Towards the prevention of rebound effects in Europe and beyond: insights for policymaking

Science for policy brief

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Publication date:
2025

Document Version
Publisher's PDF, also known as Version of record

JRC 138704

European Commission

SCIENCE FOR POLICY BRIEF

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HIGHLIGHTS

While ambitious EU sustainability policy is being deployed, the environmental impacts of EU consumption patterns are still increasing and transgressing many planetary boundaries.

The gap between policy action and environmental impacts of consumption patterns can be explained by rebound effects, which offset ca. 47% of potential environmental gains of sustainability interventions.

To prevent rebound effects, it is important to understand why and how they occur (i.e., the rebound mechanisms), as well as how economic, behavioural, and sociocultural factors influence their magnitude.

This policy brief provides best practices and recommendations for identifying, preventing, and mitigating rebound effects in EU policymaking.

POLICY CONTEXT

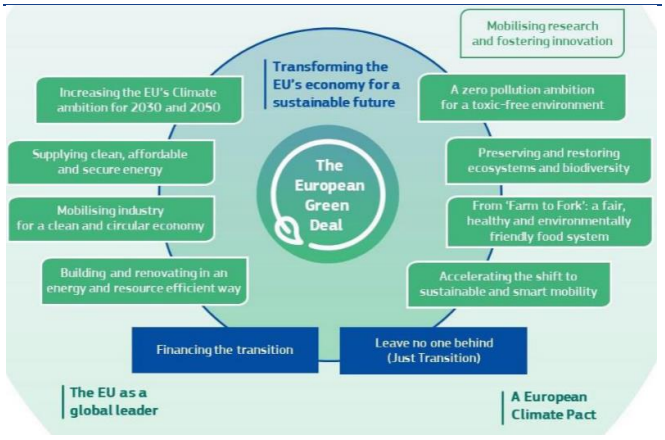
Sustainability-oriented policy in the EU

In the European Union (EU), sustainability-oriented policies are a top priority within the European Green Deal (EGD), as the roadmap to make Europe the first climate-neutral continent by 2050 while leaving no person and no place behind. For this aim, the EGD targeted the transformation of the EU into a **modern, resource-efficient and competitive economy addressing environmental and social challenges**.

The EGD is structured in eight main ambitions (Figure 1) with associated legislative measures and ambitious targets. Some targets, e.g. those aimed at enhancing reuse and recycling under the Circular Economy Action Plan, address the drivers of environmental degradation. Others address overall environmental pressures, such as reduction targets for greenhouse gas emissions (GHG) in the 2030 Climate Target Plan.

Building on the EGD, the 8th Environment Action Programme (EAP) aims to accelerate the transition in the context of the **EU's long-term vision to 2050 of living well and within the planetary boundaries**, recognising that human well-being and prosperity depend on healthy ecosystems.

Figure 1 – Main ambitions of the European Green Deal.



Source: European Commission, the European Green Deal.

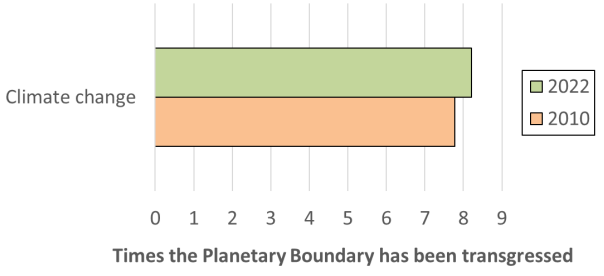
Are current sustainability policies enough?

EU policies successfully reduced some environmental pressures in the EU, such as EU territorial GHG emissions per capita by around 30% (1990-2022), according to national GHG inventories (European Environment Agency). While reductions are higher in some consumption areas (e.g., household energy consumption due to housing renovation policies), environmental impacts in other consumption areas are still growing (e.g., food or household goods) (EC-JRC, 2024).

Despite all the sustainability-oriented action, **the EU consumption footprint increased by around 9%** between 2010 and 2022 (EC-JRC, 2024), while the EU population had an average growth of around 5% (EUROSTAT). Current EU consumption patterns surpass planetary limits. For instance, the impact of EU climate change is around 8 times the limit defined by the planetary boundary, highlighting the need for actions that reduce the impact on the Earth's systems (Figure 2).

The increase in environmental impacts due to changes in consumption patterns can be partly explained by **rebound effects (RE). RE are caused by behavioural and systemic reactions to sustainability-oriented actions that offset their potential sustainability gains** (due to increased consumption, switch of expenditure among consumption areas, and change in motivation for pro-environmental behaviour, among others).

Figure 2 – EU Consumption Footprint in 2022 and 2010 assessed against the Planetary Boundaries for the climate change impact category of the Environmental Footprint method.



Source: Consumption Footprint Platform (EC-JRC, 2024).

WHAT ARE REBOUND EFFECTS?

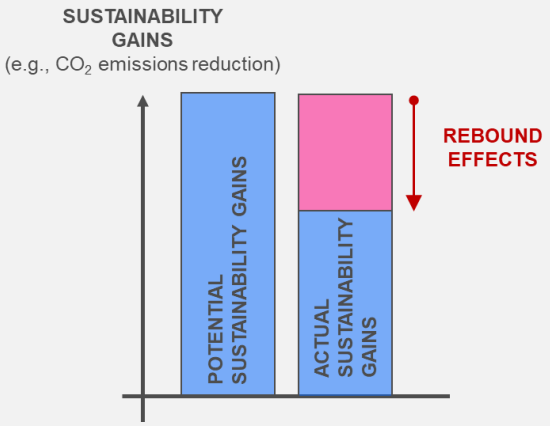
Discussions about rebound effects can be traced back to 1865, with the so-called **Jevons' Paradox** that demonstrated situations in which **technological efficiency** (primarily related to energy efficiency) **leads to an associated growth in resource use** due to economic attractiveness [1].

Over the past century, research on rebound effects has demonstrated that introducing sustainability-oriented initiatives very often entails negative behavioural consequences that offset the potential sustainability performance [2]. The definition of rebound effects is presented in Box 1.

Box 1: Rebound effect definition

"Induced changes in system behaviour that offset the potential sustainability performance of interventions" (ERC REBOUNDLESS, see Figure 3).

Figure 3 – Rebound effects as the offset of the potential sustainability gains of interventions.

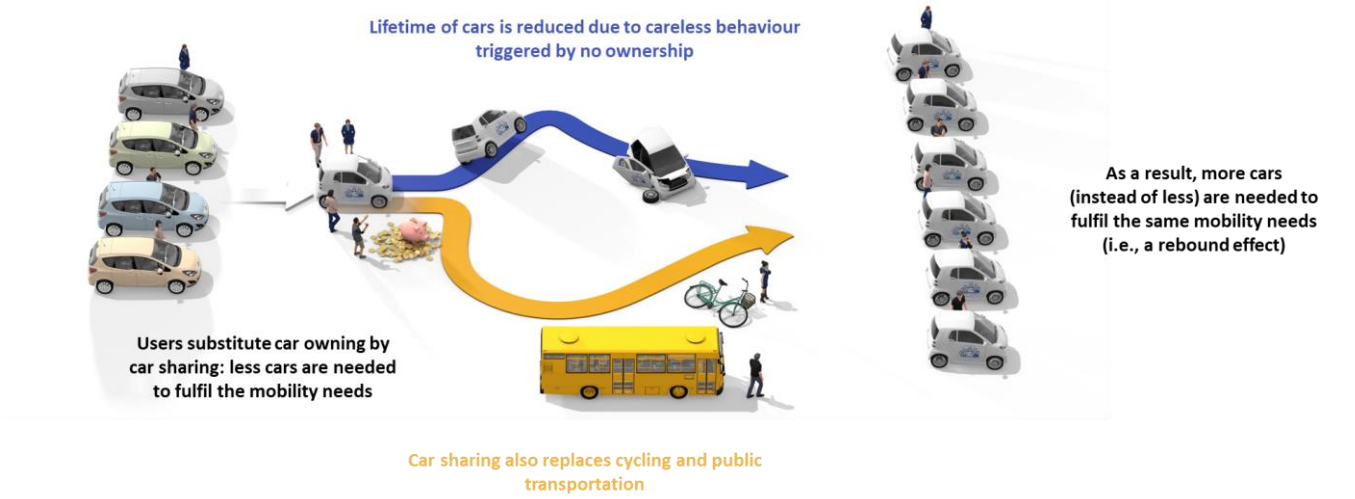


The magnitude of rebound effects **may partially or entirely offset potential sustainability gains and even lead to an overall worse sustainability performance (i.e., backfire)**.

In contrast, a **secondary benefit** may occur when the induced changes reinforce the interventions' potential sustainability performance.

'Never before has there been a stronger global focus on solving the pressing sustainability challenges faced by humanity [3], but the expected societal and environmental gains will not be achieved unless rebound effects are prevented [4].'

Figure 4 – Example of rebound effects within a car sharing system (DTU Dynamo, p.06).



As a thought exercise, take the example of car sharing, a promising sustainability-oriented intervention in mobility. The sharing system is designed to replace car ownership and decrease the need for cars (Figure 4). Nevertheless, the lack of ownership often contributes to reckless driving behaviour, increasing wear and tear and significantly shortening the car's lifetime, ultimately increasing the demand for new cars (blue arrow in Figure 4). Furthermore, instead of replacing car ownership, car sharing often replaces public transport, cycling or walking (yellow arrow in Figure 4) due to its enhanced convenience and low access costs. Another potential rebound effect is increased car utilisation (i.e., greater demand for the product/service in focus), due to lower acquisition and operational costs, which lowers the financial barriers to more frequent use.

In all cases, behavioural and systemic reactions induced by the sustainability-oriented intervention led to higher overall consumption, offsetting the potential sustainability performance of car sharing. When increased consumption occurs within the same product or system (e.g., higher car utilisation), it results in a direct rebound effect. Conversely, when increased consumption extends to other products or systems (e.g., reduced cycling), it leads to an indirect rebound effect.

In summary, rebound effects arise from behavioural, economic, and systemic responses triggered by interventions, which ultimately result in increased overall consumption at the system level, thereby undermining potential sustainability benefits.

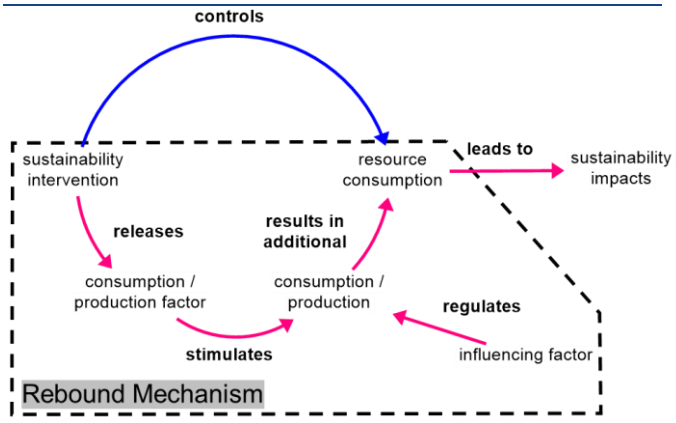
Rebound mechanisms

Rebound effects are the result of complex mechanisms [2], [5], [6] occurring at the micro, meso, and macro levels, and are subject to dynamic interactions with causal links and responses (feedback loops) due to individual behaviour driven by psychological/economic factors and further interactions between society and technology [1], [5], [7], [8].

In simple terms, a rebound mechanism (Figure 5):

- Starts from the effects of a sustainability-oriented intervention aiming at controlling resource consumption.
- Explains how the sustainability-oriented intervention eventually leads to additional resource consumption via releasing a given consumption and/or production factor that stimulates consumption or production and is regulated by influencing factors.

Figure 5 – The structure of a rebound mechanism.



Source: representation by the authors, based on [5].

Identifying the specific mechanisms at play is critical in understanding why, how, and when a given rebound effect might occur. It can also hint at specific ways of addressing the rebound effect by mitigating or even preventing its occurrence.

Types of rebound mechanisms

Rebound effects have been traditionally associated with **economic determinants** of consumption (such as costs, income and profit). From this perspective, **rebound effects for consumers can be explained as the result of income and substitution effects**, referring to a direct and indirect increase in consumption due to the increased budget available after a sustainability-oriented intervention. For example, energy-efficient cars decrease driving costs, increase the available budget, and consequently result in more driving (i.e., income effect) or higher consumption of other products (i.e., substitution effect). Furthermore, the release of **physical constraints,** such as time and space, has also been largely associated with rebound effects. For example, when an intervention frees up time for individuals, this additional time may be spent consuming other products or services, thereby increasing environmental pressures. If these pressures exceed the avoided pressures, a rebound effect occurs. Conversely, if they are smaller, there is potential for a secondary benefit.

A growing body of behavioural research expands the traditional economic explanations of rebound effects. This is done by challenging the assumption of rational, utility-maximizing decision-making and by offering alternative understandings of decision-making, placing **rebound effects as being shaped by a variety of psychological and social factors** [9].

One of the most recognized behavioural economic mechanisms underlying rebound effects is **moral licensing**, anticipating that an initial moral behaviour creates the perception of moral entitlement to perform subsequent morally questionable behaviours [10]For instance, purchasing electric vehicles could give customers the feeling of being licensed to use the car more often or to go on a vacation by plane.

Another important behavioural economic mechanism, especially in the policy domain, is **motivational crowding** [11]. Motivational crowding occurs when external incentives (e.g., penalties, rewards) reduce the intrinsic motivation for the targeted behaviour. In the context of sustainability, motivational crowding can explain why and how a law enforcing monetary incentives for returning cans can decrease the meaningfulness of the sustainable practice or increase control aversion and consequently diminish the intrinsic motivation to pursue the targeted behaviour.

In addition to moral licensing and motivational crowding, there are several other high-potential, yet underexplored, behavioural economic mechanisms [9]. One example of such a mechanism is the **diffusion of responsibility**, expecting that an intervention might shift the perceived responsibility of an actor to protect the environment to other agents such as governments or engineers [12]. For instance, following a prohibition on single-use plastic bags, consumers might perceive that governments are more capable of addressing environmental issues, thereby diminishing their sense of responsibility to participate in environmentally friendly behaviours.

The different mechanisms that can explain the reasons and means for the occurrence of rebound effects illustrate the importance of incorporating economic, psychological, and social factors for comprehensively understanding and identifying potential rebound effects. Moreover, rebound effects may affect different types of actors (consumers and producers) [13].

TO WHAT EXTENT ARE REBOUND EFFECTS HINDERING SUSTAINABILITY?

Rebound effect magnitude

A research investigation of 530 rebound effect instances within the ERC REBOUNDLESS project identified a sample of 364 rebound magnitude estimations. For those with a discrete estimate (192 instances), a median rebound reduction of 50.00% was found [14], meaning that **ca. 50% of the potential benefits of sustainability-oriented interventions were offset**.

These magnitude estimations demonstrate high variability (from -2,176% to +7,000%), even between similar studies. For example, the rebound magnitude estimations for efficiency improvements within housing ranges from -45.50% to 550.00%. This is most likely due to heterogeneous rebound definitions, system boundaries of the studies, disharmonized estimation techniques and data sources [14]–[17]. Overall, these figures indicate the extent to which sustainability-oriented interventions can go awry and how critical it is to assess extensively the potential rebound effects of any intervention.

Backfire is when all potential sustainability benefits (or more) are offset (i.e., rebound magnitude > 100%), leading to a worse-off scenario. This is seen for 80 of the 530 rebound instances (15%) and extreme backfire rebound (i.e., rebound magnitude > 200%) for 17 (3%) [14]. 'Extreme backfire' arises from various sustainability-oriented interventions,

such as those promoting "green" consumption choices, like financial incentives for energy-efficient lighting. This phenomenon occurs at multiple levels, including the consumer or firm level and the global macroeconomic level. Overall, **rebound effects persist in all social, economic, and political spheres.** Box 2 provides an overview of policies inducing rebound and backfire effects.

Box 2: Policies inducing rebound effects

Rebound effects have been associated with various consumer-oriented policy measures, including cases in which financial incentive policies, such as rebates or subsidies for sustainable alternatives (e.g., energy-efficient household appliances) or upgrades (e.g., household retrofitting), and government-led campaigns to promote sustainable alternatives (e.g., fuel switching program).

Backfire has been identified in connection with several financial incentive policies, indicating worse-off scenarios via increased consumption levels. These backfire scenarios may occur due to the re-spending of cost savings or changes in consumer preferences (e.g., preferring increased brightness given more efficient lighting). Findings from these studies indicated rebound effect magnitudes of 150%, indicating a case of backfire.

Scope of rebound effect studies

Current literature on rebound effects identified that the implications of policy-induced rebounds are mostly unknown since most studies have focused on costless and exogenous efficiency improvements that are not linked to any specific policy intervention [18]. The studies primarily assess **direct and economy-wide rebound effects of (energy) efficiency strategies** within the mobility and housing social needs areas [19]. Besides energy, an increasing interest is revolving around circular economy-related rebound effects [20], such as income and substitution RE in households associated with food waste prevention practices. **Around a quarter of the studies focus on products**, primarily "green" alternatives to consumer products (e.g., reused smartphones), a reduction of less "green" products (e.g., private vehicles), energy efficient innovations (e.g., efficient heat pumps), or "cleaner" renewable energy technology (e.g., solar panels). The few studies on the rebound effects of product-service systems focus primarily on sharing systems, specifically car-sharing systems. The socio-technical **systems** assessed were predominantly transportation, household electricity usage (mainly heating services), teleworking, and agricultural systems (like water irrigation systems). The remaining studies focus on (global) macroeconomic production, productive industries or sectors, intermediate goods, or pro-environmental behaviour/attitudes [14].

Currently, key **knowledge gaps limit the prevention and mitigation of rebound effects in policy design** and implementation [14], as described in Box 3.

Box 3: Critical knowledge gaps

High focus on energy efficiency

Around 75% of the studies focus on the rebound effects of energy efficiency. The policy-oriented studies focus on energy and fuel efficiency standards and financial incentives for more energy-efficient cars, household appliances, and houses (i.e., retrofitting measures). Little focus has been given to the rebound effects of circular economy policies or sufficiency-oriented policies.

Limited knowledge of rebound mechanisms range

Most of the rebound mechanisms examined follow a similar re-spending structure (i.e., price/income/substitution effects), at the expense of understanding the many other rebound mechanisms (e.g., time-use, motivational, psychological, and transformational rebound effects).

Lack of understanding of interlinkages

Little research has been conducted on the interrelatedness and interdependencies of different rebound mechanisms, which may lead to an underestimation of rebound magnitude.

Heterogeneity of methods

Inconsistent estimation methods make it difficult to accurately assess the level of offsetting caused by a specific intervention.

BEST PRACTICES FOR IDENTIFYING REBOUND MECHANISMS AND THEIR EFFECTS

Investigating rebound effects is crucial not only for quantifying them but also for understanding the mechanisms through which they occur. This knowledge can then be used to devise effective strategies to prevent and mitigate rebound effects.

Four best practices for **supporting the identification of the mechanisms causing rebound effects** are introduced in Box 4 (based on [8], [21]).

Box 4

Best practice 1: Expand decision-makers understanding of the potential rebound effects of actions.

Decision-makers often assume that interventions aiming for more effective resource use will translate straightforwardly into lower material or energy use, ignoring critical feedback structures and treating essential system elements as exogenous.

For instance, more efficient heating systems might lead users to leave their windows open to enable air circulation, resulting in additional energy usage. In this case, focusing only on the heating system's efficiency can hinder decision-makers from seeing the relevant potential system responses.

Best practice 2: Identify the plurality of rebound mechanisms at play, especially those with reinforcing behaviour.

Different mechanisms may share the same feedback structures, allowing different actors to release production and consumption factors simultaneously.

For example, additional consumption through the released budget (income mechanism) may lead firms to produce more through additional revenues (output mechanism), which holds reinforcing behaviour and is commonly referred to as the economy of scale mechanism.

Best practice 3: Make explicit the decision-making structures through which actors consider alternative consumption and production options.

The association of rebound mechanisms through sharing consumption and production factors can also help determine the rebound effects.

For example, a released budget enacted by a given intervention may lead to additional consumption of the same good (income mechanism), a different good (re-spending mechanism) or substituting to other goods (substitution mechanism). Therefore, the share of the released budget to consume a given good will limit the other options, so the effect of one mechanism can also limit the effect of the others.

Best practice 4: Address rebound effects by design (of policies and business practices) while nurturing secondary benefits.

The release or constraint of consumption and production factors may decrease the interventions` potential sustainability gains (i.e., rebound effects) or increase its sustainability gains (i.e., secondary benefits).

For example, if an intervention enhances a consumer's environmental motivation and helps them move away from another resource-intensive behaviour, that should be further incentivised. Considering the dynamics of secondary benefits is important so that interventions can nurture actors towards enhanced sustainability gains.

The best practices enable decision-makers to better comprehend the root causes of rebound effects, providing valuable insights to inform both public and business decision-making on how to identify rebound mechanisms and their effects.

POLICY RECOMMENDATIONS: TOWARDS REBOUNDLESS POLICYMAKING

The EU must reduce the environmental burdens caused by its consumption patterns to tackle current environmental planetary crises. **Rebound effects offsetting, negating, or surpassing the positive effects of policies** threaten these goals and **should thus be prevented or mitigated**.

The prevention and mitigation of rebound effects should be integrated into the whole EU policy cycle, thus supporting the evidence base for EU policymaking as indicated in the Better Regulation. The proposed recommendations for policymakers and scientists are detailed by stage of the policy cycle (Figure 6):

1. Agenda setting and addressing knowledge gaps

Identify a set of rebound mechanisms relevant to design and innovation in policymaking that can help recognize and explain the occurrence of rebound effects at the micro, meso, and macro levels.

Harmonize methodologies for the prospective and retrospective identification and assessment of the magnitude of rebound effects.

Make available a set of empirically validated economic and behavioural recommendations for mitigating/preventing rebound effects across several consumption and production systems, such as housing, mobility, food systems, energy, and consumables.

Invest in the education of public and business decision-makers about the meanings and means for rebound effects, e.g. inclusion in higher-education programs and EU-level training.

2. Policy design

Develop and reinforce protocols for the inclusion of rebound effects identification, estimation, and mitigation/prevention in policymaking (e.g., in Better Regulation Toolbox) and business decision-making (e.g., double materiality assessment).

Consider a broad set of environmental indicators to identify potential trade-offs due to rebound effects between environmental issues, such as expenditure swift.

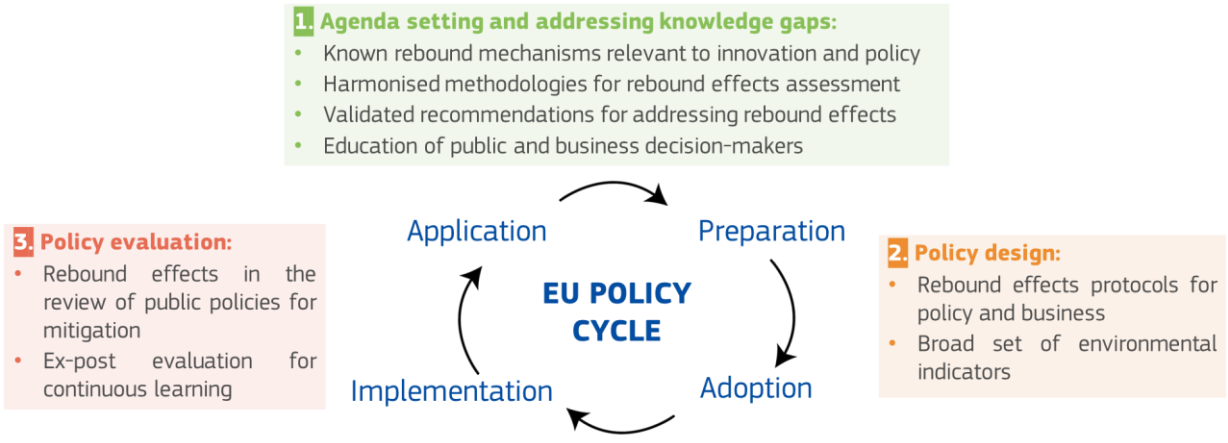
Couple environmental assessment with Behavioural Economics studies to address consumption choices and patterns of use of products in policy design [22]–[24].

3. Policy evaluation

Include signal measures of rebound effects in monitoring frameworks of implemented legislation to adapt policy measures for mitigation (e.g., in mid-term reviews).

Consider rebound effects in the ex-post evaluation for the review of public policies and innovations for continuous learning.

Figure 6 – Overview of policy recommendations along the EU policy cycle towards REBOUNDLESS decisions.



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DISCLAIMER

This brief is a joint publication of the Joint Research Centre of the European Commission with the Denmark Technical University (DTU), which is developing a project funded by the European Union and focused on Rebound Effects (ERC, REBOUNDLESS, 101043931). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Council. Neither the European Union nor the granting authority can be held responsible for them.

How to cite: European Commission, Joint Research Centre and Denmark Technical University (DTU): Guzzo D, Andrew E, van der Loo I, Sanyé Mengual E, Listorti G, Pigosso D (2025). Towards the prevention of rebound effects in Europe and beyond: insights for policymaking. JRC138704.

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