energy efficiency improvements, is questionable given the general failure of many sustainability evaluations in tourism to consider the RE (Hall, 2013). Technological improvements are paradoxically a contributor to continuing tourism growth as not only do they increase the number of tourists, but also enable access to more delicate and remote destinations (Sharpley, 2000). Research indicates that the RE can occur in tourism, however, there has been little attempt to explore its mechanisms and the contribution made to GHG emissions and sustainable tourism development.

In tourism, the RE beyond energy efficiency is also of relevance. Technological changes that save time influence energy consumption as many time-saving technologies in tourism (e.g. faster modes of tourist transport) require larger energy inputs (Sorrell & Dimitropoulos, 2008). Of particular interest is the time use rebound effect (TRE) which evaluates the impacts of time-saving technologies on time use and energy consumption. The TRE has been understudied, with most research being conducted within the household domain (Brenčič & Young, 2009).

Time is a necessary pre-condition to engage in any tourist activity and also a travel cost. As time costs are frequently higher than monetary costs of a holiday trip for some tourists, especially for high-income tourists (Jäckel & Wollscheid, 2007), the TRE represents an issue of relevance to travel. Increased consumption of air travel and, subsequently, tourism can be driven by time efficiency gains (Sorrell, 2007). Time use in tourism varies depending on trip purpose, social context of travel or cultural background of tourists. Time and energy efficiency are increasingly recognised as drivers of consumer behaviour in tourism's sustainable development (Gössling, Hall, Peeters & Scott, 2010). While Hall (2015) underlines the importance of accounting for the impacts of these efficiency gains on tourist consumption, there is a need for a critical analysis of the RE, including the TRE, in the context of tourism.

The study of the (T)RE is necessary in the context of sustainable tourism and travel to provide better understanding of consumer behaviour influencing energy consumption and related GHG emissions. This conceptual paper seeks to consider the potential (T)RE and identify its implications for the tourism industry. Acknowledging and understanding the magnitude of (T)RE are important for the industry, particularly for tourist transport, given the rapid growth of international tourism and the relatively limited opportunities for mitigating negative environmental impacts relying only on technology-focused solutions.

This paper adopts the concept of the RE to develop an innovative approach to studying sustainability concerns in tourism and especially explores the time dimension with respect to rebound consumption. It analyses technological developments within tourism, predominantly focusing on the transport sector, that have brought about efficiencies in time and energy use. A conceptual framework for the RE and TRE in tourism is presented. Lastly, the implications of the RE for sustainable tourism development are discussed.

The rebound effect (RE)

After Jevons first proposed that increased coal efficiency would intensify coal consumption in 1865, the concept of the RE, or the Jevons' paradox, was embraced by energy economists during the 1980s (Alcott, 2005). Since then, the RE has attracted increasing attention among policy-makers and academics (Sorrell, 2007), triggering further theoretical exploration. This exploration has resulted in the recognition of the RE in energy economics. In general terms, the RE describes the unexpected results in response to technological efficiency improvements, but more specifically it refers to the extent of energy-saving potential from technological improvements that are offset by increased energy consumption (Sorrell & Dimitropoulos, 2008). The RE is usually based upon consumer's price elasticities of energy demand estimating a theoretical amount of energy that could be saved due to energy efficiency improvements, when the demand for goods and services remained constant (Alcott, 2005). Thus, the RE can be expressed as a percentage of savings (equal to 100%) that might be achieved (Druckman, Chitnis, Sorrell & Jackson, 2011). When this percentage reaches 100%, the designed energy efficiency improvements bring about an increase, rather than decrease, in energy consumption, which is called backfire (Jenkins, Nordhaus & Shellenberger, 2011). These basic principles are at the core of the RE concept.

Classification of the RE

The RE generally consists of three types: direct, indirect and economy-wide (Greening et al., 2000) (Figure 1). The direct RE describes the changes in energy consumption resulting from income and substitution effects to the demand for energy-efficient goods and services such as heating or car travel (Sorrell & Dimitropoulos, 2008). While the income effect refers to the increase in consumption of an energy service caused by income gains due to cheaper energy prices (for example, using savings from cheaper fuel costs of running an energy-efficient car for making additional journeys), the substitution effect describes the increase in consumption by substituting that service for other services (for instance, substituting a more fuel efficient car with a coach for a weekend trip).

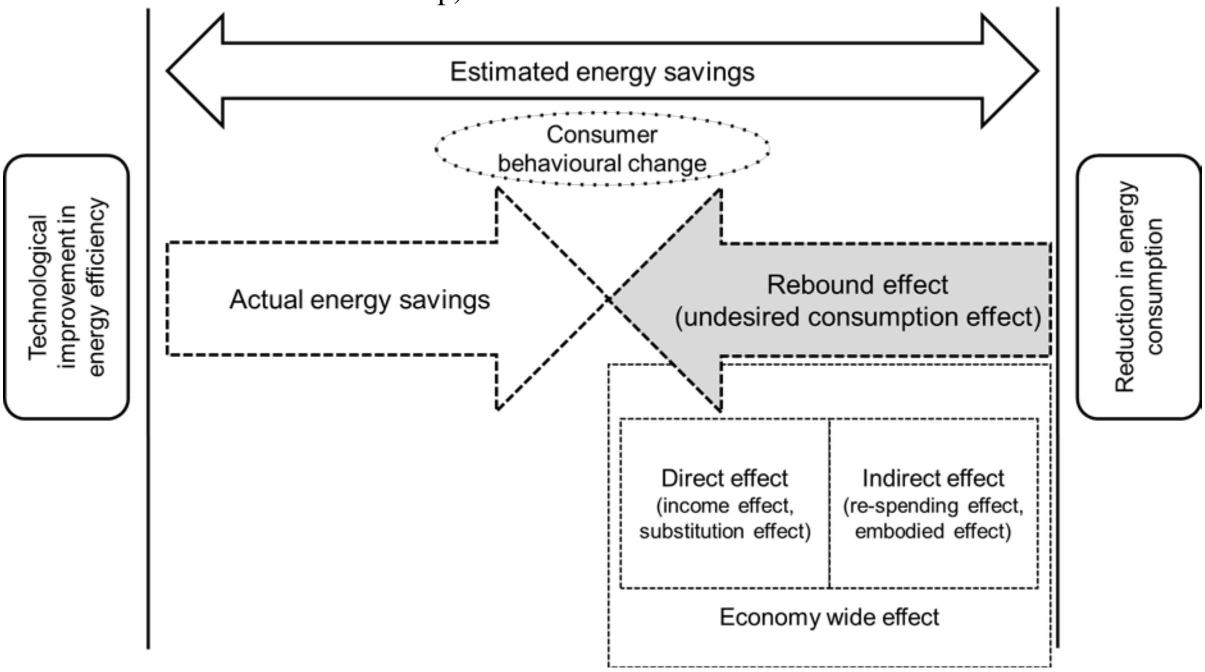

Figure 1. Classification of the RE (modified from Sorrell 2007)

In contrast, the indirect RE comes from re-spending and embodied effects by driving an increase in demand for other goods and services (Jenkins et al., 2011). The re-spending effect refers to the increase in consumption due to cost savings from energy efficiency improvements achieved for other goods and services which themselves require energy to provide (for example, savings from home heating spent on overseas holidays), whereas the embodied effect represents the equipment used for energy efficiency improvements, such as thermal insulation, as the equipment itself requires energy to be manufactured. Meanwhile, making economies more efficient stimulates overall economic output, potentially generating additional demand for energy at both consumer and producer level (Santarius, Walnum & Aall, 2016). Such efficiency-induced effects on economic growth look at the aggregate level that contribute to total economy-wide rebound due to the changes in energy service costs (the economy-wide effect) (Jenkins et al., 2011).

Although the producer-side RE can be considerable, in traditional economics consumption is assumed to drive production. This implies that more energy savings can potentially be achieved by directly changing individual behaviour than by influencing producers or using new technologies in the production process (Gillingham, Rapson & Wagner, 2016) because costs of producers are not constrained by a fixed nominal income like those of consumers, thus enlarging output effects (Stern, 2011). Moreover, the producer-side RE is hard to interpret due to many other factors influencing production (e.g. capital and labour) (Sorrell and Dimitropoulos 2008). Nevertheless, the producer-side RE also needs to be addressed when understanding the RE, although the current study focuses on the RE from the consumer perspective.

Empirical studies on the RE

Empirical research has provided evidence of the RE in different economic sectors and geographical regions, but predominantly from the perspective of economics (Table 1). The direct RE has been measured by using a variety of methods and via secondary data analysis. The findings show that the magnitude of the direct RE differs by region, despite being likely to be larger in developing nations (Jenkins et al., 2011), as each national economy is unique (Gillingham et al., 2016). Energy demand can be driven by different socio-economic profiles of consumers with attributes such as national culture playing a role (Chitnis, Sorrell, Druckman, Firth & Jackson, 2013).

Table 1. RE estimates in academic literature

Author	**Application domain H: Household T: Transport**	**Region**	**Research method**	**Indicator**	**Estimated rebound effect (% of the calculated savings)**	**Type of rebound effect analysed**
Haas & Biermayr (2000)	H (Heating)	Austria	The price elasticity with time series data (1970-1995)	Energy	20-30%	Direct RE
Roy (2000)	H (Lighting)	India	The price elasticity with time series data (1973-1974 to 1989-1990)	Energy	50% (80% for some households)	
Hymel, Small & Dender (2010)	T (Car)	USA	Elasticity of demand with state panel data (1966-2004)	Energy	9%	
Wang, Zhou & Zhou (2012)	T (Car)	China	A linear approximation of the Almost Ideal Demand System (AIDS) model and the price elasticity of energy consumption	Energy	96%	
de Borger, Mulalic & Rouwendal (2016)	T (Car)	Denmark	The elasticity of the demand with Danish register-data (2001-2011)	Energy	7.5-10%	
Stapleton, Sorrell & Schwanen (2016)	T (Car)	UK	Elasticity of the demand with time series data (1970-2011)	Energy	9-36%	
Moshiri & Aliyev (2017)	T (Car)	Canada	The price elasticity of demand with data of the annual national survey of household spending (1997–	Energy	63-96%	

			2009)			
Belaïd, Bakaloglou & Roubaud (2018)	H (Gas)	France	Linear regression models time series data (1983-2014)	Energy	60-63%	
Brännlund, Ghalwash & Nordström (2007)	H (Heating, Electricity) T (Car, Public transport)	Sweden	Price and expenditure elasticity with household consumption data (1980-1997)	GHG intensity (CO_2, SO_2, Nox)	12.9-16.1%	Direct/Indirect RE
Druckman et al. (2011)	H (Heating, Food) T (Car)	UK	IOA with national time series data (1964-2009)	GHG intensity (CO_2)	7-51% for reducing food waste, 34% for transport, 12% for housing	
Chitnis et al. (2013)	H (Heating, Lighting)	UK	LCA and IOA	GHG intensity (CO_2)	5–15%	
Murray (2013)	H (Electricity) T (Car)	Australia	Life Cycle Assessment (LCA)-Input-Output Analysis (IOA) with four household demand models with household expenditure survey data (2003-2004)	GHG intensity (CO_2)	4.5-7.5% for electricity, 12-24% for vehicle fuel	
Thomas & Azevedo (2013)	H (Electricity) T (Car, Public transport)	USA	LCA and environmentally extended IOA (EEIOA) with the U.S. consumer expenditure survey (2004)	Energy/GHG intensity (CO_2, NO_x, SO_2)	10% (direct)/5-15% (indirect)	
Wang, Han & Lu (2016)	H (Electricity)	Beijing (China)	The price elasticity of demand (direct), IOA (indirect) with time series data (1990–2013)	Energy	24-37% (direct)/46-56%(direct+indirect)	
Turner (2009)	The national economy	UK	CGE Model	Energy	For electricity: 24.75% (short-run), -1.68% (long-run) For non-electricity: 30.37% (short-run), 17.34% (long-run)	Economy-wide RE

Broberg, Berg & Samakovlis (2015)	Industrial energy use	Sweden	CGE Model	Energy	40-70%	

In comparison, research on the magnitude of the indirect RE or the economy-wide RE is rare because of the complexity of assessments. The indirect RE is typically estimated alongside the direct RE and, hence, often considered complementary (Freire-González, 2017). Unlike the direct RE, the indirect RE influences both direct and embodied energy consumption and GHG emissions (Chitnis et al., 2013). For instance, the savings from a fuel-efficient car may be spent on more driving (direct rebound and direct GHG emissions), more travelling by air (indirect rebound and direct GHG emissions) or more frequent dining out (indirect rebound and embodied GHG emissions). Meanwhile, computable general equilibrium (CGE) models can be employed to estimate the economy-wide RE by capturing the economic system-wide impact of energy efficiency improvements (Broberg et al., 2015; Turner, 2009). However, CGE analysis is criticised as having a less developed consumer perspective (Allan, Hanley, McGregor, Swales & Turner, 2007), suggesting high probability of excluding the consumption-related RE from calculations.

The majority of previous research on the RE has been undertaken in the domains of transport and household energy consumption. Transport related studies have mainly focused on passenger transport (car or public transport) rather than freight (Stapleton et al., 2016) due to the greater potential for reducing energy use in passenger transport, in particular, private cars (Jägerbrand, Dickinson, Mellin, Viklund & Dahlberg, 2014). Research on the RE in the household sector includes studies on heating and electricity (Chitnis et al., 2013). Few studies have examined the RE with respect to household food consumption and laundry services (Alfredsson, 2004; Davis, 2008). Much can be learnt from these studies for tourism because tourism's carbon footprint not only comes from increased energy consumption (tourist transport, accommodation and activities), but is also generated by transferring carbon impacts from daily life to tourist trips (Peng & Guihua, 2007).

While some researchers argue that the RE in consumption is minimal and can be ignored (Bentzen, 2004; Haas & Biermayr, 2000), others claim that it is significant and thus needs to be taken into consideration due to important economic and environmental implications (Druckman et al., 2011; Murray, 2013; Wang et al., 2016). Greening et al. (2000) and de Borger et al. (2016) assert that there is no general rule to define the size of the RE, instead it is individually gauged depending on different consumption patterns of each sector and/or country. Due to methodological difficulties in its estimation, only a few national, regional or international energy reduction policies have considered the RE (e.g. the UK's Department of Energy & Climate Change, DECC, 2012) and it remains unconsidered by the United Nations World Tourism Organization (UNWTO, 2014).

The extended concept of the RE

Different disciplinary perspectives, for example, socio-psychology, strive to understand the assumptions and establish the causes behind the RE in various consumption contexts, which have improved its applicability for sustainability assessments (Font Vivanco, McDowall, Freire-González, Kemp & van der Voet, 2016). The socio-psychology perspective considers socially and culturally defined costs as drivers of the RE, including environmental values and pro-environmental attitudes of consumers (Otto, Kaiser & Arnold, 2014). Purchasing a hybrid car (which, in principle, is more fuel efficient) reduces socio-psychological costs of car ownership because the car is accepted by the user's social networks as an environment-benign technology. As the driver feels morally justified (i.e. they drive a less-polluting car), a socio-psychological RE can occur through increasing car use (de Haan, Mueller & Peters, 2006). While a far deeper understanding of the dynamic socio-psychological mechanisms is required to intervene in the discussion of the RE in the context of tourist consumption, it will not be meaningful to treat the RE caused by socio-psychological factors in isolation (Higham, Cohen, Peeters & Gössling, 2013). Rather, socio-psychological effects need to be integrated in the discussion of the RE alongside other effects (e.g. cost) because any individual's consumption behaviour is bound with various factors including socio-psychological factors such as emotions, values and personal preference.

Socio-psychological principles indicate that time-saving technologies enable individuals to reinvest time into not-yet-attained personal goals that require resources (Otto et al., 2014). Although the implications of the TRE have seldom been researched, its impacts can be substantial (Hofstetter, Madjar & Ozawa, 2006), particularly in relation to the transport sector, which is significant for tourism.

Time use rebound effect (TRE)

Time-saving technologies inevitably lead to the reinvestment of saved time in order to maximise utility (Buhl, von Geibler, Echternacht & Linder, 2017). When part or all of the time-savings potential initiated by technologies is lost because of increased demand for a service associated with the time use, the TRE may occur (Binswanger, 2001). Many time-saving technologies intensify consumption because they require higher energy consumption to increase the speed of service (e.g. a faster mode of transport) (in production) or stimulate more frequent use of this services (in consumption) (Greening et al., 2000).

Jalas (2004) argues that consumption is influenced by the temporal dimensions embedded in the everyday life of consumers. For instance, people tend to describe travel distance in temporal terms (BBC, 2017), i.e. 'it is 10 minutes away' instead of '1 km away'. Time-saving technologies therefore generate substitution effects because time is a constraint and/or a necessary input to the use of energy services by consumers, similar to an income increase (Hertwich, 2005). Thus, some time-saving technologies, such as using cars for shopping instead of walking (substitution), may produce a rebound (Jalas, 2002). Sorrell & Dimitropoulos (2008) argue that a relative increase in time costs to energy costs should induce a substitution away from time towards energy-intensive services. With these considerations, when time costs largely govern the total cost of an energy service, consumers are concerned with time efficiency, rather than energy improvements delivered by technology (Sorrell & Dimitropoulos, 2008).

Empirical studies on the TRE

There is a lack of empirical work on the TRE. Nevertheless, the main application of the time rebound framework has been developed and some evidence has been produced in the context of energy consumption in transport and households (Table 2).

Table 2. Empirical estimates of the TRE

Author	Application domain	Region	Dimension	Th
Jalas (2002, 2005)	Home technologies	Finland	Energy	Iden
Takahashi, Tatemichi, Tanaka, Nishi & Kunioka (2004)	ICT (videoconference)	Japan	GHG emissions	Iden
Wang & Law (2007)	ICT	Hong Kong	Travel behaviour	Iden
Spielmann, de Haan & Scholz (2008)	High-speed transport	Switzerland	GHG emissions	Iden
Brenčič & Young (2009)	Home technologies	Canada	Energy	Iden
Aall, Klepp, Engeset, Skuland, & Støa (2011)	Home activities/outdoor recreation activities	Norway	Energy	N spec
Druckman, Buck, Hayward & Jackson (2012)	Home activities (non-working time)	UK	GHG emissions	Iden

Jalas & Juntunen (2015)	Home technologies	Finland	Energy	Iden
Nässén & Larsson (2015)	Reduced working hours of household	Sweden	Energy/GHG emissions	Iden
Buhl & Acosta (2016)	Reduced working hours of household	Germany	Resource	Iden
Sekar, Williams & Chen (2018)	Home technologies	US	Energy	N iden

The TRE originates from transport research, where the concept of the travel time budget was first proposed (Binswagner, 2001). The travel time budget describes the time allocated to travel between an origin and destination, and varies depending on individuals and travel-related factors such as trip purposes, additional activities during the trip as well as the punctuality of arrival (Lo, Luo & Siu, 2006). In the hypothesis of travel time budget, the potential time savings by using a faster mode of transport may partly or completely be offset by travelling more frequently, or covering longer distances. Spielmann et al. (2008) analysed time allocation applied to new high-speed metro technologies in relation to different mobility scenarios (commuting, leisure, shopping and business) of an average Swiss traveller. The study shows that if the travel speed increases in all scenarios, the TRE occurs and triggers additional environmental impacts. When focusing on leisure travellers, if high-speed rail services allow tourists to travel the same distance within less time, tourists may demand more of this service or substitute it with other tourist activities at a destination. Although these substituted activities may or may not be energy intensive (e.g. compare jet skiing with museum visit), the overall time savings have potential to increase energy consumption in tourism. However, this study did not explicitly use the notion of the TRE, nor measure the environmental impacts of tourism relating to time use.

Jalas (2002, 2005) analyses daily energy consumption in Finnish households focusing on the temporal activities outside working hours, and identifies that the TRE may transfer household activities to the market (e.g. eating at home to restaurants). However, Jalas (2006) recognises the methodological limitations of paring time use and consumption expenditure data in the time use analysis of activities. Nevertheless, his work has provided an important starting point for academic debate on time use and energy consumption concerning the TRE (Rau, 2015).

Whether or not time savings increase or decrease carbon footprint depends on the activities that consumers undertake when given additional discretionary time (Knight, Rosa & Schor, 2013). Some researchers attempt to capture substitution for activities that can take place outside home, such as holiday travel or tourist accommodation services (Aall et al., 2011; Jalas & Juntunen, 2015; Nässén & Larsson, 2015) as those activities tend to be more energy intensive than home activities (e.g. 32.9 kWh/h for 'free time trips' but 13.5 kWh/h for 'shopping, services, public admin and related trips' in Jalas & Juntunen, 2015). Yet, most studies exclude these activities, primarily focusing on leisure activities in and around home such as TV watching or attending cultural events (Brenčič & Young, 2009; Druckman et al., 2012; Sekar et al., 2018). Further, Druckman et al. (2012) and Nässén & Larsson (2015) claim that the TRE has implications for the generation of GHG emissions, thus calling for a deeper understanding of the linkages between how people use time and consume energy. This is significant for tourism.

The TRE has often been regarded in the context of changes in working patterns of household members. Nässén & Larsson (2015) show that fewer working hours of Swedish households contribute to reduced energy consumption and GHG emissions primarily because of the income effect Buhl & Acosta (2016) reveal that time savings from fewer working hours are reallocated into varied activities such as voluntary work and care that have positive impacts on the environment. They also show that changes in leisure time do not always generate clear environmental benefits because there may be a substitution with resource-intensive activities, such as motorsports. Dickinson & Peeters (2014) call for more careful analysis of working hours with respect to tourist consumption. Changes in working hours (for example, reduced working week) may not only be related to less energy consumption and GHG emissions as expected; however, these changes may impose various time pressures on tourists and trigger the need for faster modes of transport, and may also affect travel frequency.

The concept of household lifestyles has often accounted, albeit implicitly, for the TRE (Peters, Sonnberger, Dütschke & Deuschle, 2012) with the implications of time for lifestyle choices considered important to better understand future energy use and environmental impacts (Jalas & Juntunen, 2015). In fast-paced modern lifestyles, time is considered a scarce resource. As a result, technologies have become more time efficient (e.g. airplanes) while the consumption of these technologies has increased (Xu, Song & Zhang, 2014). For example, due to the on-going economic development, China's consumption structure has changed with growing consumption of cars, electronic products and overseas holidays that significantly affect energy use and related GHG emissions (Wang et al., 2016). In contrast, Sekar et al. (2018) demonstrate that, due to technology, the US lifestyle has shifted towards spending more time at home than elsewhere (e.g. increased home-based work), thus engaging in relatively less energy-intensive activities than outside home activities. Instead, increased energy consumption was observed with the increase of 7.8 hours of time spent in homes (increased residential energy consumption of 480 trillion British-Thermal-Unit in 2012 from 2003). Wiedenhofer, Smetschka, Akenji, Jalas & Haberl (2018) find that living in dense urban areas reduces mobility-related GHG emissions, triggering greater use of faster and relatively cheaper public transport, which may bring about the RE due to time savings as well as cost savings. Nevertheless, a switch in people's time use patterns towards less energy-intensive activities could be a way to curb overall energy consumption (Buhl et al., 2017), such as through local living, increased community engagement or improved accessibility to nature by public transport. Lifestyle can be shaped by socio-cultural factors such as national culture when it comes to energy related behaviour and use of energy and/or time-efficient technologies; e.g. using a big car as a social status symbol (Gołembski & Niezgoda, 2012). Therefore, it is important to understand what particular changes in consumers' everyday life imply significant changes in energy consumption in the cultural context.

In business travel Takahashi et al. (2004) identify higher energy demand for new activities facilitated by information and communications technologies (ICT), i.e. video conferencing. They demonstrate that the saved time by not going on business trips is used for other activities, such as commuting and holding other videoconferences, thus causing direct and indirect environmental impacts. Similarly, Wang & Law (2007) demonstrate that the use of ICT for personal and business purposes generates additional time, and this time is used for outside home activities such as shopping or leisure trips. Aall et al. (2011) pinpoint that historical changes in the nature of leisure activities have brought about the potential to increase energy consumption and consequent environmental impacts. These changes include increased number of holiday trips per year, transport intensity, resource intensity and reduced number of time-consuming activities. In particular, Aall et al. (2011) highlight that time saved at home (e.g. cooking and cleaning) results in more time available for consumption outside home, thereby increasing energy consumption; however, they do not explicitly consider the TRE or provide empirical evidence to support this argument.

Time use and tourism

Availability of time is a necessary pre-condition to engage in tourist activities (Gołembski & Niezgoda, 2012) and therefore people are willing to invest time (as well as money), which is saved elsewhere, in tourism. Accordingly, time is a cost in terms of the time length of a journey (Jacobsen, Gössling, Dybedal & Skogheim, 2018). Maat, van Wee & Stead (2005) argue that individuals are not primarily interested in actual travel distance but rather in the costs of bridging that distance, i.e. time, money and effort. Time is a particularly scarce resource, which must be allocated among different activities including time en-route and on-site (Krakover, 2002). Spending more time on travelling means cutting into the time available for other activities (Maat et al., 2005). Reduced working hours have released more time available for holidays albeit minimised money to be spent on travel (King & van den Bergh, 2017), while technological developments have increased time availability and reduced distance constraints when travelling.

Technological improvements in tourism have focused on transport because transport technologies are closely associated with travel costs (Kelly, Haider & Williams, 2007) and therefore stimulate demand for tourism, enabling particular travel activities to be performed at lower time costs (Prideaux, 2000). In the fixed time budget approach, tourists tend to pack as much activity, enjoyment and experience as possible into the fixed time without limiting their consumption (Stein, 2012). Studies on time use in tourist consumption are scarce despite their significance in terms of the potential TRE and negative environmental consequences (Santarius, 2012).

If insufficient time budgets are available for travelling, tourists may choose a faster mode (e.g. airplane) because time spent on travel to/from destinations is seen as wasted time (Lyon & Urry, 2005). For instance, tourists who are time-sensitive or travel longer distances when visiting the Greek islands would not substitute boat (more environment-benign compared to air travel) for airplane because of the travel time although boats are offered at lower costs (Rigas, 2009). The accessibility of destinations is influenced by time (i.e. travel speed) as well as their location (Litman, 2017). Locations convenient for private car travel, such as rural areas where poor public transport services make travel time longer, tend to be difficult to access by other modes of transport (Dickinson & Robbins, 2008). It is not popular with British tourists to travel to Eastern Europe by overland modes of transport due to perceived undeveloped transportation infrastructure within the region, but such modes are often preferred to travel to Southern France due to short(er) travel time and convenient/frequent travel schedules of high-speed rail within France (Filimonau, Dickinson & Robbins, 2014).

Length of stay at a destination has implications for tourism's energy use and GHG emissions. Becken (2008) argues that tourists tend to allocate time to energy-consuming activities when staying longer at a destination, but other researchers contradict this (Gössling, Scott & Hall, 2013; Hall et al., 2015; Scott et al., 2016; Scott, Peeters & Gössling, 2010). A longer holiday stay could be beneficial in terms of the environmental impacts when calculated on a per capita per day basis relating to travel transport. This is observed by Sun & Lin (2017) who find that time savings from newly built Taiwan's high-speed rail have minimal impacts on the destination's environment. UNWTO (2014) notes that the average length of stay per visitor should be increased to enhance the eco-efficiency of travel as the impact of transport to arrive to a destination is distributed over a longer period. In this regard, potential carbon reduction can be achieved by shifts to shorter travel distances with longer stays as well as to less energy intensive modes of transport (Scott et al., 2016).

While time affects tourist behaviour in absolute terms, the impacts are subject to the purpose of travel (McKercher & Lew, 2004). A family must fit the entire trip within the allocated time budget and most business travel is performed by people who are time sensitive. Such tourists will tend to directly transit to a destination in order to maximise the time spent on-site or to attempt to accelerate a chosen activity (e.g. visiting a national park without leaving car). In contrast, backpackers or retired holidaymakers, who purposefully take a longer trip, have much flexibility in their total time cost budgets. Tourists to rural destinations or at campsites would enjoy cycling in a park as pleasantness is more important than saving time (Smith, Robbins & Dickinson, 2019). Subsequently, they will spend their time budgets differently within destinations, ultimately having a positive value on the act of travelling.

Time in tourism also has a subjective character and a social meaning (Dickinson & Peeters, 2014). The experience of time varies in response to the social context of individuals (Stein, 2012). As Gołembski & Niezgoda (2012) assert, perception of time and the use of it varies across social groups and societies; therefore, the flow and pace of time are culturally specific, which often plays a significant role in the dynamics of tourist behaviour (Kim & Filimonau, 2017) and can be used to categorise tourists (Lewis, 2006). Therefore, social and cultural perception of time is essential to understand changes in tourist consumption.

Alternative perspectives on time and its use when on holiday have led to novel types of tourism. For example, slow travel focuses on quality of time (Dickinson, Lumsdon & Robbins, 2011). It may be seen as irrational in terms of time costs, but slow travellers would instead apply additional principles to consider the effects of their travel behaviour on the environment or for a particular travel experience based on a chosen transport mode. The perception of time can also change tourists' perspectives on the value of their visit as, for instance, in last chance tourism where the desire to see something disappearing, such as polar bears, increases with the growing perception that time is running out (Fisher & Stewart, 2017).

Energy and time-saving technological improvements in tourism

Technological improvements have contributed not only to tourism growth but also to major efficiency gains in energy, time and other resources, thus driving sustainable tourism development (Gössling & Peeters, 2007). Yet, time-saving technologies have often influenced energy consumption as many time-saving technologies require increased energy inputs. Time-saving technologies and innovations have not only increased the speed (and distance covered) and flexibility of service, but also brought about such effects as the elimination of unwanted activities (e.g. waiting in a queue) and long-haul travel-related stress. Increased speed would cause the direct RE, while the latter effects would not incur any direct RE but the indirect RE (e.g. using saved time from waiting in the check-in queue for other travel). To identify technology-induced potential savings in tourism, a sub-sectoral approach is often applied, including transport, accommodation and tourist activities (Peeters, 2010). A variety of technological developments that have led efficiency in energy and/or time continue to be made, indicating the potential for the RE and also the TRE.

For example, in transport, technological advances in aircraft design have enabled tourists to travel faster and to reach distant destinations, and reduced the carbon footprint of aviation (Knowles, 2006; Munk, 2018; Winchester, McConnachie, Wollersheim & Waitz, 2013). Meanwhile, road transport development has dramatically increased the ability to undertake travel to remote destinations, with a rise in car trips per person and in trip length (Gössling et al., 2010). Responding to growing concerns about significant energy consumption and GHG emissions from road transport and other associated adverse externalities (e.g. congestion), vehicle technologies have evolved to include the use of alternative fuels and autonomous vehicles. Cars enable more flexibility in travel time and distance, i.e. without passively squeezing time into an official timetabling of mobility such as trains (Merkert & Beck, 2017). With the expansion of car ownership, tourist travel patterns have been altered from constrained (e.g. railway lines) to more diffuse and flexible (e.g. same-day excursions by car to many different cities) (Page, 2009). Improvements in railways have allowed tourists to travel over considerable distances at unprecedented speeds and at a lower unit cost (Hall & Lew, 2009) alongside greener rail systems (Perl & Goetz, 2015). The provision of high-speed rail reduces travel time significantly and offers greater flexibility in time use at a destination. High-speed rail can give short-haul travellers advantages due to the time required to reach airports and for pre-boarding procedures (e.g. check-in and security) (Sun & Lin, 2017). Sea transport is a core tourist activity (Page, 2009). The passenger ship industry is working with higher energy efficiency and lower emissions technologies in shipbuilding (e.g. heat pumps in cruise ships) and high-speed ferries have increased speed (Lamers, Eijgelaar & Amelung, 2015).

Although the penetration of technological improvements into tourist accommodation and activities has been slower compared to tourist transport, they play an increasingly important role in enabling progress towards environmental sustainability. Similar to residential buildings, the application of technologies in hotels has improved energy efficiency (e.g. geothermal space heating/cooling), and some new technologies (e.g. self-check-in) have reduced time-consuming tasks for hotel guests and improved in-room entertainment, thus changing in-room behaviour with respect to time use (Biesiada, 2017).

Activities at destinations can be energy-intensive (Gössling, 2015). Transport technologies have influenced the tourist activity patterns in two ways: first, by enabling tourists to have more time to engage in activities on-site through time savings by faster modes of transport en-route, and, second, by providing tourists with a broader range of activities facilitated by transport (e.g. heritage railways and scenic helicopter rides) (Page, 2009).

The RE and the TRE in tourism

Peeters, Higham, Kutzner, Cohen & Gössling (2016) argue that new technologies to mitigate tourism's GHG emissions justify continued inaction when considering changes in tourist consumption beyond efficiency improvements and shift the environmental burdens to future generations. Technological optimism favours the ability of technological solutions to make the world more sustainable, at times underestimating the potential for future, unaccounted for in sustainability assessments demand for energy services that can be substantial (Arvesen, Bright & Hertwich, 2011). Lenzen et al. (2018) argue that tourism-related technologies are unlikely to curb tourism's GHG emissions because of the rapidly increasing tourism demand.

According to Gössling et al. (2013), the increase in tourism's GHG emissions is driven by the growth in travel frequency, travel distance and length of stay. Tourists in China, for instance, have made a major shift towards faster modes of transport: from train to car and/or airplane, despite the potential for increasing tourist demand for domestic rail travel due to China's newly built high-speed railways (Wang, Niu & Qian, 2018). Hence, the notion of the RE in the context of tourism and travel is essential.

Although some types of the RE from the traditional rebound studies are relevant to tourism services and tourist behaviour, little research has been conducted on the implications of the RE for tourism or attempted to conceptualise the RE of tourist consumption (Gössling et al., 2013). However, UNWTO (2014) observes that increased demand for air travel and tourism can potentially be driven by increased energy efficiency gains, implying the existence of the RE. Although there is no dedicated research agenda on the RE in the tourism literature, a few studies have either directly or indirectly highlighted the impact of the RE and/or the TRE in the context of tourism (Table 3). While Gössling et al. (2013) emphasise that the relevant RE at different scales needs to be considered in the GHG emissions projections and mitigation scenarios for the tourism industry, Hall (2013, 2015) stresses that the RE will occur in tourism unless resource use globally is limited by caps that introduce absolute upper limits of consumption. In the case of the latter, it is important to address not only efficiency, i.e. the value of technological changes, but also the sufficiency, i.e. that behavioural changes of tourists are key to the contribution of tourism to environmental impacts (Hall, 2009, 2015; Hall et al., 2015).

Table 3. Anticipated RE and TRE in tourism

Author	Anticipated drivers	Anticipated rebound effect	Rebound representation in tourism
Prideaux (2000)	Cost saving Time saving	Price effect Time effect	Transport Accommodation (higher standard) Tourist activities
Becken (2005)	Time saving	Time effect	Transport
Gössling et al. (2010)	Cost saving Time saving	Price effect Time effect	Transport Accommodation Tourist activities
Peeters (2010)	Cost saving Time saving	Price effect Time effect	Transport
Gössling et al. (2013)	Cost saving	Price effect	Transport Accommodation
Dickinson & Peeters (2014)	Time saving	Time effect	Transport
UNWTO (2014)	Cost saving	Price effect	Transport
Hall (2013, 2015), Hall et al. (2015)	Cost saving	Price effect	Transport
Nisa, Varum & Botelho (2017)	Not specified	Not specified	Accommodation
Filimonau, Mika & Pawlusinski (2018)	Socio-psychological cost saving	Socio-psychological effect	Transport

Table 3 suggests that the RE in tourism research has been analysed from two main perspectives, time and cost, with the latter being dominant, and within the tourism transport context. Peeters (2010) uses a causal loop diagram, which visualises interrelated variables, to explore the achievement of technological improvements (both positive and negative) in tourism transport and demonstrate the existence of the RE. However, existing research fails to identify the causes and consequences of increased travel and consumption or the implications for pro-environmental consumer behaviour in tourism.

Traditional rebound studies from energy economics have implications for the tourist accommodation sector. While the use of residential energy-efficient technologies (e.g. home heating) can serve the purpose of efficiency gains in tourist accommodation buildings, individuals may adjust their behaviour, often leading to higher demand (Nisa et al., 2017). For example, hotel guests are less likely to conserve energy as they are not directly paying for their consumption (Barker, Davis & Weaver, 2013) and this may reduce the effectiveness of hotels' sustainability policies (Budeanu, 2007). Moreover, with time-saving technologies in hotels, tourists are no longer kept waiting in lines but instead use the saved time for other activities, which possibly result in additional environmental impacts at destinations (the TRE). Complimentary in-room entertainment technologies are found to directly correlate with the amount of time guests spend in their room, making hotel stays more enjoyable, while triggering higher energy use (Bilgihan, Smith, Ricci & Bujisic, 2016). Thus, for some tourists, a stay in luxurious hotels equipped with hi-tech technologies and energy-intensive facilities (e.g. pools), is preferred (Scott et al., 2010). When the RE or the TRE occur, corresponding increased consumption of tourist accommodation and tourist activities is expected (Nisa et al., 2017). Hall et al. (2016) emphasise the need to pay attention to changes in actual consumption of tourists as well as the adoption of (energy and time) efficient technologies.

Conceptual framework of the potential RE and TRE in tourism

It is critical to identify the underlying assumptions behind the RE that link efficiency changes in time, energy and resource use derived from technological solutions with increasing demand in the context of tourism. This requires an innovative approach to studies and practices of sustainable tourism (Gössling et al., 2010) and highlights the need for a framework, which assists in identifying and evaluating any potential RE, including the TRE, and the impacts on consumer behaviour in tourism (Figure 2).

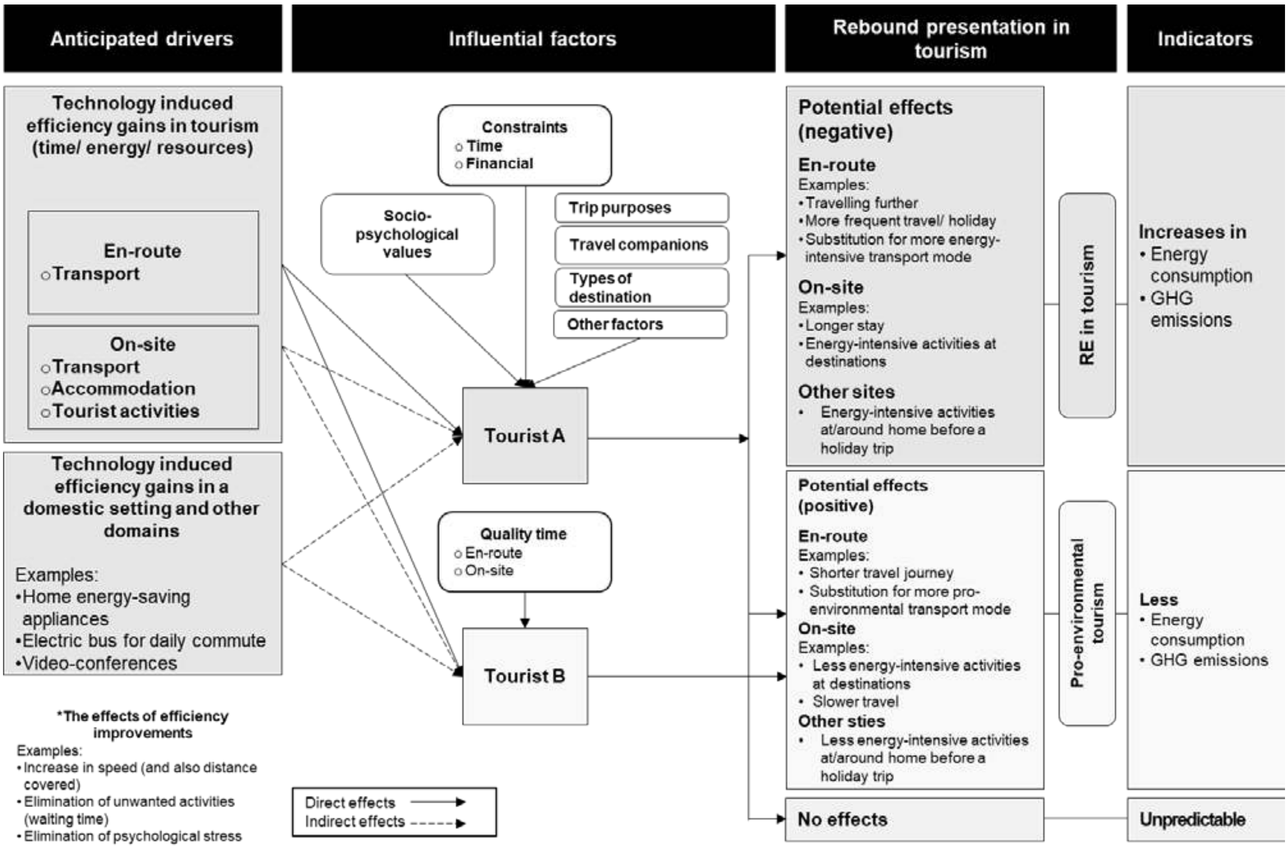

Figure 2. Conceptual framework of the potential RE in tourism

In the context of tourism, the RE implies greater consumption in its three sub-sectors, i.e. tourist transport, accommodation and activities, relating to efficiency gains both en-route and on-site. It is important to recognise that discretionary time (as well as money) from efficiency gains in a domestic setting and/or other sectors is often, in the long-term, spent on increased travel and tourism activities. These efficiency gains directly or indirectly affect tourist's behaviour throughout a holiday journey through inter-related effects including time, money (income/price), socio-psychological effects and other factors. Particularly, time and financial constraints can be of major influence for a tourist to engage in any tourist activities when efficiency changes from technological improvements occur.

Driven by these effects, tourists may show a potential behavioural shift to energy-intensive activities en-route, using in-room services and undertaking activities on-site. For instance, when the time effect plays a key role in determining behavioural changes in tourist consumption (for tourists with time budget constraints), it can be defined as the TRE. Then the potential RE is observed including: travelling further afield, more frequent holiday trips, staying longer, engaging more in energy-intensive activities at destinations and/or substituting for more energy-intensive transport mode. These effects are likely to generate higher energy consumption and GHG emissions (negative impacts). In the opposite case, efficiency gains have potential to enable pro-environmental tourism by engaging tourists in more environment-friendly modes of transport en-route and less energy-intensive activities during their stay (positive impacts). Lifestyles, changes in working hours or cultural impacts on time perception and consumption may act as drivers of the RE.

Meanwhile, it should be recognised that there are tourists who seek quality time en-route as well as on-site and are concerned about their environmental impacts. Regardless of efficiency gains relating to time, these tourists are likely to show a meaningful contribution to mitigate tourism's carbon footprint by engaging in slower movements en-route/on-site.

The proposed conceptual framework can support development of a series of scenarios and response options of tourists. For example, a holiday trip of a tourist with constrained time budget would be governed by the time effect (influential factors in Figure 3) and therefore would tend to engage in a faster mode of transport (likely to choose to travel by air over train), if available, so as to arrive at the destination faster in order to have a better holiday experience. In this case, the tourist has more time to spend at the destination, so they may go for an additional scenic river cruise using time saved from air travel (potential effect 1 in Figure 3). Scenic cruise ships generate disproportionally high amounts of GHG emissions (indicators in Figure 3), where the RE is demonstrated. Yet, there are other important factors such as financial constraints which should be recognised in identifying the (T)RE in tourism.

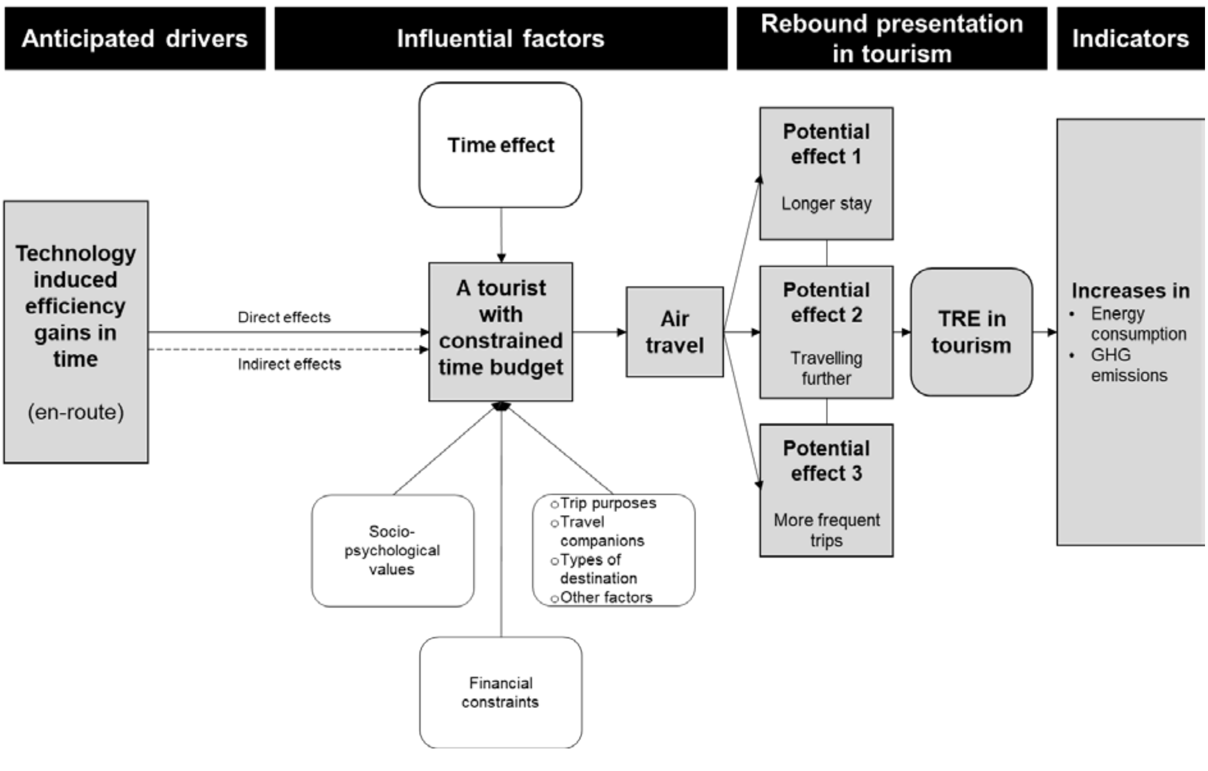

Figure 3. Tourism RE scenarios and the environmental impacts

Meanwhile, the same tourist may decide to travel to a more distant destination (potential effect 2) as airplanes have enabled longer distance travels within the same or less time. Also, the tourist could choose to travel more frequently (potential effect 3). In these cases, the RE generates undesired environmental impacts from air travel. In these scenarios, technological developments that enhance time efficiency are unlikely to bring about environment-friendly effects due to the RE, more specifically the TRE.

Conclusion

This paper has conceptualised the potential RE in tourism and explained the implications of the RE for sustainable tourism development by re-evaluating the use of time in the context of tourist consumption. The paper has shown that the technology-based approach, where the focus of sustainable tourism development policy and practice has been on technological interventions, is questionable as the actual environmental savings from technological improvements can be less than expected due to the RE. While more energy-efficient products and services have been provided in the tourism sectors, especially transport, consumer responses to efficiency gains have rarely been taken into account in tourist studies. Recognising the limitations of existing approaches this paper has explored technological developments in tourism and the relationship with potential behavioural responses of consumers using the concept of the RE.

This paper has outlined how technological advances in tourism have accelerated time efficiency improvements, enabling people to travel with less time and fewer space constraints. As time is considered a cost as well as a necessary pre-condition of travel, particularly for those tourists with restricted travel time budgets, time-saving technologies can affect the transport mode choice, destination choice, the activities and the length of stay at a destination. As time is perceived differently depending on trip purposes or social meaning by individuals, it is essential to identify how time is used in relation to tourist consumption. The TRE, therefore represents an important factor in tourism's environmental impacts when the consequent effects of time savings are related to more consumption in energy and resources.

This paper makes a theoretical contribution by establishing a conceptual framework to identify the potential (T)RE based on the analysis of the underlying assumptions of the traditional RE and empirical studies in the tourism context. The framework reflects the need for the application of the concept of the (T)RE in tourist studies that creates new knowledge for sustainable tourism development with the consideration of consumer behavioural responses and environmental impacts. Thus, the framework linking theoretical research questions and empirical analysis calls for future development of analytical tools that investigate the impacts of the (T)RE.

This paper indicates a number of avenues for future research. Firstly, research needs to address the role of the RE, including the TRE, in tourist behaviour and environmental impacts to find solutions to sustainable tourism development beyond sole technological efficiency improvements. In addition, a detailed examination of tourist behaviour and consumption patterns integrating time use is required in order to better comprehend how tourist consumption during travel could be managed to make it more responsible. Furthermore, empirical research ought to be undertaken to respond to previous studies that have explicitly stressed the high probability of the RE occurrence in tourism, thus supporting the proposed conceptual framework and yielding more robust evidence within the tourism context. Lastly, future research needs to pay attention to the comparative capacities of technological, behavioural and managerial approaches, and to consider the relevant RE in analysis of different tourism's sectors in regard to energy consumption and scenarios of GHG emissions.

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