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Improving energy efficiency in industry

A pathway to reducing the greenhouse gas footprint in manufacturing: determinants for an economic assessment of industrial decarbonization measures

Note by the secretariat

Summary

The Task Force on Industrial Energy Efficiency, following its Industrial Energy Efficiency Action Plan (ECE/ENERGY/GE.6/2020/3), conducted research on possible economic measures to reduce the greenhouse gas footprint. The outcomes of this research are contained in the present document.

The Task Force on Industrial Energy Efficiency argues that achieving a reduction of the greenhouse gas footprint towards net-zero is feasible with the help of a wide variety of measures. It identifies six types of measures that differ in terms of their impact on investment and running costs. These measures are grouped into three categories: reduction, substitution, and compensation. The present document evaluates the identified measures from an economic point of view and assesses them with regard to necessary actions and their consequences.

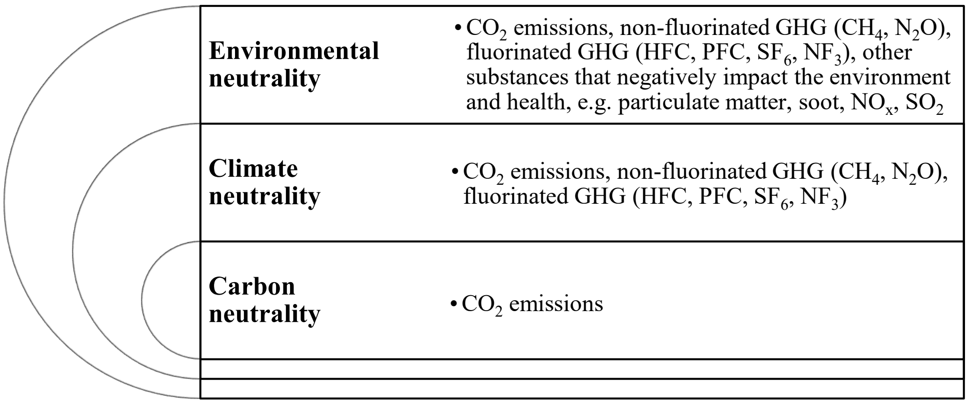
I. Introduction

1. Finding an economic mix of measures to achieve net-zero emissions should be clear, on the one hand, about the point in time by which this should be realized, and, on the other hand, whether there are structural limitations in the available instruments.

2. It is also particularly important to establish clarity on the terminologies and ensure common understanding among stakeholders,[1] as one would have tackled aspects not that crucial for achieving the goal while at the same time neglecting to address other that would have been necessary. The ways of achieving "carbon neutrality" and "climate neutrality" are deemed to be different, so homologation of these goals might be one example of insufficient clarity.

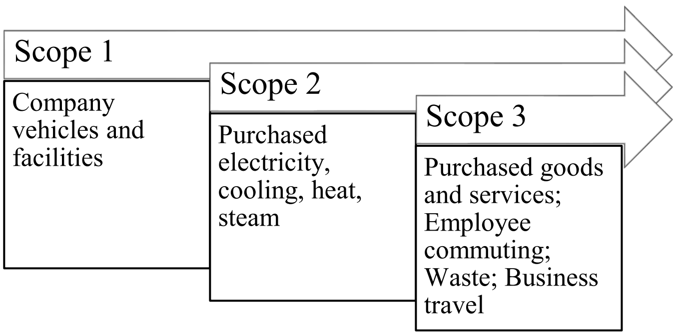
3. Possibly decisive in this frequent confusion, is that mitigation of greenhouse gases (GHG, including carbon dioxide, CO_2, itself) is measured in "carbon dioxide equivalent" (CO_2-eq) units, where the suffix "-eq" might be lost resulting in just "carbon neutrality" as the target dimension. The situation is not much different when it comes to identifying the emissions footprint (Figure I).

Figure I
Carbon, climate, and environmental neutrality and GHG inventory they include



4. How stakeholders define their system barriers for decarbonization activities, also determines the scope and its elements (Figure II). And while elements of Scope 1 and Scope 2 are often in immediate control of companies, Scope 3 includes indirect emissions that are more difficult to address.

Figure II
Scope for carbon footprint assessment (based on the GHG protocol)



Source: World Resources Institute, available at: https://bit.ly/3dkkvEG

5. In the United Nations Economic Commission for Europe (ECE) region, a trend towards climate neutrality 'at the point of handover' may be noticed in several legislative initiatives. Nevertheless, target dimension, target scope, and how these are understood, vary.

[1] See: https://www.unece.org/fileadmin/DAM/energy/se/pdfs/geee/geee7_Sept2020/GEEE-7.2020.INF.2_final_v.2.pdf.

Therefore, initially a common understanding needs to be created, and a clear minimal objective shall be determined with due consideration of individual actors' values and external factors.

6. In addition, there are other relevant definitions for which a common understanding among decision-makers is required, notably "energy-related emissions" and "process-related emissions". Energy-related emissions occur when energy carriers are converted into e.g. electricity. Process-related emissions emerge during the production process, such as by-products or methane emissions from livestock.

7. While the determination of energy-related emissions is trivial when data on the consumption per energy source and its composition (electricity mix) are available and multiplied by the corresponding emission factor,[2] this proves more challenging for process-related emissions: firstly, these are frequently misconceived as the energy-related emissions of a process; secondly, actual process-related emissions are harder to measure accurately and may be hardly noticeable or not known to exist. Companies that have to report (and pay for) their process-related emissions are more likely to also know the energy-related footprint of their operations, as energy-related emissions should be comparatively easy to identify and are (in case of electricity) often already factored into the price of energy charged by energy suppliers and hence are a noticeable cost-driver.

8. It is also indispensable to be familiar with emission pricing system (where applicable) and whether the pricing system explicitly includes all GHG emissions (CO_2-equivalents) or only CO_2, whether it applies to energy- or process-related emissions or both, or whether this is dependent on specific industry sectors.

9. The following primarily addresses emissions that are under direct control of a company. For this, three principal categories of decarbonization measures are defined:

(a) Reduction of GHGs by adapting (increasing efficiency of) business processes;

(b) Substitution of energy sources and materials (preventing emissions);

(c) Compensation of the emitted GHGs.

II. Types of measures and their impact

10. The types of measures assessed in the frames of this document are summarized in Table. Knowledge of the economic effects of these categories can already help select and prioritize possible measures to achieve net-zero emissions. However, to determine an economic mix of measures, it is also necessary to consider higher-level interrelationships and external factors.

[2] Intergovernmental Panel on Climate Change (IPCC), Emission factor database, available at: https://bit.ly/3wuVAEG.

Overview of the six types of measures and their impact

Category	*Measure*	*Potential economic effects*		*Examples*
		Non-recurrent expenditures	*Lasting effect*	
Reduction	1. Energy consumption	Initial investments	Reduced energy costs Reduced energy-related emissions	Machinery replacement Installation of heat control system
	2. Process-related emissions	Initial investments	Reduced or increased energy costs Reduced or increased running costs Reduced process-related emissions	Steel production using direct reduced iron 3D printing
Substitution	3. On-site renewables-based generation	Initial investments	Reduced energy costs Reduced energy-related emissions Possibly increased maintenance costs	Installation of photovoltaic systems Waste heat recovery
	4. Purchase of renewable energy	Initial investments	Increased energy costs Reduced energy-related emissions	Renewable energy power purchase agreements
Compensation	5. Certificates and projects	–	Increased expenses No effect on real energy- and process-related emissions	Trade of carbon credits Financing of environmental projects worldwide
	6. Carbon capture, use, storage	Initial investments	Increased running costs No effect on energy costs Reduced net emissions	Carbon capture, use, and storage facilities

A. Reduction

11. The category includes types of measures that, regardless of the energy source, lead to a reduction in emissions.

(a) Reduction of energy consumption, through a variety of selective or systemic energy efficiency measures maintaining production quantity or quality with less energy input (measure 1). Reducing the amount of energy required to achieve a particular output not only leads to lower energy costs, but also to a reduction in energy-related emissions. Depending on the type of measure, various one-off interventions are required, which are, in most cases, investments for the acquisition and installation of more efficient products, machinery, and equipment. However, relevant savings can also be achieved through organizational and awareness-related measures (e.g., switching off lights or appliances that are not needed) and optimized use of existing control systems (e.g., heating control) without investments in hardware. The amount of energy required for a unit of output decreases permanently amid energy productivity increase (revenue per unit of energy). The higher is the energy cost share of a product, the more significant is the positive impact of energy efficiency gains on energy productivity and competitiveness;

(b) Reduction of process-related emissions, which is often only possible with a fundamental adjustment of the production process itself, a change in the form of energy required for the process, or a combination of these (measure 2). Significant one-off investments are required to avoid structurally induced process emissions through process adaptation. In addition to the investments, there are also production losses for the time of conversion and new set-up. Therefore, such modifications make sense when major maintenance is due. Compared to the original process, the emissions released per output decrease, the effect on energy- and other running costs however depends on the alternative production technique chosen. Therefore, it can also happen that the energy input per product increases. Particularly, it is important to assess what effect a changeover would have on emissions and on energy requirements and costs. Not discussed in detail, but also falling into this category, are emission reductions through a reduction of the scrap rate and a more efficient use of the material or the use of waste products, offcuts, or other leftovers. These material and resource efficiency measures also lead to cost savings, as either less raw material is needed for the same output, or the latter may be increased.

B. Substitution

12. Substitution includes measures in which one energy source is replaced on an equivalent basis.

(a) Substitution with renewable energies generated on-site (including hydro, wind, geothermal, solar, biomass, etc.) or recovered (such as heat pumps, waste heat conversion, and other that fall on the borderline of energy efficiency measures) (measure 3). One-off investments are required to explore which type of generation is possible at the location and for the acquisition, construction, and connection of a technology. While some renewable energy sources guarantee a continuous energy supply (e.g., geothermal energy), energy output varies for most sources thus requiring an adequate energy storage system (e.g. thermal, electrical, mechanical, or chemical) to ensure continuous energy supply, peak load management, and/or energy supply flexibility.[3] Instead of or in addition to the one-off investment in an energy storage system, it is also possible to check which energy consumers could be automatically throttled or switched off (or change the energy source) without any problems at times of insufficient generation. In principle, nine forms of energy demand response may be considered. but are not discussed in further detail here. Although there are maintenance costs, ongoing costs for on-site energy generation are in most cases relatively low;

(b) Substitution through the purchase of renewable energies (sourcing from outside via local heating networks, biogas plants, etc.) (measure 4). In most cases, this requires no one-off investments. Yet amid technological advances and other effects leading to increased competitiveness, the price of renewables-based generation is still often higher than conventional generation. At the same time, in many cases it allows reducing energy-related emissions to almost zero. The substitution of materials can also reduce emissions, especially concerning the product-related footprint.

C. Compensation

13. Compensation refers to those voluntary and involuntary measures that do not prevent the energy- or process-related emissions themselves but aim to offset their effects.

(a) Compensation through certificates or climate protection projects, where two types of measures can be distinguished: trade of certificates and financing of projects (aimed at reduction of emissions elsewhere) (measure 5). Although the purchase of certificates occurs selectively or a project is financed on a one-off basis, transaction costs need to be considered in the overall financial assessment. Moreover, energy- and process-related emissions remain unchanged and continue to occur because of ongoing economic activity. Consequently, offsetting these remains an ongoing expense;

[3] See: https://unece.org/info/Sustainable-Energy/Energy-Efficiency/events/18744.

(b) Compensation through capture and storage of emissions (carbon capture and storage (CCS))[4] and their further processing and use as raw materials elsewhere (carbon capture and utilization (CCU)), e.g. in chemical or building materials industries (measure 6). There are only a few, often experimental, plants so far. Accordingly, there is still little information on the predicted capital and operational costs. Furthermore, these largely depend on how and where the emissions are to be stored and how they are captured and transported there. Additionally, energy is required to operate a CCS/CCU plant, which means that extra energy costs are incurred (and in case of CCS, additional transport and storage costs might also arise). The bottom line is that current emissions are not reduced but rather prevented from causing damage, the ongoing energy costs from economic activity remain unchanged, and a plant incurs additional energy, operating, transportation, and storage costs for the CCS/CCU facility (which may be partially offset by additional revenues in case of CCU).

III. Review of external factors

14. Following on the general economic analysis of the types of measures, these must be assessed in the context of individual objectives and the overall system an actor operates in (i.e., on the one hand, legal-regulatory requirements, geographical conditions, and market conditions, and, on the other hand, societal expectations and impact of an actor’s action).[5]

15. From the point of view of “simple” and “fast” implementation, the purchase of renewable energies (measure 4) or investment in emission certificates and in climate protection projects (measure 5) appear to be the most obvious solutions. However, a decision for a simple change of electricity tariff would lead to an excess demand for a least-cost option (this particularly constitutes an issue in geographies where expansion of renewables-based generation and transmission infrastructure advances slower than the demand for it. Limited availability of emission certificates and credible climate protection projects (and those who can identify, check, plan, and implement them) should equally be noted.

IV. Consideration of price fluctuations

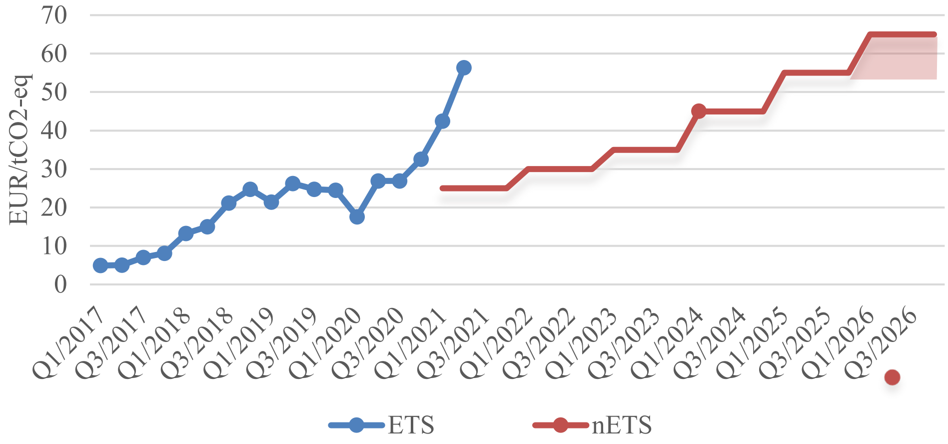
16. The one-off economic effects and permanent impact of measures are supplemented in consideration of the effects of energy and emission price development, as these influence the cost savings that change over time. Although the ongoing costs change over time, the change is often analogous to a regular price increase and can thus be estimated. In contrast, energy prices often fluctuate more, among other due to policy landscape. For example, a considerable increase is visible when looking at the price history of the European Union Emissions Trading System (ETS) (Figure III).

[4] IPCC (2018): Carbon Dioxide Capture and Storage, https://bit.ly/3yGwVhI.

[5] In countries and regions where there is a price on energy-related and/or process-related emissions, the ongoing costs will likely increase per unit of the emission type concerned. Should there be no emission charges in the country or region the company manufactures in, but carbon border adjustments (CBA) in place in a region that the company exports to, these additional ongoing costs would apply for the embodied emissions of the goods exported to the country or region with a CBA in place. This also defines a reference, “no-action”, scenario.

Figure III

Example of emission price development in a market-based ETS and a fixed-price system with staggered increases (nETS on energy-related emissions not covered by ETS, in Germany)



17. Various factors influence emissions and energy prices, but they can also influence each other (e.g. increase in green electricity prices because of a higher demand of electricity from renewables when emissions prices rise, unless the global expansion of renewable energies progresses to an extent that there is no significant price increase). Therefore, five of the six types of measures are considered concerning the expected price fluctuations in the following. The reference scenario serves as a basis for comparison, in which a company does not cat and is therefore subject to fluctuations of both energy and emission prices.

18. Reduction measures lead to:

(a) Reduction in energy consumption compared to the reference scenario, provided that energy is purchased externally, and thus less dependence on energy price developments as they consume less;

(b) Reduction in emission compared to the reference scenario, regardless of which energy source is ultimately used and whether it is a reduction in energy consumption or emissions, and consequently less dependence on emission price developments as they emit less.

19. Substitution measures lead to:

(a) A significant reduction in emissions, as emission costs are lower in comparison with the reference scenario. In case of complete substitution, there is no dependence on emission price development as no direct emissions arise;

(b) No dependence on energy prices development in case of complete substitution through self-generation as no direct energy costs are incurred;

(c) Dependence on energy prices development and the availability of renewable energies when it comes to substitution through the purchase of renewables. The tariff and pricing of the supplier determine whether there are supply guarantees, or whether a fixed price per energy unit or the current spot price is agreed.

20. Compensation measures lead to:

(a) Amount of emissions remains unchanged compared to the reference scenario Emission costs are lower than the reference scenario, as the "penalty costs" (referring to emission prices) are higher in comparison to certificate or project costs;

(b) Energy consumption remains unchanged compared to the reference scenario;

(c) Dependence on the certificate/project price development if full offsetting is sought via certificates or project financing. With rising emission prices, this may result in many companies relying on such offsetting, and thus drive the demand for certificates or projects and consequently the price for them. This price increase can be significant if there is a political or social reaction.

21. Opportunity costs, particularly energy and emission price fluctuations, need to be systematically considered in the economic efficiency calculation or economic consideration of alternative actions. A new procedure and recommended action are proposed and explained in detail in unofficial document “Recommendations for an economic assessment of industrial decarbonization options” (GEEE-8/2021/INF.2).[6]

V. Conclusion

22. Depending on the nature of economic activity (including size of a company, its energy- and emission-intensity, its economic planning horizon, etc.), one-off and ongoing costs play a different role. Moreover, this role may change over time, for example if the framework conditions change or if the most cost-effective measures have been implemented but the emission reduction target has not been achieved.

23. Economic efficiency calculations of individual measures are then to be evaluated and prioritized in consideration of energy and emission prices. The described calculations would have to be carried out across all available alternative actions to determine the most economic mix of measures at the time. Due to variability of energy and emission prices and efforts required to evaluate possible action alternatives, it makes sense to map economic aspects together with technical and other influencing factors, ideally in a digital model.

24. There are interim targets, as well as associated timelines: internally, this is at least the year by which the target emission level is to be achieved, often accompanied by interim milestone years and emission levels. Of large relevance are, however, also political milestones. Many countries and regions have set interim targets for 2030 and aim to achieve net-zero by 2050 at the latest. Considering a quickly changing environment, and to allow comparability to conventional economic efficiency calculations, it makes sense also to include the first three years after kick-off. No ideal mix can be of a static nature: it evolves over time, attention needs to be paid to the financial performance of the selected measures by the determined target year. Doing so will avoid choosing a mix that will turn out to be very costly in the long-run, and at the same time ensure taking measures that are economically superior to a mix suggested by traditional calculation approaches.

25. This results in a scientifically and technically sound decision-making and planning tool for short- to long-term observation and impact assessment, which also considers the factors that can be influenced on. For example, suppose production processes are aligned in terms of time and quantity according to the availability of renewable energy. In that case, procurement can be optimized, and a contribution can be made to maintaining grid stability.

26. Considering the described measures, interdependencies, and calculation methods, the possibility of quasi-dynamically determining the most economical mix of measures for net-zero is within reach when employing digital mapping.

[6] This document and the referenced GEEE-8/2021/INF.2 are an adaptation and extension of a study by S.M. Buettner et.al. (Rainer Hampp Verlag, 2021) to the ECE region and the international context.