# Rebound effects

## Management and Prevention

Guideline for Companies

Handbook within the framework of the project
"Holistic Management of Energy and Resource Efficiency in Companies"
(MERU)

One type of rebound effect occurs when the financial or material resources gained through efficiency measures are used to increase the company's output. If more is produced, savings from efficiency measures are eaten up by new consumption. This is referred to as the "output effect".



# Rebound Effects

## Management and Prevention

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## Contents




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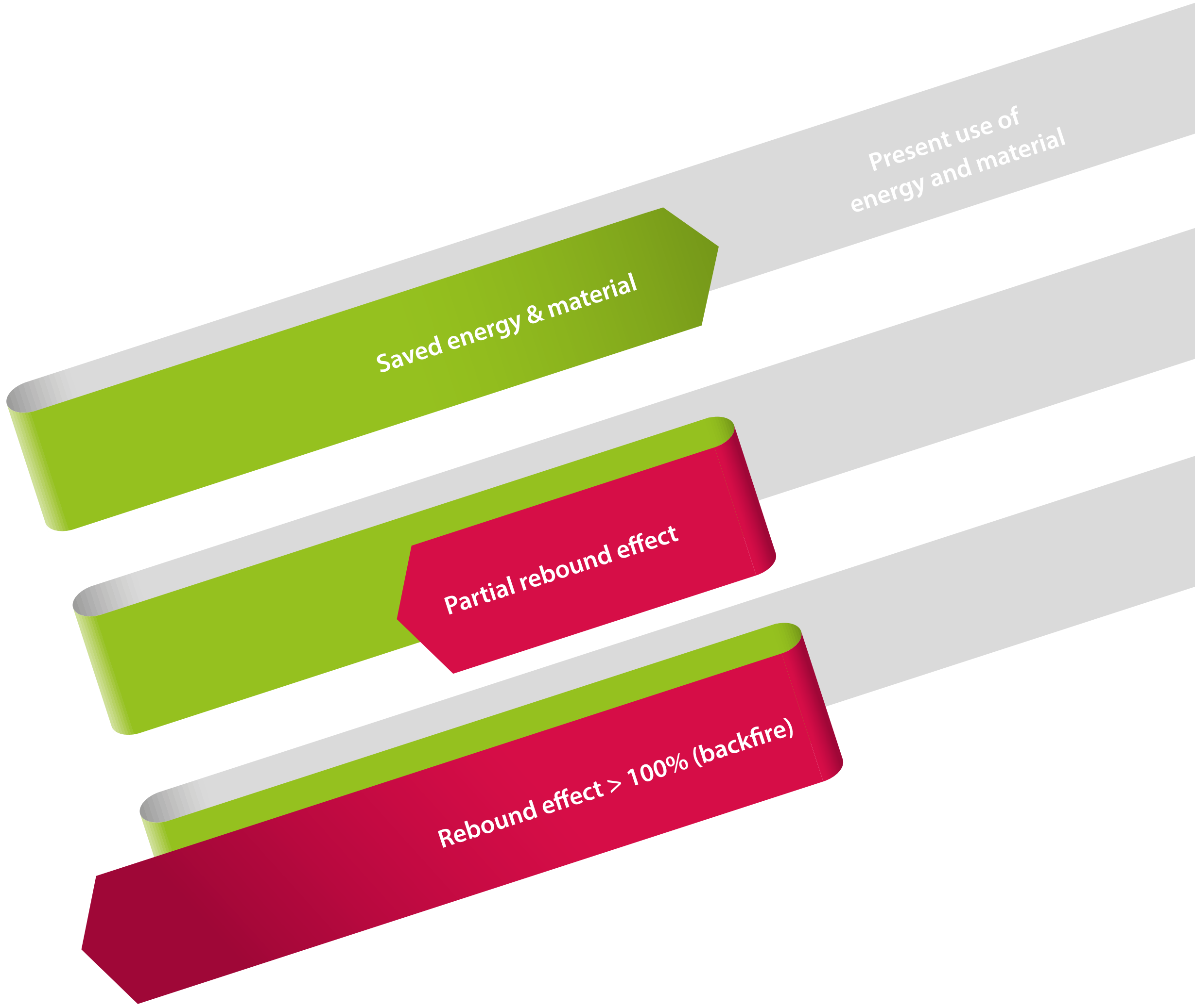
Chapter 1

# Overview

What are rebound effects? Why are they problematic? Where in the company can they occur, and why? This guide explains the phenomenon of rebound effects and how companies can deal with them.




Using energy and materials efficiently benefits companies and the environment. However, if companies implement efficiency measures, new material or energy consumption can arise as a side effect – for example, if higher resource efficiency reduces costs and companies use the saved funds for investments or to expand production. **This phenomenon is called the rebound or boomerang effect.**

Rebound effects contribute to the fact that, despite increased productivity of resources, absolute material and energy consumption, as well as greenhouse gas emissions continue to rise in Europe and the rest of the world. The overuse of natural resources is thus not reduced to the necessary extent and the climate targets of the German government cannot be achieved.

Rebound effects occur when consumer behaviour changes during or after improvements in efficiency, which results in the erosion of part of the expected savings. Therefore, they are a specific impact deficit of efficiency strategies.

## Aim of the guide

**The guide intends to help companies understand the problem of rebound effects.** In the past, rebound effects were mainly discussed with regard to private consumption; however, they also occur in companies. This guide helps to better understand and evaluate the phenomenon of rebound effects. It provides information on how companies can reduce rebound effects and implement efficiency more effectively through the holistic management of energy and materials. The guide also supports companies in complying with statutory energy efficiency obligations[1].

**Rebounds are lost opportunities for environmental improvement.** Addressing them will help make your organisation more environmentally friendly, more independent of energy and raw materials, and therefore more climate neutral. In the context of EU taxonomy, these measures also improve a company's access to capital.

## Target Groups

**The guide is aimed at managerial levels in companies** such as executive management, team management, technical and product management, as well as environmental and energy officers, and those responsible for sustainability.

## Contents of the guide

The guide answers the following questions:

- What are rebound effects?
- Why are rebound effects problematic?
- Where and why do rebound effects occur in companies?
- What can companies do, specifically, to identify and reduce rebound effects or to turn them into positive effects ("reinforcement")?

The guide does not provide guidance for companies on how to generally improve their energy or material efficiency. Several guides and tools already exist for this purpose (see page 21). In this handout, we focus specifically on dealing with rebound effects and similar impact deficits of efficiency measures.

The guide was developed as part of the BMBF-funded research project "Holistic Management of Energy and Resource Efficiency in Companies" (MERU). It addresses the many suggestions and ideas contributed by the project's corporate partners and other companies during a five-part dialogue.

Mitigating company-related rebound effects requires not only corporate, but also governmental action. Recommendations on this can be found in a separate paper.[2]

Chapter 2

# Efficiency and Rebound Effects

The planetary boundaries are being exceeded primarily because we are not efficient enough in our economic activities. However, even when companies implement measures to increase their energy or material efficiency, various impact deficits can occur. Rebound effects are one form of such impact deficits. Different types of deficits arise from changing consumption behaviour, usually after the actual increase in efficiency.

We use the term resource efficiency to summarise the efficient use of energy and materials. The economic-ecological measure of efficiency is basically the ratio between a resource input and a service output. Efficiency measures in companies aim to reduce the amount of energy or materials used per unit of output or service, thus increasing its resource efficiency. Efficiency refers to a product and certain functions that this product should fulfil, to a need of B2B customers or end consumers that the service should serve, or to a production process.

**Resource efficiency can be increased in companies through different types of investments** such as expansion and innovation investments, along with basic replacement and improvement investments.

As mentioned in the introduction, rebound effects describe the phenomenon when theoretically possible and expected reductions of energy or material use are often not achieved or are only partially achieved. The reason: Either the consumption behaviour in the company changes after a (successfully implemented) efficiency measure; or after it has already been initiated in the planning stage that the (more efficient) technology in question is to be used more intensively later. As a result, part of the savings that the efficiency measure was supposed to generate is consumed again. Rebound effects are therefore a specific impact deficit[3] of efficiency strategies.

## Types of rebound effects

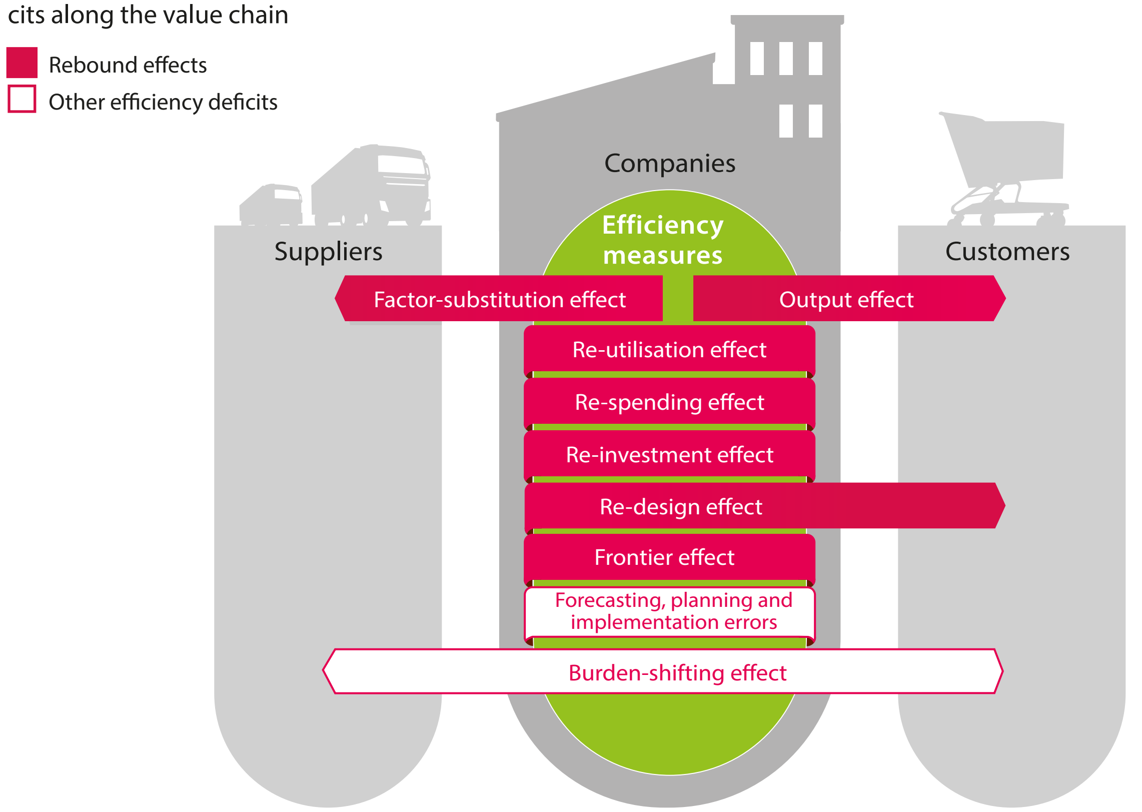
**Different types of rebound effects can be distinguished,** depending on how efficiency gains are (partially) counteracted (see pages 8-9). One example is output effects, where financial or material efficiency gains are used to expand production and sales. In the case of re-investment effects, efficiency gains are used to finance medium- to long-term investments, such as the development of new products. The re-design effect, on the other hand, uses efficiency gains to achieve an increase in performance or other improvements in product benefits (comfort, safety, etc.). All these effects are accompanied by the consumption of new materials and energy.

**Rebound effects can arise at different "places" in the company** – in product development, production processes, building management, etc. They can also occur in the company's value chain.

The trigger here is the entrepreneurial benefit that can result from efficiency gains: Freed-up funds can be invested in various purposes – for example, in maintaining competitiveness, in higher salaries or in research and development.



**Chart 1:** Rebound effects and other impact deficits along the value chain




## Rebound-like effects

Rebound effects are easily confused with similar effects. To facilitate differentiation, we distinguish between impact deficits of efficiency measures and counteracting effects.

**In addition to rebound effects, the impact deficits of efficiency measures include:**

- **Forecasting, planning and implementation errors:** Errors and problems occur when forecasting energy and material requirements or when planning and implementing efficiency measures. As a result, potential savings are not (fully) realised.
- **Burden shifting:** The implementation of an efficiency measure is accompanied by additional consumption in other life cycle phases of a product or impacts other environmental media and impact categories.

In addition, there are counteracting effects ***independent*** of an efficiency measure that can reduce its impact or even prevent the measure from taking effect:

- **Demand effects:** Irrespective of an increase in efficiency, output rises due to growing demand and thus resource requirements.
- **Accompanying effects:** In the context of a causally independent increase in efficiency, resource requirements for processes or products increase due to accompanying external requirements (safety, environmental protection, etc.). Regulation, social expectations, or technologies can trigger such external requirements.
- **Efficiency Gap:** Measures to increase efficiency are not implemented, even though they would be environmentally sensible and economically profitable. The causes range from a lack of knowledge and capital, distorted energy prices and uncertainty about future price developments. Also, attitudes of decision makers towards energy efficiency and their risk perception regarding the necessary investment play a role.

Examples of these effect deficits can be found on page 11.

# Types of rebound effects in detail

Rebound effects vary because companies deal differently with the financial or material resources saved by the efficiency measure ("efficiency gains"). The types of rebounds in companies are explained and illustrated in more detail below.

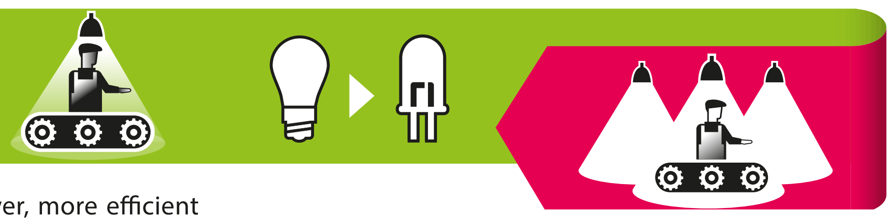
## Output-effect

The efficiency gains are used to increase the company's output. As a result of this increase, the savings from the efficiency measure are consumed (at least partially) by new resource consumption.

**Example:** If material or energy inputs in the product composition or in the production process are reduced (i.e., resource productivity increases), the production of more products with the same input and thus an expansion of production is directly enabled.

**Example:**The efficiency measure reduces costs. These financial efficiency gains are passed on (fully or partially) to customers in the form of lower prices, or are invested in sales promotion (e.g., advertising). Both can increase demand and, indirectly, production volume.

## Re-Utilisation effect



After an efficiency measure, the newer, more efficient technology or process is used more intensively than before.

Re-utilisation effects may emerge because actors in the company evaluate the environmental compatibility of the technology or process better than before, because of the increase in efficiency. Therefore, they may pay less attention to economic planning or to how much the more efficient technology or process is used.

**Example:** A new, more efficient lighting technology is installed. However, during the new planning, the lighting level is increased and/or more areas are illuminated than before, or the lighting is switched off less frequently after installation than before. The savings are therefore lower than theoretically possible.

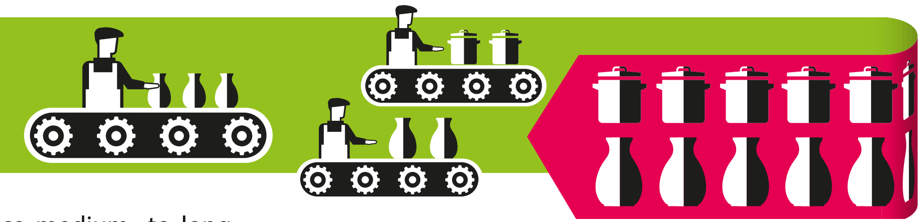
## Factor-substitution effect

Mechanisation, automation, and digitisation enable substantial efficiency gains over human labour. Companies are therefore increasingly replacing labour with energy or material services. As a result, consumption of energy and materials increases.

**Example**: An increase in efficiency makes generating compressed air for production processes less expensive, which in turn enables further automation of processes. This in turn reduces the use of human labour, increases energy, and, in some cases, material consumption.



## Re-investment effect



Efficiency gains are used to finance medium- to long-term investments, including the differentiation of existing products, the development of new products or the establishment of new business areas.

**Example:** The financial efficiency gains are used to expand the product range. Production and sales of the new products or services are accompanied by new energy and material consumption within the company.

## Re-spending effect

Efficiency gains are used to cover short to medium-term expenses.

**Example:** The financial savings from improved efficiency are used for operating equipment (e.g., larger vehicle fleet, additional IT) or to increase wages, salaries, and dividends. These uses of funds cause new consumption elsewhere.

## Re-design effect

The efficiency gains are used to further develop existing products. In anticipation of presumed customer preferences, product performance and/or convenience are increased.

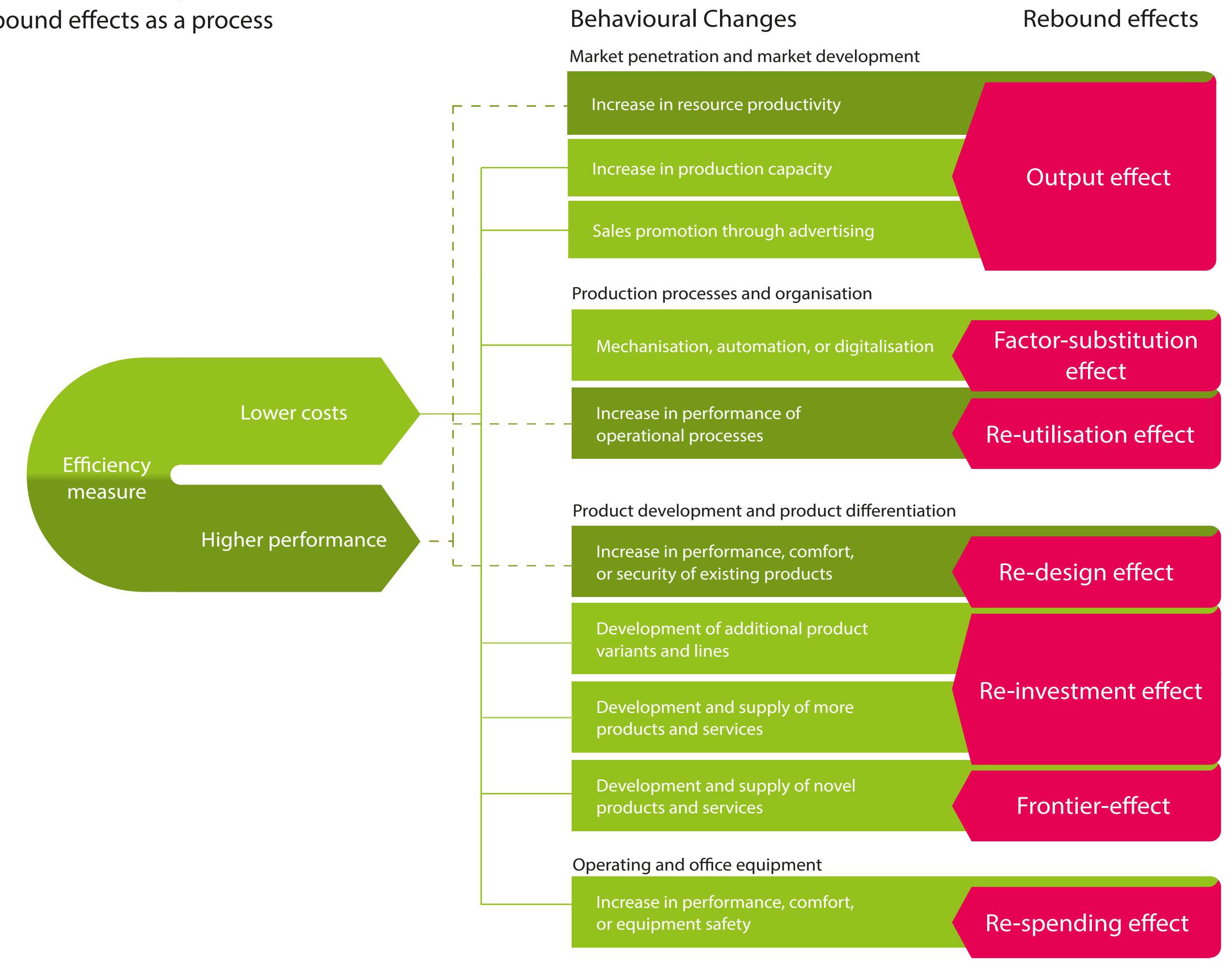
**Example**: In the automotive industry, efficiency improvements in engine technology are not (only) used to reduce fuel consumption, but (also) to increase vehicle performance, safety, or comfort. The vehicles therefore save less fuel than would have been possible, regardless of user behaviour.

## Frontier effect

Various long-term increases in the efficiency of technologies enable the development of new types of applications and products. Their implementation is accompanied by energy/material consumption that (over)compensates for savings from the preceding efficiency improvements.

**Example**: The increase in efficiency of the steam engine by James Watt, which reduced the consumption of hard coal by more than 60 %, made mining and the use of coal as an energy source significantly cheaper. Over time, it led to the application of the steam engine in more and more industries (e.g., textiles, transportation) and the expansion of other energy-intensive industries (e.g., steel). As a result, after the increase in efficiency, a significantly larger absolute amount of coal was consumed than before.

**Figure 2:** The emergence of rebound effects as a process




## Problematic nature of rebounds

Rebound effects mean that despite increased resource efficiency, absolute material, and energy consumption worldwide, including in Germany, is not falling sufficiently, or is even rising. **This cements dependencies on energy and raw material imports and exacerbates ecological burdens.** In view of the advancing climate crisis and further transgressions of planetary boundaries, rebound effects represent a serious problem that must be addressed jointly by politics, business, and society.

## Holistic efficiency management in companies

In companies, the holistic management of energy and material efficiency addresses this challenge. This means that decisions for greater energy and material efficiency in companies are based on a broader understanding of economic efficiency. Corporate investment planners are aware of the fact that different investment calculation methods have different effects on whether an ecological investment is considered profitable or not.[4] They account for life cycle costs and external environmental costs (as well as benefits). During the implementation of efficiency measures, various impact deficits are identified and mitigated. In addition, planning and implementation errors, burden-shifting and rebound effects are considered. Finally, holistic efficiency management means being open to adopting more environmentally sound technologies ("consistency"), recycling of materials ("circular economy"), and consciously limiting production and growth ("sufficiency"). While all these aspects are relevant, this guide focuses on rebound effects.



## Examples of rebound-like effects

**Forecasting errors**
Incorrect demand forecasts can mean that the savings potential of an efficiency measure is not (fully) realised.

**Example**: Data centres are often oversized due to uncertain demand forecasts. In sub-optimal partial load operation, however, energy-efficient IT and infrastructure does not function efficiently, but actually increases energy consumption.

**Planning errors**
Errors in the planning of an efficiency measure can lead to the savings potential of the measure not being (fully) realised.

**Example**: When planning a new heating system, errors in the switching of heating circuits and boilers can reduce potential efficiency gains.

**Implementation errors**
Errors in the implementation of an efficiency measure can result in the savings potential of the measure not being (fully) realised.

**Example**: A new, more efficient facility is incorrectly installed, controlled, or operated by the personnel. The potential efficiency gains can therefore not be (fully) realised.

**Burden-shifting**
The implementation of an efficiency measure is accompanied by additional consumption in other life cycle phases of a product, or by changes to other environmental media and impact categories.

**Example**: A more efficient production line reduces energy or material consumption in the company, but is accompanied by upstream resource consumption in the manufacturing of the production line.

**Example**: A new product composition may reduce material consumption, but, at the same time, involve the use of more toxic materials.

**Demand effect**
Irrespective of an increase in efficiency, increasing consumer demand fuels the company's energy or material consumption.

**Example:** While data centres are becoming increasingly energy-efficient, the demand for computing power is also rising. Digitalisation in companies, Industry 4.0, simulations in research, and streaming and internet communication by private users require more and more computing power and thus energy. Causally independent of efficiency measures in data centres, this demand effect counteracts the savings achieved through greater energy efficiency.

**Accompanying effect**
In the context of an increase in efficiency, but causally independent from it, resource requirements for processes or products increase due to accompanying external requirements. Accompanying effects can be triggered by politics and regulation, standards or norms in the industry, societal requirements, or new technologies, etc.

**Example:** Parallel to the introduction of energy-efficient technology in exhaust purification, the statutory limits for pollutants in exhaust air were being tightened. Compliance necessitates higher temperatures in the incineration of residual materials. Despite more efficient technology, there may be an increase in energy consumption.

**Efficiency gap**
Companies do not invest in more efficient technologies or processes, although it would be profitable for them to do so. The triggers are manifold: information costs, financing difficulties, unfavourable payback periods and discount rates, fossil energy subsidies, etc.

**Example:** During an economic downturn, companies do not risk investing in efficiency measures; during a boom, they lack the time and capacity to plan and make the investment.

Chapter 3

# Steps towards managing and mitigating rebound effects

Do you want to implement a measure to increase your energy or material efficiency as effectively as possible, and therefore keep an eye on rebound effects? The following steps can help you with a holistic management of energy and material efficiency.

If your company is subject to mandatory energy audits or has implemented an environmental or energy management system (EMAS, ISO 14001, ISO 50001), you already have some important processes in place to reduce rebound effects. The following tips will provide support in integrating the rebound issue further and anchoring it at the strategic level.

## Strategy

The strategic orientation of the company has a decisive influence on whether efficiency measures achieve their intended consumption-reducing effect. Technical aspects are not the only decisive factor for success!

After all, **the goals and benefits of an efficiency measure are usually manifold.** In addition to reducing energy and material consumption and the associated costs, the aim may also be to improve product quality or increase production volume. Thus, the theoretically possible saving of resources is often in competition with other operational goals (conflicts of objectives). An ecologically ambitious corporate strategy tries not to resolve these trade-offs at the expense of environmental goals.

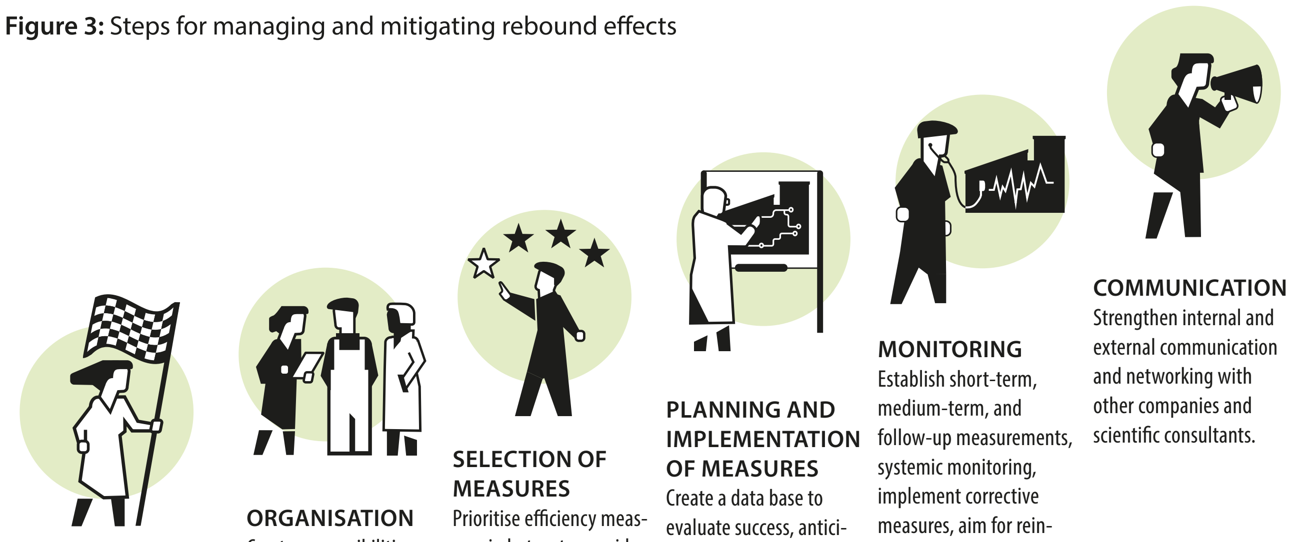
To avoid environmental impact deficits of efficiency measures, **it is necessary to consider the entire target system of the company**, and to give greater importance to environmental and climate protection. This requires fundamental, strategic decisions at management level. In this case, absolute reduction targets for energy and material consumption must be set for the company, because (relative) efficiency targets alone do not guarantee an actual reduction in resource consumption. The absolute reduction targets are to be anchored with responsibilities and tasks in the corresponding organisational units (e.g., development, planning, production, purchasing, environmental management) and to be considered when making investments. Job and task descriptions as well as performance evaluation should also be based on these objectives for employees, especially in the case of management positions.

If absolute reduction targets are anchored in the organisational areas, possible **conflicts of objectives** become clear in the planning, implementation, and monitoring of efficiency measures, making it easier to identify rebound effects. If, in the case of such conflicting targets, your company decides to resolve them in favour of other operational goals, the ecological costs become transparent in the form of theoretically possible, but unachieved reductions in resource consumption.

If targeted reductions in consumption are not achieved, it should be examined how the savings can still be realised through **subsequent corrections** or further efficiency measures. After all, the success of a company is judged by society, customers, and consumers, and is measured in terms of absolute resource (and thus ecological) savings.



**Figure 3:** Steps for managing and mitigating rebound effects




## Organisation

Resource efficiency is a challenge for the entire company. When efficiency strategies are developed and measures are planned, the following organisational aspects must be clarified:

? Who should be involved? Depending on the scope of activities (overall strategy, bundle of measures, individual measures), an internal "resource efficiency" project group can vary in size and composition. If the focus is on concrete investment and measure planning, the core team consists of management, technical management, product, or business unit management, and those responsible for environmental, energy, or sustainability management. For holistic efficiency management, it makes sense to include and integrate product development, purchasing, sales, facility management, controlling and employees in the development and implementation of ideas. Also make use of your suggestion scheme.

? Who assumes which responsibilities? Clear responsibilities are needed for planning and implementing measures, monitoring, evaluation, as well as reporting and communication. The principle of dual control is recommended for data collection.

? Does a holistic understanding emerge? Communication channels, operational routines and individual decision-making competencies should enable all employees to understand at which points different resource consumption and environmental impacts influence each other. To better manage processes, all areas and operational functions affected by the measure should be coordinated across the board.

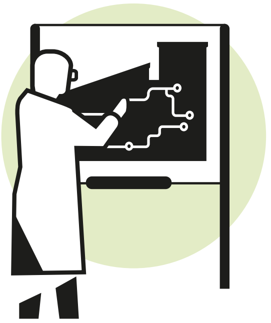
? Which processes must be considered? Depending on the type of efficiency measure, it can be product development, production, financial controlling, but also other ongoing investments and efficiency measures.

? Are there already goals, policies, guidelines, procurement criteria and processes within the company regarding resource efficiency, or environmental relief that need to be considered?

? Do the operational tools and systems capture consumption as well as consumption-related costs and efficiency gains? Environmental and energy management systems should systematically record and map the key figures in relation to measures. Financial controlling should consider the use of savings from efficiency measures. Supporting tools and systems are software for life cycle analysis and material flow costing. It is advisable to call in specific expertise from employees, consultancies, universities, and efficiency networks.

# Selecting measures

The management of rebound effects already begins with the selection and planning of appropriate efficiency measures.



In principle, an efficiency measure can have different starting points: It can be applied to input materials, products, services, but also to facilities, processes, or organisational structures, such as logistics or sales. Efficiency measures do not necessarily have to be in the company itself but can also be initiated by the company at other stages in the value chain. In this context, it is first necessary to examine which concrete efficiency measures are possible and sensible in your company. Here, the company's existing environmental goals and policies are relevant. For established standard solutions, there are several sources of information in addition to technical guidelines and management systems (EMAS, ISO 14001, ISO 50001, VDI 4800, VDI 5208, IEC TR 62824, etc.) (see box on page 21). For other questions, individual consulting is necessary. Another possibility is to develop unique technical and/or organisational solutions, for example in cooperation with a plant manufacturer. If there are several options to choose from, a contribution and materiality analysis can be helpful for prioritisation.

Here, for example, the following questions are important:

- At which point in the value chain are the "hotspots" located, i.e., where are the most resources consumed and the highest emissions generated? Hotspots can also be found in the supply chain, with B2B customers, or through product use by end customers. Accordingly, product design, procurement, supplier, and customer relationships must also be put to the test.
- For which measures is a side benefit ("co-benefit") possibly expected?

> **Example**: A more efficient manufacturing process can lead to a reduction in exhaust and can lead to a reduction in exhaust and cooling.

**Corporate responsibility in the value chain**

Developments such as the increasing relevance of Scope 3 emissions[5] in corporate emissions accounting, or the Supply Chain Act make it clear that companies must increasingly assume responsibility for social and environmental impacts along the entire value chain of their products and services. This also applies to the reduction of energy and material consumption at upstream or downstream stages in the value chain.



An explanatory video on the rebound effect can be found here: https://www.macro-rebounds.org/projekt/video/

**Which measures can have negative side effects?**

> **For example**: Shading windows to prevent offices from heating up in the summer and increasing energy consumption through air conditioning can lead to employees switching on more lights during the day and consuming more electricity.

Such side effects can also include increases in consumption while planning or after implementing efficiency measures – in other words, rebound effects. If you suspect that a rebound effect could occur, this does not necessarily mean that you should abandon the measure. However, you should keep a close eye on how the actual efficiency gains develop and "set prices" for possible reductions in your considerations: How likely is it that a rebound will occur, and what level of rebound can be expected? (For more information on dealing with rebound effects, see page 18).

**Which of the measures can complement, or be combined well with other measures?**

> **For example**: It may be possible to optimise a process by pairing it with an ecologically beneficial machine update, or by deconstructing a corridor that unseals the area and, at the same time, provides space for a green area for employees to relax.

**Hotspot analysis**

To identify hotspots, you can use the methodology of the hotspot analysis in the context of the "Product Environmental Footprint" (PEF) or the "Organisation Environmental Footprint" (OEF). In this process, essential impact categories, like life cycle phases and processes, elementary material, and energy flows for products or organisations are worked out in a structured way.[6]

**Low-hanging fruits**

From a business perspective, there is a strong case for focusing first on measures that are easy to implement and have a high probability of success (so-called "low-hanging fruits"). This can range from replacing conventional lighting with LEDs to introducing an automatic switch-off system for machines and energy-consuming equipment. In the second step, at the latest, efficiency measures should address the hotspots that are relevant from an ecological point of view.

# Planning and implementing measures

## Initial analysis

**First, you determine the real consumption values.** At the beginning of the planning process, you need knowledge on questions such as:

- What is the consumption of energy, materials (raw materials, consumables, supplies), or water in the relevant process, or for the relevant product (input)? How much waste, wastewater and emissions of problematic substances are generated (output)?
- What future needs and usage patterns can be expected? What are the environmental impacts of the new capital goods to be procured?

In addition to quantitative aspects such as the level of material consumption, you should also consider environmentally relevant qualitative aspects when collecting data, such as the use of materials containing harmful substances.

Precise knowledge of the actual situation is essential for a subsequent rebound analysis: If the initial data are not available, it is no longer possible to assess, in retrospect, whether a measure has led to savings and how high these savings were. A possible rebound effect can therefore no longer be identified without a comparative figure.

## Determination of efficiency or savings potential

**In a second step, calculate or estimate the environmental savings potential of the measure based on available data.** This does not necessarily have to be a single figure. Especially when uncertainties complicate planning, it may make more sense to forecast a corridor. This can occur, for example, when a completely new plant is purchased, or a bundle of measures is implemented that may influence each other. However, an attempt should always be made to create demand or utilisation forecasts that are as accurate and realistic as possible.

The predicted savings potential also forms the target value or target corridor of the respective measure. To identify whether the measure may have led to a rebound effect, **all data should not only be available or forecasted as relative figures, but also as absolute figures.**

As a particularly efficient company, you can offer products and services at lower prices on the market and possibly displace competitors who operate less efficiently and ecologically. In this case, the absolute energy and raw material consumption of your own company may increase, but the overall consumption in the relevant segment of the entire market may decrease. However, this ecologically beneficial effect is difficult to plan in the context of non-transparent markets and inertia effects. The focus of corporate strategy, as already stated above, should therefore target the reduction of energy and raw material consumption in absolute terms.

### Notes

! In many cases it is not sufficient to rely on the consumption data of manufacturers (of comonents, facilities etc.), since these since these do not necessarily correspond to the actual consumption in the concrete process.

! Nevertheless, it will, in some cases, be unavoidable to use default values. This applies, for example, when Scope 3 emissions[5] are to be calculated. In these cases, real consumption and emission values should be determined selectively.

! When procuring machinery and equipment, it is important to request running costs and life cycle costs from suppliers, in addition to consumption data.

! Planning errors, which can also reduce the effectiveness of efficiency measures, often result from inaccurate demand and utilisation forecasts or from "safety margins", which lead to overcapacities. If the efficiency technology is optimised for the oversized design variable, underutilisation, or partial load leads to (possibly disproportionately) poorer efficiency.



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Data centres are often planned in an oversized manner due to uncertain demand forecasts. In sub-optimal partial load operation, however, energy-efficient IT and infrastructure does not function efficiently but is even accompanied by increased energy consumption. While rebound effects can also occur in data centres, the effect described is not a rebound effect but a forecast error.

# Checking for potential rebound effects and other impact deficits

You have already dealt with possible negative side effects of proposed measures in the measure selection phase (pages 14-15). In this step, you will deepen this analysis for the selected efficiency measure. The following questions can help you to identify possible rebound effects and other impact deficits in advance:

## a. Planning

- **Where are uncertainties** in the determination of requirements, consumption values and savings potentials that could lead to an overestimation of efficiency gains?
- **Where are possible weaknesses in the assumptions and methods used?** Do these have a negative impact on the ecological effectiveness of the measure? How can this be prevented?

## b. Implementation

- **Where can implementation and operating errors** that would reduce the expected efficiency gains occur?
- **Who needs to be trained** on how to avoid them?
- **Which control routines** are necessary to detect errors promptly?

## c. Rebound effects

- **Financial implications:** How much is the measure expected to save? How are the saved funds expected to be spent, and how might this lead to new consumption? Specifically: Are the funds saved to be used to increase production volume or sales volume? (In contrast, see p. 19).
- **Technical consequences:** Can the measure have technical consequences associated with additional consumption? (cf. also "Burden-shifting" below).
- **Changes in utilisation:** Is intensified use of the now more efficient process or technology (facility, etc.) to be expected?
- **Change of attitude:** Can the measure influence the perceptions, attitudes, and behaviours of employees of different functions in a way that leads to new resource use?

  ! It is conceivable that after efficiency measures have been implemented, employees attach less importance to their individual consumption ("The system consumes less electricity, so we no longer need to switch it off and can let it run") , or the motivation of those involved to become more eco-efficient in other areas of corporate management decreases ("We've already done so much, it's enough now"). The measure may even justify environmentally damaging behaviour elsewhere ("We can now afford to do that"). Such psychological drivers of rebound effects can be countered by a comprehensive ecologically oriented corporate strategy, the dissemination and recognition of successfully saving, and the strengthening of a "green" awareness among employees throughout the organisation.

## d. Burden-shifting

- **Can burden-shifts within the value chain or between life cycle phases be expected because of the measure?** What upstream consumption is associated with the acquisition of a more efficient machine? For example, do more efficient processes in one's own company lead to products being more energy-intensive in use? Or, conversely, does the development of a more efficient product and its usage lead to increased consumption in production?
- Can shifts in pollution between environmental media or impact categories be expected because of the measure? For example, does a reduction in material consumption lead to higher energy consumption or pollutant loads, or poorer recyclability of the product, etc.?

Include colleagues who are not on the designated project team and can bring fresh perspectives to the discussion of these issues. Develop a plan for whether and how you will deal with the identified risks.



# Developing a policy on managing financial efficiency gains and aiming for reinforcement effects

As described, a central trigger for the emergence of rebound effects is the reuse of the resources saved – primarily financial resources, but possibly also saved materials, personnel, or time. If the funds saved are used in such a way that they lead to an expansion of production and sales, to improvements in the performance of products and services, to corporate expenditures or investments, etc. (cf. Chapter 2), then new energy and material consumption is likely to occur in the wake of the efficiency measure (and due to its success): Rebound effects.

Therefore, clarify what is to be done with the future savings as early as the measure planning stage. To reduce rebound effects or even positively reinforce efficiency measures ("reinforcement"), the funds saved can be used for the following future purposes:

- Extending the efficiency measure to further products or processes using learning effects or planning and implementation of further efficiency measures

  ! **Note:** Ideally, the identified hotspots of energy and resource consumption should be addressed. Particular challenges arise when the hotspots are in the upstream and downstream value chain, where your company's ability to exert influence is limited. Here, long-term supplier or customer relationships and personal exchange with the relevant players are key to success.

- Supplementing the efficiency measure with complementary measures (example: After a product has been designed to be recyclable, the company develops a recycling system as a complementary measure).
- Using more sustainable materials (e.g., less polluting (pre-)materials, Fairtrade ingredients in food).
- Closing material and energy cycles: Starting points include sustainably designing products ("eco-design") and increasing their service life, the recycling of raw materials, consumables, and supplies of products and components, cascade use and zero-waste strategies. Finally, service offerings can be developed for reuse, repair, remanufacturing, refurbishing, recycling of products and components, or business models such as "using instead of owning".
- Resource-saving and environmentally friendly expenditures in the company (e.g., greening the vehicle fleet, offering organic food in the company canteen at the price of conventional food, financing public transport for employees, and bike-leasing programmes).
- Raising employee awareness of resource-efficient or fundamentally environmentally friendly behaviour in the company – and beyond.
- Raising awareness among equipment manufacturers and suppliers for transparency regarding operational and upstream "embodied"[7] energy and material consumption of equipment, components, input materials, etc.
- Raising awareness of resource efficiency and rebound effects among equipment manufacturers, suppliers, other companies or (end) customers.

Develop criteria or use existing criteria from your environmental/sustainability strategy for earmarking financial efficiency gains.

> **Drilling thick boards**
>
> The experience of committed companies shows: Particularly when no standard solutions for more efficient processes or products are available, the selection and planning of effective efficiency measures can be time-consuming – from cross-departmental coordination to querying consumption with plant manufacturers. Expect that you will have to keep drilling thick boards and stay tuned!

In factor-substitution rebound, an increase in efficiency makes production processes less expensive. This enables further automation of processes, which in turn, reduces the use of human labour, increases energy and, in some cases, material consumption.

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## Establish controlling processes

Once you have developed a policy for dealing with financial efficiency gains, set up the controlling processes. Make savings visible and tangible as an independent variable and use the surpluses to finance your next efficiency measures.

- **For example, you can establish a separate cost centre for the funds save**d to finance your next efficiency measures ("intracting"). It is less time-consuming to balance cost changes at the end of the year.
- **Clarify whether you collect and spend efficiency surpluses on a unit-specific or company-wide basis.**
- **Use accruing funds for annual action planning** according to developed ecological criteria.

## Internal communication and further training

- **Actively communicate your new rebound-sensitive strategy** around energy and material efficiency within the company!
- **Take employees with** you, explain the changes to them, and emphasise and value the contributions that everyone can make to resource conservation. Refer to your suggestion scheme.
- **Provide targeted training for employees.** This can relate to technical aspects – for example, how to make the best use of monitoring new equipment or systems and how to monitor it in detail (see pages 22-24). It can also be about financial and administrative aspects that should be considered by those responsible for investment decisions and monitoring.

### Sources of information on energy and material efficiency in companies


Carbon Trust (2022). A guide to Net Zero for businesses.
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https://www.wwf.ch/sites/default/files/doc-2020-02/Resource_light_business_models_Concept_Note_Final_Logos.pdf

# Monitoring and evaluation

Monitoring and evaluation of the measure are central to rebound analysis. Only a systematic approach will give you reliable results.

## Systematic approach to monitoring and evaluation

**Guiding questions of monitoring and evaluation are:**

- Could the absolute savings targets be achieved in the short term?
- Could the absolute savings targets be achieved in the medium term?

Embed the answers to these guiding questions into a systematic approach to monitoring and evaluation:

- **Do not just evaluate isolated technologies or components, but the system.** Measurements should be carried out both on a measure-by-measure basis and on a system (e.g., machinery, production line, factory).
- **Record contextual conditions and their changes and include them in the measurement if possible.** Which contextual conditions have changed and how – compared to the potential determination or during the measurements after implementation?
- **Include all relevant environmental parameters.** Particularly in the case of more complex efficiency measures, there are interdependencies between energy and material consumption of different methods and processes that cannot always be precisely predicted during planning. However, the dependencies can at least be estimated in terms of relevance and magnitude. This way, unintended effects can already be considered in the planning phase and alternative approaches can be examined.

**In the case of extensive measures, it may make sense to involve external parties in the monitoring process.** This particularly applies to parties previously involved in the development and implementation of the measure.

## Short-term follow-up measurement within the relevant process

**Take the first follow-up measurement in the process concerned within one month or, at the latest, one year after implementing the measure.**

The aim here is to compare the environmental savings potential determined in advance, and the savings achieved. This allows you to evaluate the short-term environmental effectiveness of the measure and identify immediate impact deficits – in the same process and related to the specific measure.

**Has the efficiency measure achieved its specific savings targets in the short term?** For example, is the same output now achieved with less resource input?

- If yes, the measure, considered in isolation, was successfully implemented.
- If not, planning errors or implementation problems could be the reason (see page 24, section "Searching for causes").

**In the short term, has the efficiency measure achieved its absolute savings targets in addition to its specific ones?**

- If yes: Very good! Try to identify success factors and draw lessons for implementing future efficiency measures.
- If not: By how much were the savings targets missed? Is a rebound effect the cause of this – i.e., did behavioural changes or corporate decisions take place during the efficiency increase or in its aftermath? Did behavioural changes or corporate decisions take place, because of which a part of the expected savings was eroded again? Or are there other reasons (e.g., implementation errors, demand effects; see page 24, section "Searching for causes")? If a rebound effect can be identified: How high is this (see box "Rebound calculation")? Were 'only' the targeted savings not achieved or was the measure accompanied by an absolute increase in consumption?

## Medium-term monitoring beyond the process in question

In addition to the measure- and facility-related measurements, overarching monitoring should be carried out three to five years after the introduction of the efficiency measure. The comparison of the ecological savings potential with later measurements serves to determine the medium-term effectiveness of the measure, and to identify indirect impact deficits beyond the process in question:

- **Will the measure save ongoing financial costs?** If so, how will these savings be used?
- **How have the absolute energy and material consumptions developed?** Which changes are related to the implemented measure?

  Even if changes cannot be attributed to the measure alone, since many factors in the system under consideration usually vary over time, the holistic monitoring of this target variable is of critical importance (cf. page 12). The system boundaries should be chosen as wide as necessary, but as narrow as possible: The absolute consumption does not necessarily refer to the company as a whole. It can also make sense to select a production line or an organisational unit as the reference frame if no further effects occur. Furthermore, even if the system boundary for the consideration of measures is selected more narrowly, the absolute consumption or target figures, such as climate neutrality of the entire company must always be kept in mind, since they form the central reference.
- **Does the efficiency measure have any other ecological** impacts beyond the process in question that were not considered during planning and implementation?

**Example**: Shading the windows to reduce cooling requirements leads to increased lighting requirements (see pages 14-15). Or in a positive sense: Improved exhaust recovery from a facility also reduces heat in production facilities and thus cooling requirements.

**Detection of efficiency and, if applicable, rebound effects in the supply chain (Scope 3 emissions)**

For companies whose main emissions and consumption take place in the supply chain rather than in their own processes, capturing efficiency gains is a particular challenge. On the one hand, this can be done using standard values. On the other hand, for a realistic picture, it will be necessary to increasingly record actual consumption. The recording of upstream consumption and Scope 3 emissions[5] is particularly important where the company can influence efficiency measures and potential rebound effects in the supply chain.

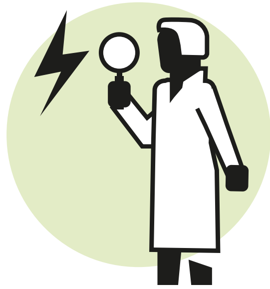
### Rebound calculation

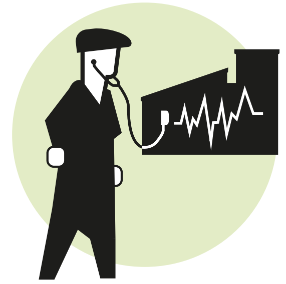
A rebound effect (RBE) is an impact deficit that results from a consumption-increasing behavioural change during or following an efficiency measure. Impact deficits can result from rebound effects and other causes, if, for example, implementation problems limit the intended reductions in consumption or sales are expanded due to increased demand (cf. page 24). A three-step schematic allows the calculation of the rebound effect as a percentage value of the theoretically possible savings:

1. **Impact deficit ID = ( theoretically possible saving) – (actual saving)**
   → *Impact deficit and factors as absolute quantities, e.g., kWh/year or t/year.*

2. **$RBE_{abs}$ = ID – (savings reductions not due to behavioural adjustments)**
   → *Rebound effect and factors as absolute quantities, e.g., kWh/year or t/year.*

3. **$RBE_{rel} = \left( \frac{\text{theoretically possible savings} - RBE_{abs}}{\text{/theoretically possible savings}} \right) \cdot 100$**
   → *Rebound effect as relative value (percentage value or share of theoretically possible savings)*





## Searching for causes

**If applicable, why were the savings not achieved to the extent planned?**

If you should have noticed that savings related to the efficiency measure are lower than you expected, systematically check which causes could be responsible: Incorrect demand forecasts, difficulties in planning and implementing the efficiency measure? Or rebound effects – behavioural changes and corporate decisions during or after a successful efficiency measure, which led to new consumption? These can be triggered using material or financial efficiency gains for an expansion of output, for the more intensive use of the now more efficient processes, the re-design of products, for investments in product differentiation, in the development of new business areas, or in better operating equipment. They all go hand in hand with new consumption. There may also be factors that are not causally related to the efficiency measure – for example, a simultaneous increase in demand from customers (demand effects) or external requirements that lead to higher consumption (concomitant effects)? The explanations and examples on pages 6-11 will help you find the causes.

## Assessment

You have measured the extent to which the efficiency measure has reduced energy or material consumption in absolute terms and, in the event of an impact deficit, have set about finding the cause. Now you need to evaluate the result. In the case of rebound effects, this must be considered: The business decisions and behavioural changes that can impact the environmental effects of an efficiency measure sometimes produce operational benefits – for example, increased product quality, sales, or employee comfort. Here, the realisation of ecological savings through efficiency measures competes with other operational goals.

Be aware of these conflicting goals. Perceive ecological costs in the form of non-achieved, but theoretically possible consumption reductions as a separate variable. Evaluate on this basis:

- **Which rebound effects should be avoided** because the other operational benefits do not justify increasing the ecological costs, and jeopardise the goal of absolute consumption reduction?
- **Which decisions are still sensible for the company in the overall view,** even if they possibly lead to ecological rebound effects in relation to the concrete measure?

## Corrective measures

If you decide to accept rebound effects, you can still develop measures to realise the savings not achieved by means of subsequent adjustments or further efficiency measures. In the best case, you can achieve reinforcement effects. To design corrective measures, refer to the policy developed for dealing with financial savings (see page 19).

In the case of re-investment rebound, the financial efficiency gains are reinvested, for example to expand the product range. The production and sale of the new products or services is accompanied by new energy and material consumption.

# Communication and networking

In your internal and external corporate communications, describe the extent to which the company's resource management is sensitive to rebound effects. This helps to disseminate appropriate ideas and create acceptance within the company (see page 21) y, but also in the industry, region, and vis-à-vis politics. Constant and diverse communication with suppliers and customers can also sensitise them to the issue of resource efficiency and rebounds.

## The Sustainability Report

To increase the informative value of sustainability reports regarding rebound effects, we recommend the following steps when presenting efficiency efforts at company level and when considering of concrete measures[8]:

- **For each environmental category concerned, both absolute and specific consumption and emission data should be provided over as long a period as possible.** In the case of information on specific environmental impacts, the reference value should also be precisely defined. To classify the development of specific and absolute consumption and emissions, it is helpful if the growth rates, regarding the organisation-specific parameter, are also given and placed next to them.

  > **Example:** If $CO_2$ emissions per monetary unit of sales decrease over time while the company's absolute $CO_2$ emissions increase, the development of sales should also be indicated.

  This is the only way to provide a direct assessment of the influence that corporate growth could have on the development of environmental impacts.

- **Targets for reducing consumption or emissions should be formulated for the respective environmental category in both absolute and specific terms.** If you do not set absolute reduction targets, it is difficult to keep track of the overall goal - to reduce the absolute environmental impact of the company's actions. This can promote the occurrence of rebound effects.
- **Information on concrete and significant efficiency measures** should include consistent quantification of the central savings, as well as references to corresponding business units, and total consumption to classify the relevance of the measures. In addition, quantified information on the targets of the measures is necessary to be able to check their effectiveness.
- Where appropriate and feasible, **the description of an individual efficiency measure should include the following information:**
  - **qualitative explanation** of the key aspects of the measure itself (e.g., technology, scope) and explanation of the efficiency gain (e.g., through technological or organisational innovation).
  - **Objective and background** (e.g., savings targets, investment amount).
  - **Data sources** used to determine savings or efficiency gains (e.g., manufacturer specifications or the company's own measurements) and methods used to evaluate success.
  - **quantitative information** on the reduction of consumption as well as qualitative classification of ecological relevance (e.g., as critical raw materials).
  - **Comparison between expected and actual savings** (rebound check).
  - **Reach and potential** to expand or transfer the measure (e.g., to other sites).

## Networking

Finally, networking is an important factor for success: The joint development of instruments, processes, or evaluation methods with scientific institutions, and networking with other companies (e.g., in energy and resource efficiency networks at regional or national levels) help to find a variety of solutions. In addition, ideas that have been proven successful in one's own company can be passed on to advance the social transformation process toward sustainable development.

**Endnotes**

1 e.g., in the context of national or EU regulations on energy efficiency or securing the energy supply.

2 MERU project (2022): How can rebound effects be reduced in companies? Options for policy action (in German language only). www.meru-projekt.de/publikationen

3 In our understanding, "impact" (and impact deficit) refers to relative or absolute resource savings. In the conceptual world of LCA, where a distinction is made between life cycle inventory quantities (measured in tons of material, megajoules energy usage, etc.) and their associated impacts (Global Warming Potential, Resource Depletion Potential, etc.), it would be a life cycle inventory quantity.

4 This is a consequence of the fact that the system boundaries of the calculation are set differently, different types of costs and benefits are included, different assumptions must be made, etc., cf. Braungardt S. et al. (2021), Rethinking Economic Efficiency – Investment Decisions in the Service of Environmental Protection (German language, with English summary), published by the Federal Environment Agency, Dessau, Texts | 179/2021.

5 Scope 3 emissions are indirect emissions of a company that occur along the value chain.

6 See e.g., Zampori, L. & Pant, R. (2019): Suggestions for updating the Product Environmental Footprint (PEF) method. Joint Research Centre, chap. 6.3.

7 Embodied or "grey" energy / materials are the energy and material consumption that flow into the extraction of raw materials, the manufacture of preliminary products, the transport, storage, sale, and disposal of products.

8 The following sections are taken from Lautermann, C. & Schöpflin, P. (2021): Company-related rebound effects: What indicators do sustainability reports provide? Working paper in the project "Holistic management of energy and resource efficiency in companies" (MERU), (German language), www.meruprojekt.de/publikationen

If companies use energy and resources efficiently, they benefit just as much as the environment and society. However, as a side effect of efficiency gains, new energy or material consumption can arise – for example, if consumption costs fall and the money saved is reused.

These rebound effects contribute to the fact that, despite major increases in efficiency, absolute, worldwide energy and material consumption does not fall to the ecologically necessary extent.

How exactly do rebound effects present themselves? How do they differ from similar impact-reducing effects? How can companies implement energy and material efficiency holistically?

Thise guide answers these questions and provides concrete steps for companies to deal with rebound effects. Examples and graphics illustrate the connections.

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