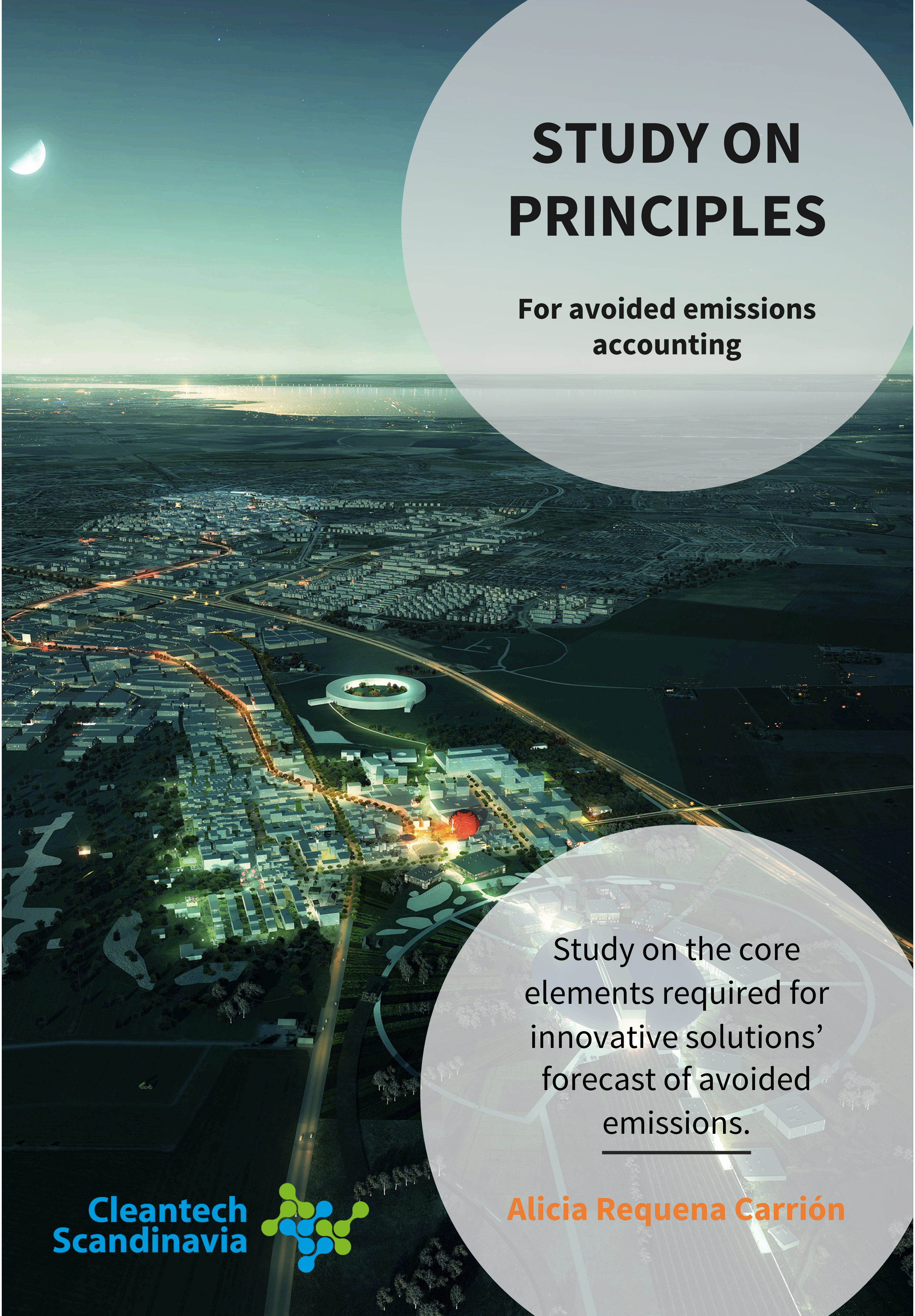
STUDY ON PRINCIPLES

For avoided emissions accounting



Study on the core elements required for innovative solutions' forecast of avoided emissions.

Alicia Requena Carrión

Cleantech Scandinavia

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List of abbreviations

BAU – Business as usual

BM – Build Margin

DEFRA – Department for Environment, Food or Rural Affairs

EIB – European Investment Bank

ETS – Emissions Trading System

EU – European Union

FU – Functional Unit

GeSI – Global Enabling Sustainability Initiative

GHG – Greenhouse Gas

ICT – Information and Communication Technology

IEA – International Energy Agency

IFI – International Financial Institutions

LCA – Life Cycle Assessment

NPS – New Policies Scenario

PM – Particular Matter

TRL – Technology Readiness Levels

SEA – Swedish Energy Agency

WBCSD – World Business Council for Sustainable Development

WEO – World Energy Outlook

WRI – World Resources Institute

1.Executive Summary

Introduction

The current climate crisis, which goes on despite the pandemic, is one of the major challenges that humanity faces. Its development will not only change the temperatures, but also entire ecosystems, and will potentially disrupt every system, human and natural, upon which we rely. The decisions that humanity will make, in terms of product development, consumption choices and investments will be fundamental to control our climate impact and contribute to mitigate the increase in global temperatures.

The impacts of climate change affect everyone and are derived from most everyone: our daily actions have related emissions that further the problem. This is true mostly in the developed world, where the levels of consumption are highest. The citizens of the least developed countries in the world have a much lower level of consumption and travelling in general, which counteracts the excesses of the first world and keeps the climate change from going at a much faster pace – but also keeps us from seeing the issues related with business-as-usual scenarios. However, if we aim for a better world in which we find equal distribution of opportunities and quality of life we must do it without accelerating the levels of GHG emissions; in a nutshell, we must find innovations that would allow us to maintain and improve our quality of life without hindering future life on the planet. We have to implement new solutions that would allow a good life without the negative impacts currently related to that quality of life. We need a systemic and structural change.

How can we proceed towards those changes? We first need to analyse our options to choose those that are best suited for our interest. We need to have the most reliable information to undertake this analysis. The results of the assessments should be consistently replicable and should allow comparison between solutions without having to go through extensive re-calculations. This analysis, that seems simple at first sight, requires a certain level of accuracy to have real potential. Otherwise, we risk creating yet another tool for greenwashing.

This report stems from the need to obtain comparable results in avoided emissions assessments regardless of the framework used for the calculations. The objective of this report is to obtain the potentials for variability in the different frameworks and generate a space for a productive discussion towards consistency through the different methodologies. This report is not aiming to create a new framework of calculation or to define a set of guidelines; the goal is to engage as many actors as possible to agree on which standard guidelines or criteria should be followed to improve assessments in terms or replicability and consistency.

Brief history of the frameworks: pears and apples.

The general conception of this analysis is to compare options and choose the least impactful one. However, that would often lead to comparing pears and apples, and it is common knowledge that this comparison would just not do. The definition of boundaries and the conversion of certain parameters can help bringing pears and apples together for proper comparison. But how has this issue been dealt with over time?

This report has gone over 15 different frameworks. One of the oldest attempts to deal with the avoided emissions issue was issued in the early 2000s through the development of the **Greenhouse Gas Protocol – project standard**. As a continuation of the work on the Corporate Standard for accounting enterprise GHG emissions, the World Resources Institute published a standard that would calculate the positive impact of large climate mitigation projects in terms of “Avoided emissions": how much carbon would be emitted if the project were not to be built? To allow for comparison, this framework went into a lot of depth in the definition of the baseline, or the system that would be in place was the mitigation project not implemented. In other words, what is the fruit that we are comparing our apple with that serves as much as our apple. The criteria for the choice of a baseline were developed in depth and required not only a deep understanding of the current state of the market, but also the tools to estimate the changes in the market in the absence of the project. This is useful mostly considering that large infrastructure projects often have a long life span. If a new generation facility is expected to last 50 years, it is questionable that the current generation methods would be the baseline for comparison during that time. It is likely that new, more efficient technologies, would be deployed. Therefore, a dynamic baseline should be considered and periodically updated.

After this standard, there have been several frameworks and applications that are trying to provide this service not only for projects, but also for new products, solutions and components. The first sectors to introduce these types of studies where ICT, through the methodology developed by the Global Enabling Sustainability Initiative (GeSI) in 2010, **Evaluating the carbon-reducing impacts of ICT**; and the chemical sector through the WBCSD and its **Addressing the avoided emission challenge** in 2013. After that, there are a series of attempts to offer a non-sectorial system to tackle the issue of avoided emissions, one of the most important being the **Guidelines for Assessing the Contribution of Products to Avoided GHG Emissions** by the Institute of Live Cycle Assessment in Japan (iLCAj) in 2015.

In the past years, we have seen a huge development in this field. The need to provide consumers and investors with the proper tools to assess their potential expenses has been a motivator that has led to the definition of new frameworks, applications, and taxonomies. A very relevant framework is the one issued by Mission Innovation, the **Avoided Emissions Framework**, a comprehensive method to forecast the emissions of new solutions as a way to foster innovating proposals. Regarding applications, or calculators, it is important to mention the **Crane Tool**, which uses algorithms to calculate the impact in terms of avoided emissions of certain technologies. And finally, among the taxonomies two systems are on top of the field: **Drawdown Project** and the **EU taxonomy**, which have defined lists of technologies per sector that have to potential to move the needle towards the Paris Agreement and the limit of temperature rise to 2 °C.

Definition of the solution and their elements

As we go through all the frameworks and calculation methods that exist nowadays, we see there are differences in stringency and criteria. Therefore, the whole process of comparing something that looks like an apple with something that also looks like an apple can end up comparing different things, in such a way that results can change depending on the tool used and the considerations and assumptions of the assessor.

There are several elements that we should consider obtaining an accurate and replicable assessment. In addition to that, the data supporting the definition of each of those elements must be of the highest possible quality: it must be complete, relevant, consistent, transparent, and accurate, as most frameworks clearly point out.

The definition of the baseline often is determined by the boundaries of the solution: geography, timeframe, and system boundaries. Depending on where and/or how long a solution, project or product will be in place, the baseline can differ. Renewable electric generation will have different baselines if the solution's location is Sweden or Poland, and it will be different in the next two years than, hopefully, in 10, when it is expected that most networks would have already adapted to lower emissions technologies. In addition to that, depending on how far our assessed system reaches, if it is a cradle-to-grave assessment or a gate-to-gate, could provide insights that would determine that a baseline is a better fit than other because of the impact in the different steps of the value chain.

Technology Readiness Levels (TRL), allocation and market effects, all seem to also determine the scope of the assessments in certain extents. TRLs can increase uncertainty on the impact, the distribution of the impact among different actors influences the relevance of a specific solution in the impact it claims to make, and the market effects can limit the global extent of the impact or, even, modify the baseline if the markets of baseline and solution do not coincide.

Interestingly enough, even though there are many parameters that can influence the outcome of an assessment, more often than not the variability of the results following the indications and restrictive levels of a system or the others can be very high. In fact, during our research we tried to study the variability in which we could incur if we applied different frameworks to the same solution and the results are concerning.

Potential variations

The current report has used a study case to confront the results of different frameworks. The study case refers to the use of a new component in feminine products, a bioplastic that can substitute the plastic currently used in tampons and sanitary pads. Depending on the restrictions and allowed assumptions acknowledged by all the frameworks, it is easy to find high differences from one assessment to the other.

Since not all the frameworks use the same elements, the variation can be up to almost 100% in the results for avoided emissions. This is the case for system boundaries (cradle-to-grave or gate-to-gate), geography (global or national, for instance, Sweden), timeframe (one year to 100 years), and market effects (measuring different things, like market penetration and market share).

In the case of allocation and secondary effects, the variation is smaller. In the case of the allocation, the current study case shows a variation of 18%, but it depends very much on the assumptions or agreement regarding the contribution of the product to the avoided emissions. Therefore, it is likely that this variation could also change drastically in other cases. Regarding secondary effects, we assumed a 10% of reduction on avoided emissions as a potential estimation, but this is an assumption made by the assessors. It could have been more, or less.

Conclusions

The analysis and study case show a high potential for variation in assessments. The fact that the lack of resources often motivates the relaxation of the levels of stringency in some frameworks creates an ambiguity that can lead to differing assessments of the same solution. Two different assessors, both trying to do their best work, can potentially obtain greatly different numbers depending on the choices they make in their assumptions.

Not only that, but there is also a risk of allowing tailoring the results to obtain specific results, leading to greenwash. We understand that the election of criteria to reduce this risk is difficult, mostly when we are looking into new ventures or solutions, where the resources are low and the levels of uncertainty are high. However, if we aim to effectively impact the environment and mitigate climate change through innovation, we need to agree on the best way to define these criteria to allow the development of new climate positive solutions.

As assessors, it is important to us to obtain more guidance to be able to measure and compare; frameworks need to offer said guidance to reach their own goals.

2.Introduction

It is common knowledge that we are going through a climate crisis. This crisis requires that we reduce our current GHG emissions and that we manage to keep future emissions at bay, both in the developed world, where GHG emissions are higher, and in the developing countries, where the need to improve living conditions has the risk of increasing the emissions. At the same time, there is a fast pace of creation in the realm of technological innovation aimed at tackling climate change and that will be crucial to tackle the climate crisis. These innovations can use very different strategies to attain their goals; from energy efficiency increases to carbon removals, directly and indirectly, these solutions work towards a climate change neutral future. Knowledge on the impacts of these novel solutions is fundamental to define the paths ahead.

Carbon accounting, or climate impact assessment, is an area that has been developed for a long time. The usual process for accounting climate impact required organisations and companies to measure the emissions of different processes and activities, record them and later report them. It is important to mention that those are emissions that have already happened; they cannot be avoided since they already took place. But all these assessments provide a ground of work from which we can start inferring what would happen if some things were different.

A further development of this process is to broaden the scope in two different directions: object of the analysis and reach of the analysis, as it is clearly stated in the report **Carbon Impact Analytics** by Carbone 4. Firstly, the impact should be accounted in terms of solution, corporate and investment portfolio perspective. Investors should be able to understand the climate impact of all the investments they are making. In addition to that, all the actors in the value chain can use the information to assess potential future developments and act towards a reduction in emissions in operations or in the portfolio.

Climate impact is an issue that affects us all: the regular citizen wants to know the impact of his or her actions; public institutions such as cities want to improve the quality of life of their inhabitants and strive for a resilient environment in which they don’t have to deal with extreme weather events; NGOs want to understand the causes of all the negative effects that are already visible; and the economic and financial sectors want to answer their customers’ requirements of cleaner products and services. Not only that, but the current regulatory trends, especially in Europe, tend to develop more stringent legal requirements for climate and environmental protection, which means that companies can “future-proof” themselves by aiming for more ambitious environmental targets. All these stakeholders require knowledge to make grounded decisions in terms of enabling policies, funding, and consumption. It is key that the estimates of impact are reliable and trustworthy. This implies that many of the investments, developments, and infrastructures would benefit from an analysis that investigates the future and not the past, forecasting the impacts instead of merely recording them.

Forecast of avoided emissions has been in place for over 10 years. There are several frameworks that investigate how to predict the emissions of a product, service, or project and how that can potentially have a positive impact in the shape of reduction of emissions (Figure 1). Forecasted emissions calculations often rely on concepts extracted from Life Cycle Assessment (LCA) practices, and data obtained from emissions reporting. In addition to that, it might also be relevant to consider market penetration and market share, as well as potential market changes.

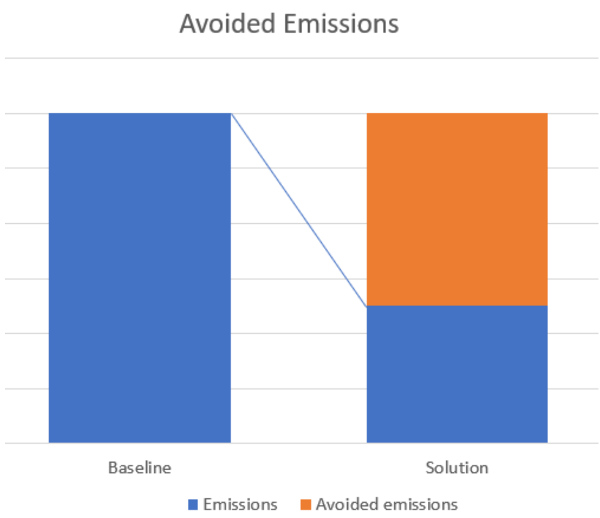


Figure 1. Avoided emissions of a solution.

The market study is not a minor issue. A product or service is replicated. Its unitary impact might be very low, but a high outreach can make a difference; therefore, it is important to understand not only the physical attributes of the product, but also the spread that this solution can potentially experience, how many times will it be used, by how many users, etc.

On another note, projects require a slightly different approach. They are often one-time initiatives which have a high unitary impact and a long lifespan. In the case of projects, technology spread can be relevant, but the project itself might have a much smaller reach.

In any case, the main aims of forecasting the avoided emissions are both to know the amount of greenhouse gases (GHG) emitted and to assess whether a specific solution will take us closer to the goal of mitigating climate change or further from it. In other words, how many tons of carbon dioxide, CO2, are avoided by using the new solution instead of current mainstream practices, hence the name of Avoided Emissions Accounting. These calculations are only relevant if we compare them with other solutions, or baselines, and calculate the difference. The baseline is considered the most common product, service or process that would be substituted by the solution under study. Let us take electric cars in a very direct example. What product or service are electric cars substituting? An approach would be to assume that electric cars will substitute conventional combustion cars. How many tons of CO2 will we be saving with the change? What is the actual comparative impact? In this example, the solution under assessment would be the electric cars, and the baseline conventional combustion cars. However, baselines can change over time just as markets change. What if the liquified gas petroleum (LGP) would become mainstream in 5 years as main car fuel? Then, our calculations would need to be readjusted. Baselines are, therefore, complex elements in the study of avoided emissions.

A generalisation of the methods on how to calculate the avoided emissions of new solutions would roughly follow these steps (Figure 2):

1. Define the solution and its boundaries: system, geography, time, and technology readiness levels included.
2. Define the baseline or baselines that would apply during the time of the assessment.
3. Find the emission factors that would be applicable for the new solution and the baseline considering the boundaries chosen.
4. Estimate market penetration and/or market share of the solution.
5. Calculate the units of product/service of both solution and baseline
6. Calculate the emissions of both solution and baseline by multiplying the units by the emission factors.
7. Subtract the emissions of the solution from the baseline's emissions to obtain the avoided emissions of its implementation.
8. Consider if the avoided emissions should be allocated to other solutions in addition to the one under assessment.

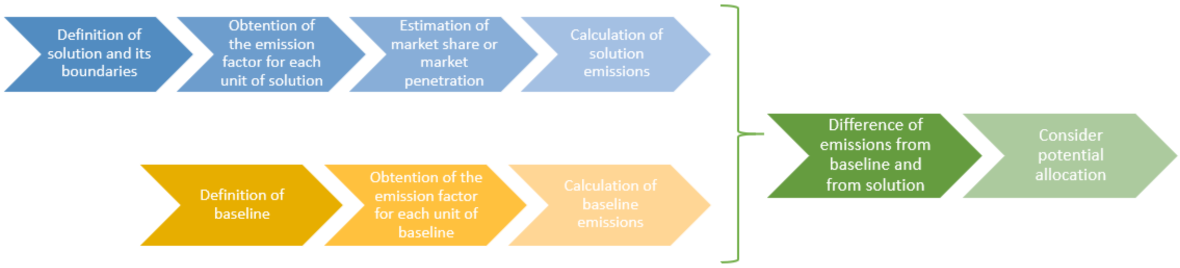


Figure 2. General procedure for the calculation of avoided emissions

It is of vital importance that the data used to estimate the emissions is *complete, relevant, consistent, transparent, and accurate,* and that it is clearly referred to in the report on avoided emissions. We should consider if the emission factors that are used are referring to the geographic area where the solution will be implemented or somewhere else. It is convenient to use as many points of reference as possible to increment accuracy.

This overlook of the process does not reflect all the complexity that we find once existing frameworks are compared with one another. Not all parameters are acknowledged in all frameworks, as we can see in Annex I: Main elements in each Framework and 2, and the criteria to deal with them also change from one to the other. Therefore, a potential for variability in results exist.

It is of the utmost importance to be able to trust the results of an avoided emissions assessment regardless of the source, or authorship, of the assessment. Homogenization of the process can increase the adequacy in investment and purchasing choices, as well as in policy definition. In the specific case of investors, for instance, it is important that avoided emissions assessment can be trusted at the same level than the economic and financial forecasts, if not more.

Purpose and limitations of this report

This is the main goal of this report: to start the conversation on the variability of results among assessments that follow different frameworks; where that variability comes from; and how it could be better addressed. It is not within the scope of this work to find the ultimate framework, to define a set of guidelines to be followed in assessment projects, or the ultimate answer to those questions, but merely analysing the current state and phrase those questions in a productive way. We want to identify relevant aspects of the assessments that can potentially affect different stakeholders; and we want all those stakeholders to be able to participate in the conversation of how the assessment can be levelled so we are reassured that the comparison between different solution is made in equal conditions. After all, information is key in the fight against climate change.

This report will first introduce the frameworks that have been analysed so far, and then we will continue to analyse potential key elements in the avoided emissions assessment in depth, one by one, and following the frameworks that deal with them. Finally, we will include the results of a scenario analysis in which the differences in results between different frameworks are quantified for better understanding of the implications of the choice of framework.

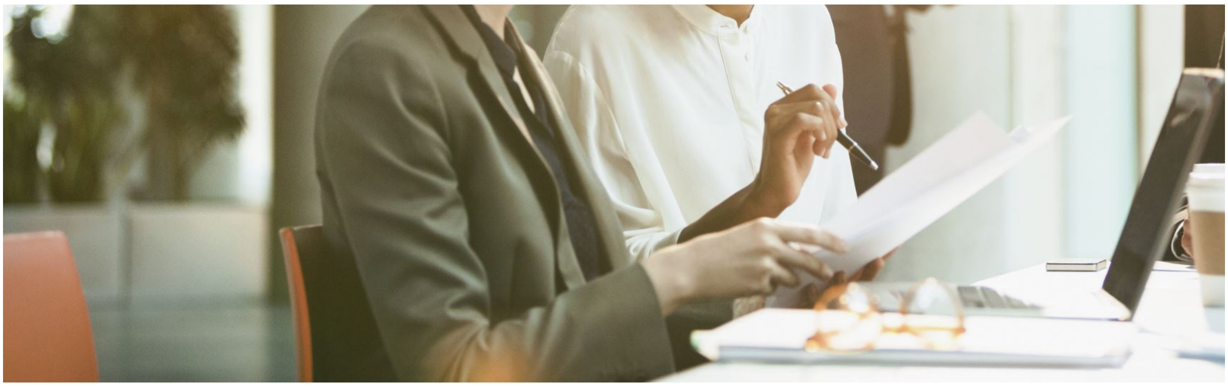
The main elements that we are analysing are:

1- Scope of the framework
2- System Boundaries
3- Secondary Effects
4- Geography
5- Timeframe
6- Technology Readiness Levels
7- Baseline
8- Market penetration/Market share
9- Allocation

Initial findings

After the study of these elements, we see that there is much heterogeneity regarding what is included and what is excluded from the assessments depending on specific frameworks. There are aspects that seem to be addressed by most of them, such as the definition of baseline, and others that, despite its potential importance, are considered by just a few of them, such as Technology Readiness Levels (TRL). In addition to that, the description of how to address these aspects in an assessment range from a mere definition of the issue to specific steps on how to quantify it. In sum, the potential for variability is large, and as we have seen in the case study, we have a high range of variability that is non-dependent of objective or quantifiable parameters and criteria.

We are not advocating for high level of stringencies in the frameworks, since high development rates require some flexibility. However, we want to raise these questions to every actor involved in the process that we can reach. It would be of the utmost importance to come to agreements that would help us avoid high levels of discrepancies.



3. Historic development of avoided emissions calculations

The initial steps of carbon accounting date from over a century ago and at the beginning they only registered the amount of carbon dioxide in the atmosphere. The physical carbon accounting was the main process used by scientists to record the CO_2 concentrations in the atmosphere and companies to report their emissions. However, the inclusion of the concept of carbon markets in the Kyoto Protocol in 1992 started to shift the balance towards forecasted emissions to plan for the financial implications that these could have in the general accounting system. (Ascui & Lovell, 2012)

In addition to the carbon markets, already started such as in the case of the EU Emissions Trading System (ETS), the public is providing increasing importance to supporting technologies that drastically reduce GHG emissions. This has led to the development of several assessment frameworks, most of them based on Life Cycle Assessment (LCA) methodologies, to determine the future climate impact of products, services and projects, and single out those that have a more positive potential outcome.

Ever since the beginning of the 2000s, different institutions created their own frameworks for the estimation of future emissions. These institutions are both private and public, some oriented towards practical direct application in the market and some with a more theoretical positioning. Therefore, the frameworks that stemmed from them vary greatly.

One of the first frameworks is the **Greenhouse Gas Protocol – project standard**. As with the GHG protocol for enterprises, it was initiated by the World Resources Institute. Its main goal was to support the development of climate change mitigation projects by establishing the positive impact that they would have in terms of GHG emissions. It was written and "road-tested" in 2003 through the collaboration of many experts on the field. It provides a deep and throughout system to define the baseline or baselines that should be considered along the duration of the project.

2010 saw the initiation of a series of frameworks developed by the Global Enabling Sustainability Initiative (GeSI). This initiative had already started to publish a series of reports on the impacts of ICT in 2008. The first one, **Evaluating the carbon-reducing impacts of ICT**, is a first step towards the recognition of the importance of enabling effects of some technologies. Instead of avoiding the emissions themselves, what enabling technologies do, is to allow other systems to reduce them. This would be the case of sensors that increase production efficiency. The same level of analysis goes to rebound effects. Even though many other frameworks acknowledge the importance of the secondary effects, few of them go as far as GeSI with them. Later on, in 2017, GeSI and the Carbon Trust published a set of detailed guidelines within the scope of the GHG Protocol for Products to align the carbon accounting of the ICT sector with the GHG Protocol. It does not consider the comparison between products, but it does addresses avoided emissions due to the importance of enabling effects by ICT systems.

A year later, both the **Greenhouse Gas Protocol** and **Defra** published each their own framework. The first one released its standard to report the **emissions of the entire life cycle of products**. Although it is not a forecasting framework, it applies the LCA approach and serves as a reference for the case of scalable products and solutions, and their specificities. In the case of Defra, they released their latest version of the **PAS 2050:2011** that seems the first non-sectorial approach to the reporting of estimated GHG emissions through an LCA approach that focuses only in one category or environmental aspect, which would be climate change.

The World Bank Council for Sustainable Development (WBCSD) released in 2013 its **Addressing the Avoided Emissions Challenge** framework. This framework is specific of the Chemical sector and uses a multicriteria LCA to estimate the avoided emissions. It defines the selection and use of the parameters that can influence the result of a calculation, although it does not exhibit calculation formulae. One of the specificities of this framework is the encouragement to find trade-offs between climate impact and other environmental issues in the case of low-carbon products, at least acknowledging the possibility that high climate performance could also carry negative impacts in other environmental aspects.

It is not until 2015 that we find one of the frameworks of reference, the **Guidelines for Assessing the Contribution of Products to Avoided GHG Emissions** by the Institute of Life Cycle Assessment in Japan (iLCAj). This framework develops a systematic methodology to estimate and quantify future emissions by diving into the industry processes through the life cycle of products. The framework seems to encourage the increasing adoption of low-emission products in the use phase.

Lafarge-Holcim, the cement company, developed its **Accounting and Reporting Protocol for Avoided Greenhouse Gas Emissions along the Value Chain of Cement-Based products** in 2016. Its main objective is to compare the climate performance of new products with the old ones already in their product group through the entire lifecycle.

A year later, the book **Drawdown** was released. It is a description of the main technologies that would bring the global emissions down to the level of avoid a planetary catastrophe. A series of technical documents stemmed from this book. Experts in each field are developing these documents, in which they show the positive impacts of specific technologies. The development of the whole set of documents is still ongoing.

At approximately the same time as the publication of Drawdown, the PRIME coalition, the Clean Energy Trust and NYSERDA, started to develop a new tool, the **CRANE** tool, based and developed from the report "Climate Impact Assessment for Early-Stage Ventures". This is a web-based application that is aimed at providing investors with clear and fast information of potential for positive climate impact, or avoided emissions, of a specific technology they might be looking into funding. Their goal then is to help investors decide between innovations in the cleantech realm. One of the most important aspects of it is the systematization of the market penetration. They use an S-shaped function to show the usual pace of adoption of any technology before market saturation.

The tool investigates the importance of the technology in itself and not so much of the specific goals that a company can reach to allow for easier and clearer analysis and comparison.

The European Investment Bank (EIB) also created its own **Project Carbon Footprint Methodologies** in 2018 to assess potential projects to fund among the high emission sectors, such as energy generation. This means that they would only analyse projects that involve at least 100Ktons of absolute annual emissions. Its aim is mostly informative and not oriented towards supporting clean solutions.

The **International Finance Institutions** from the UN is developing since 2015 different frameworks to evaluate the projects that fall under the categories of renewable energy generation, energy efficiency and transportation. The evaluation provides another piece of information to the analysis of the investment.

In the last year, the Swedish Energy Agency (SEA) and World Wildlife Fund (WWF) released through Mission Innovation the latest version of their **Avoided Emissions Framework (AEF)**, a comprehensive method to forecast the emissions of new solutions. It is aimed at supporting the design of low-carbon products and services that would generate a positive impact on the climate through technological innovation. This information is supposed to provide investors with additional data for their investment decisions, presenting clean innovations as desirable options.

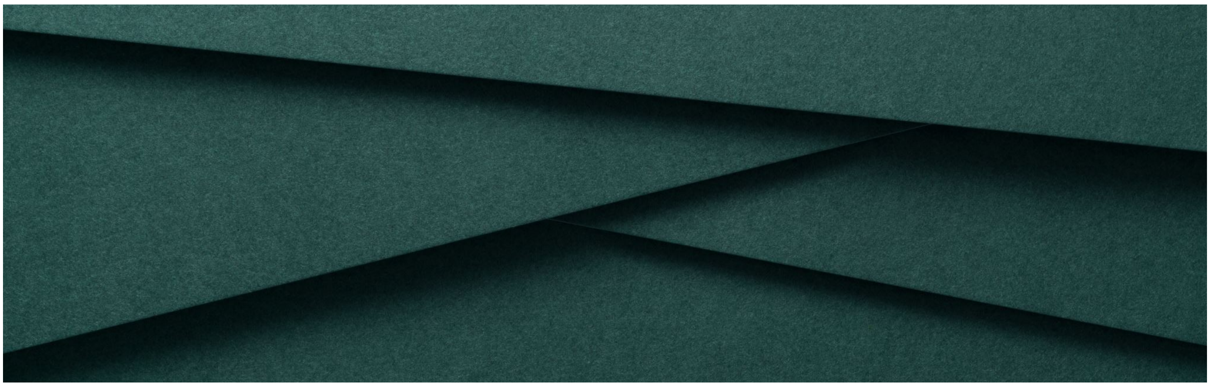
In 2019 as well, the World Resources Institute (WRI) started to work on another paper, **Estimating and reporting the comparative emissions impacts of products.** This document is aimed at comparing similar products and forecast which one would have a more positive impact. In general, the analysis would be of a product in relation to another that would act as a baseline, even though the concept of baseline as business-as-usual or the primary market option is not addressed in this document.

And as recent as August 2020, the EU made available a new methodology regarding the calculation for avoided emissions. This methodology, and attached set of guidelines, is aimed at assessing the positive impact of the projects that apply to the **EU Innovation Fund**. This fund intends to provide capital to innovative low-carbon technologies. The first call for proposals is aimed at large mitigation projects and it includes four fields in which the projects should be framed: innovative low-carbon technologies and processes in energy intensive industries (including carbon capture and utilisation), carbon capture and storage, innovative renewable energy generation and energy storage. The methodology attached to the call for proposals is tailored to every specific area and many of the assumptions are solved beforehand, such as the system boundaries and the time frame, but the basic concepts are similar to the rest of the frameworks. There is expected to be a new call for proposals, for small projects in this case, towards the end of 2020.

Finally, other schemes that could offer insights about what estimated carbon accounting could be were investigated. However, due to lack of relevance, they are not addressed in detail as the others. In this group we could include: *Science based targets initiative*, that helps companies to set their own climate goals in line with the Paris Agreement, this is, to keep global temperature rise below 2 degrees Celsius, and aiming for 1.5; International Energy *Agency's Energy Technology Perspectives*; GRI 305 – *Emissions,* as GRI is one of the most important reporting tools world-wide; *ISO 14064:2018/2019 Greenhouse gases*, which is not a reporting or estimation methodology but a certification system to ensure the existence of a proper carbon accounting system within an organisation. They could all serve as providers of a point of reference, but not of specific definitions of aspects that would complement the main frameworks presented above.

From all those frameworks and documents not included in the in-depth analysis, I would like to mention the importance of the **EU Taxonomy**. The European Union is developing the **EU taxonomy** through their Technical Expert Group on Sustainable Finance. This ongoing process is aimed at creating a list of activities that can be considered aligned with the European policies regarding six environmental objectives: climate change mitigation; climate change adaptation; sustainable and protection of water and marine resources; transition to a circular economy; pollution prevention and control; and protection and restoration of biodiversity and ecosystems. Up to the spring 2020, only the first objective, climate change and mitigation, had been developed. The description of the activities and the technical screening criteria to choose them should serve as an orientation for investors and companies to develop their own goals and to choose investment recipients or corporate strategies for their own operations.

Annex II shows a list of all the frameworks that have been included in the study.



4.Definitions

During the study of all the frameworks, we have encountered several concepts with which we might not be familiar. This chapter is dedicated to the analysis of those concepts and the names that they are given depending on the issuer.

Attributional and Consequential approaches

We can take on two different approaches when looking into impact assessments: attributional and consequential. These concepts were developed in LCA studies and have been used within the theories of several of the frameworks under analysis.

The attributional approach merely analyses the direct impacts that can be allocated to an activity or product through the partition of the impacts between different sources.

The consequential approach is an approach that deals with the interaction of the product or solution to the broader system and dives into the changes in global impacts using the product. It looks at the consequences (hence the name) of the existence and use of the product and not only what the direct inputs and outputs are.

Avoided and reduced emissions.

Although we have begun by talking of avoided emissions in this document, it is important to define what different frameworks mean by it or by the term reduced emissions. In some cases, both words, avoided and reduced, refer to the same concept; in other cases, it will be something different. To avoid confusion, I will go through how the frameworks and some other documents of reference use these terms and then choose a specific meaning for the rest of the current report.

- **Avoided emissions.**

  Many frameworks use the term “avoided emissions” as the aim for their calculations. However, the definitions for it vary for some of them.

  One of the first definitions would stem from the LCA theory, in which avoided emissions are considered those allocated to a project due to project expansion. Project expansion refers to the inclusion within the system boundaries of processes that are often related but different from the process under study, such as the use of its waste as by-product or prime matter for a different process. An example would be the left-over beet pulp generated by sugar production that is afterwards used as animal fodder.

Most of the frameworks under study consider avoided emissions as those related to Scope 3 emissions, or even enabling effects downstream: primary or also including secondary effects. There are minor differences among these. For instance, the CRANE tool does not include the emissions for production nor transportation in the assessment while others include it as a factor that reduces the potential for emission avoidance, looking into the entire life cycle of the product, such as the Institute of Life Cycle Assessment of Japan (iLCAj).

Some of them would include the possibility of market-mediated effects, meaning the changes in consumption that can affect the avoided emissions, such as in AEF, GeSI, CRANE tool and WRI Products following the consequential approach. However, WRI does not include them in its attributional approach.

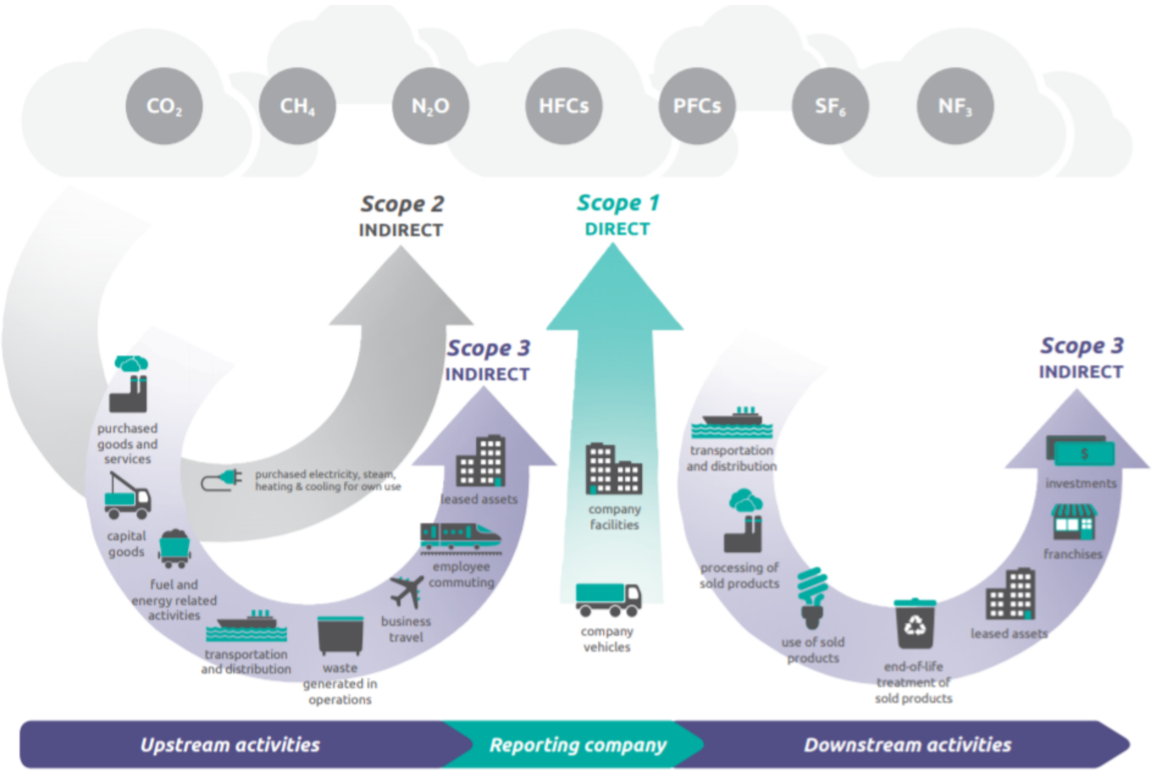


Figure 3. GHG emission scopes according to the GHG Protocol.
Source: GHG Protocol. Technical Guidance to Calculating Scope 3 emissions

- **Emissions reductions.**

In other cases, the term that is used is *Emissions reductions.* This is also a case in which we can find differences between the frameworks.

The LCA theory would consider emissions reductions those that happen within the product's boundaries due to a reduction emission project. This definition is similar to the one in the GHG Protocol Scope 3, which establishes that emissions reductions are those changes in the corporate emissions inventory over time related to a base year. The GRI 305 defines them likewise but using the previous year as reference.

For IFI – Energy Efficiency, it is the difference between the baseline and the project emissions excluding construction, leakage, scope 3 emissions, and other secondary effects that are not deemed significant.

On a completely different note, GeSI consistently refers to emissions reductions as the carbon emissions that are cut through ICT enabling effects, which is completely different to the concepts considered above.

Every assessment should clearly state what term is being used and with which meaning. The current report will, from now on, use avoided emissions for the emissions of the entire life cycle including enabling effects and/or secondary effects, and emissions reductions for those that have to do with the production of a product, and its related processes.

Corporate/project/product assessment

Carbon accounting can be undertaken in different levels: corporate level, project and product or service. Although they all have similarities, they are not exactly equal. The differences would apply to avoided emissions calculations as well.

Corporate assessment, which is not covered in the current study, would be the aggregation of impacts of all the activities and products of a specific company.

On the other hand, project assessment would evaluate the avoided emissions of a project, and it mainly applies to climate mitigation projects. This report is also including the forecasted emissions of highly intense projects in carbon emissions, since they are still an important part of the economic support system and relevant for the finance industry. They are often a single-time operation and therefore it is not expected to find a high number of replications of the same project. However, the technology can have a high level of market penetration, and it can be relevant to understand the global impact contribution of this single project in comparison with technological baselines, as we will see in the 11Baseline chapter.

Finally, products and services are highly replicable solutions whose impact and commercial success depends to a great extent on the market share they achieve and the market penetration that their technologies reach. Therefore, it is important to study their potential market effects in addition to their impact per unit of product provided, since that will inform both the potential for impact and the need to modify the reference baseline after some time.

Functional Unit

The functional unit is the classic definition of the unit of product or service that is analysed in a Life Cycle Assessment. It is defined as "quantified performance of a product system for use as a reference unit" by the ISO 14040:2006. In other words, the functional unit is the amount of product or services that serves a specific quantifiable purpose.

For instance, in the case of hand drying strategies, it would be the amount of service or product required to dry hands properly. To effectively define it, we need to have the amount of material and the time during which the product needs to be used to obtain the result. If we are analysing paper towels, it would be the number of towels required to dry hands in less than a specific time in the region where they are used. But if we are studying the impacts of electric hand dryers, then we need to take into consideration the amount of energy required to have the product working, where is the product going to be used, and the time that is needed dry hands using the device.

The functional unit has served as reference in most of the analysed frameworks to be able to compare different products or solutions with each other or with a baseline. Its definition can be crucial for the results but there is little or no discrepancy in this aspect. Therefore, it has not been included as one of the elements to analyse.

Life cycle emissions

Life cycle emissions refers to the Greenhouse Gases emitted by a product during its entire lifetime. This lifetime would encompass from the extraction of the raw materials involved in the manufacture of the product or its components, to the emissions related to the end of life of those materials, even if they are only auxiliar to the manufacture. These emissions at the end of life can be originated by the management of the waste or, depending on the type of waste, by the mere landfilling as a product of decomposition.

Sometimes the information related to some of the life stages of a product (extraction of raw materials, end-of-life management, transportation, use phase, some component manufacturing process) is not available, relevant to a specific case or not reliable. In these cases, it is possible to establish shorter lifecycle boundaries to be able to assess a specific solution. The most common used boundaries are:

Cradle-to-grave: from extraction to end-of-life. It is considered a full life-cycle solution

Cradle-to-gate: from extraction until the product leaves the manufacturing facility

Gate-to-gate: from the moment the product begins manufacture until it leaves the facility

Market Size/Penetration/Share

Potential market size is the quantity of customers that a solution can potentially have.

Market penetration refers to a technology, and not specifically to an initiative, and it represents the percentage of the market size that is effectively reached by the technology.

Market share of a solution is the percentage of the market penetration of a technology that belongs to a specific initiative or solution. This means that if several solutions with the same technology reach a certain number of customers, the percentage that belongs to each solution would be the market share of each of them.

5.Scope of the Frameworks

This section wants to clarify what scope, or aim of study, each framework has. It is important to understand that perhaps not all frameworks are exactly looking at the same activity, set of circumstances, or point of view when addressing the climate impact of a solution or initiative. Even frameworks that do not look specifically into avoided emissions can provide interesting points of view and information, which has happened in some of the cases below. Therefore, I intend to clarify which is the aim and scope of each of them.

- **Avoided Emissions Framework.**

The framework is theoretically applicable to 1) product/solutions; 2) System solutions; and 3) Companies/cities. The calculation of the avoided emissions is done by comparing the solution's emissions with a baseline that represents the business-as-usual (BAU) scenario. Theoretically, a solution aimed at providing the same service with less emissions will have a positive scenario. In this case, a positive scenario yields a negative amount of CO2 equivalent emitted to the atmosphere when comparing the new solution with the baseline.

Greenhouse Gas Protocol – Products

This framework provides a procedure to calculate the emissions of specific products. However, since it is reporting and not forecasting, it does not investigate avoided emissions. Firstly, because it only refers to past experiences; Secondly, because it does not compare with another solution that can be considered baseline or even business as usual to claim positive potential gains. As stated in its descriptive document, this framework cannot be used to compare one product to another.

- **Greenhouse Gas Protocol – Project**

This protocol intends to measure carbon emissions avoided or saved by the development of a specific project, specifically climate change mitigation projects.

- **CRANE tool (PRIME coalition)**

The CRANE tool is aimed at measuring avoided emissions in the long term by the deployment and implementation of new solutions in the market during an extended period of time. The process to measure them is to compare one solution against another.

- **Drawdown project**

The drawdown project is basically a database of different potential solutions, not a methodology to be applied by stakeholders to come up with the impact of a specific innovation. Each technology described in their documents is analysed individually by their team of experts. "Project Drawdown has developed a realistic, solution-specific models, technical assessments, and policy memos projecting the financial and climate impacts of existing solutions deployed at scale over the next thirty years".

- **Addressing the avoided emissions challenge – WBCSD (Chemical sector)**

This framework considers downstream emissions reductions and enabling processes for GHG emissions reduction in the specific case of the chemical sector. Again, this document describes a process to compare two equivalent solutions in terms of user benefit and reliably conclude which one is superior in terms of GHG emissions.

- **EIB – Project carbon footprint methodologies**

This project is aimed specifically at projects that have a significant amount of GHG emissions (positive or negative). The threshold to be included in the GHG footprint would be 100,000 tonnes of CO2e per year in absolute terms or 20,000 tonnes of CO2e per year for relative emissions. The relative emissions refer to the amount of CO2e que that is emitted or captured in relation to a baseline in which the project does not exist.
This protocol requires reporting after the project has been made, and both absolute and relative emissions need to be controlled once it is running.

- **Evaluating the carbon-reducing impacts of ICT – GeSI**

The framework by GeSI shows how to calculate avoided emissions enabled by Information and Communications Technology (ICT) systems. This sectorial framework emphasizes the systemic changes that ICT can enable in processes that ICT systems support and how this support can lead to a systemic reduction of GHG emissions. Sometimes the ICT systems themselves have small direct impacts, but the potential for the rest of the involved processes is relevant. The suggested procedure can be considered an extended LCA approach.

- **Guidelines for assessing the contribution of products to avoided Greenhouse Emissions – The Institute of Life Cycle Assessment – Japan**

This framework takes an LCA approach which includes upstream and downstream impacts of any product, material, or component, and compares it with a baseline to obtain avoided emissions numbers. "The Guidelines are intended to guide companies and organizations in calculating and assessing the contribution of their products, materials and components ("targets") to avoided greenhouse gas emissions through the life cycle in comparison with a baseline, such as product(s) manufactured by the company or organization in the past."

- **Accounting and reporting protocol for avoided emissions along the value chain of cement-based products (Lafarge-Holcim)**

This sectorial framework, aimed only for cement-based products, is structured following an full life-cycle LCA, and presents an attributional approach. It mainly compares new products with their earlier or current versions and aims to find out the potential benefits of those new solutions. Potential trade-offs with other environmental aspects should be identified, so we would be talking of not only climate impact, but potentially any other sustainability aspect. Therefore, this framework looks at more than just carbon emissions.

- **PAS 2050:2011**

This framework is aimed at assessing the life cycle of products and cradle-to-gate GHG emissions of organisations. It follows an attributional approach, therefore priming direct impacts over indirect and secondary effects. It includes all fossil and biogenic sources of all products, except for those emissions and removals arising from biogenic sources that become part of the product, which can be excluded.

- **IFI Framework: Renewable energy projects**

The IFI Renewable energy projects framework is applied specifically for the renewable sector.

- **IFI Framework: Energy efficiency**

This framework applies only for Energy Efficiency projects. "The proposed approach is primarily focused on accounting for the reduction of energy intensity induced by investments in the rehabilitation, retrofitting and/or replacement with more efficient technologies at the recipient facility. Where the project design and operation consider efficiency gains from demand-side measures, including process and behaviour change, these impacts can also be taken into account in the calculations".

To undertake the calculations, the assessor will use a baseline to compare the new solution with the old one to establish the emissions reductions as the differences between one and the other.

- **IFI Framework: Transport**

This framework is focused on the downstream emissions of the infrastructure projects it deals with. That means that this methodology emphasizes Scope 3 emissions, those that are not directly related to the project's operations. The rationale behind this is that most of the emissions that stem from transportation infrastructure projects are originated in the vehicles that use such infrastructure and not the infrastructure itself.

This framework also focuses on CO2 emissions, since it is considered the main source of GHG gases, even though there are reasons to believe that other GHGs are originated within the project (e.g. use of bio-methane as the transport fuel)

- **Estimating and reporting the comparative emissions impacts of products – WRI**

This framework has two potential scopes of application depending on the assessment approach. Following the LCA terminology, the assessment can be attributional or consequential. Depending on the approach, the scope would be different: scope 1 and 2 only (direct and indirect emissions) for attributional approach; if using consequential approach, scope 3 needs to be included.

The consequential approach is recommended for informing decision-making and when market effects mediate comparative impacts. The attributional approach should be used in the case there is not enough data to inform a consequential approach.

- **Conclusion:**

There are many frameworks to choose from when looking into the issue of the calculation of avoided emissions. However, not all of them tackle the problem equally, be it because they are sectorial or because they establish different perspectives. We will dive deeper into those differences in the following chapters.

6. System Boundaries

Impact assessments deal with the impact that is originated in the processes to obtain, use, and discard a product or service. Therefore, its assessment requires the definition of the boundaries of the system under study, that is, what processes are included in the definition and which ones are not. As it was already mentioned in the definitions chapter, the impact should ideally be considered from cradle to grave, which means since the raw materials of every piece involved in the process are sourced until all those materials are disposed of and treated after use. However, this is often unviable. Therefore, to allow for a more pragmatic analysis, the boundaries of an assessment are narrower, and it is part of the assessment process or framework to define which processes are included and why.

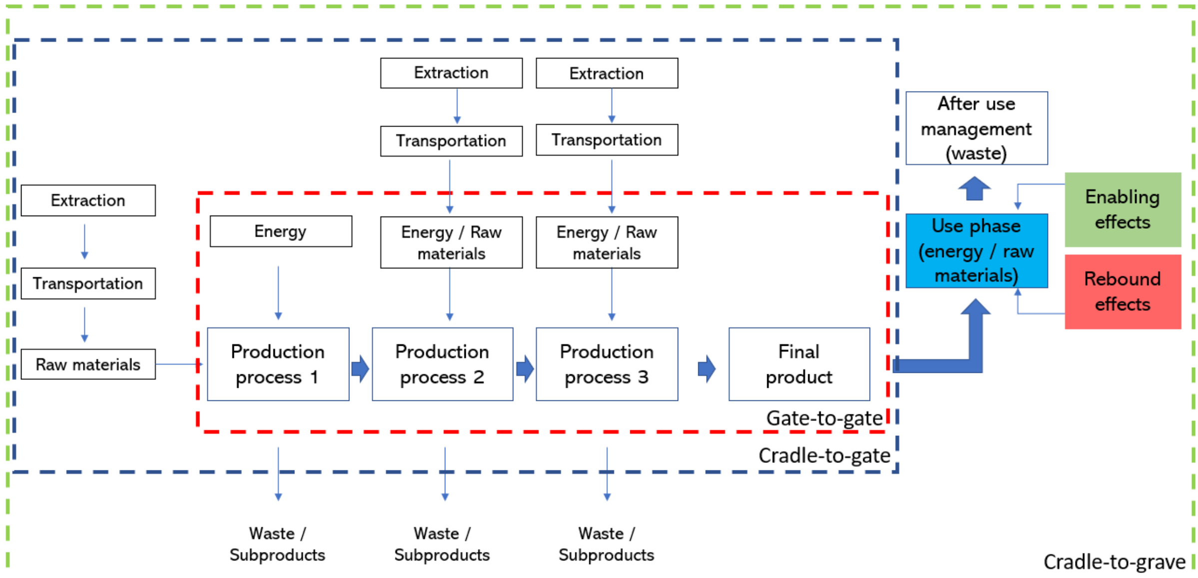


Figure 4. System boundaries

- **Avoided Emissions Framework**

The AEF only addresses the importance of the transparency and consistency in terms of the criteria used to establish a specific boundary.

“The system boundary should clearly define what is included and what is excluded from the assessment. The following are examples of where there should be clarity over the inclusion or exclusion of specific items: embodied emissions of products; transportation of equipment and people; environmental control (e.g. cooling) of equipment; capital goods; and buildings.

A consistent approach and boundary definition should be adopted for both the BAU scenario and the enabling solution scenario. It is also important to state clearly what secondary enabling effects are included (if any), and similarly what rebound effects are included in the system boundary."

- **Greenhouse Gas Protocol – Products**

The established boundary in this protocol is cradle-to-grave unless stated that the reporting will only comprise the cradle-to-gate phases. A partial analysis will not include either product use or end-of-life processes.

- **Greenhouse Gas Protocol – Project**

This protocol requires the analysis of the full lifecycle of the project and acknowledges the existence of secondary effects.

"The GHG assessment boundary encompasses all primary effects and significant secondary effects associated with the GHG project."

Primary effects would be those related to the following activities:

- "Reduction in combustion emissions from generating grid-connected electricity.
- Reduction in combustion emissions from generating energy or off-grid electricity, or from flaring.
- Reductions in industrial process emissions from a change in industrial activities or management practices.
- Reductions in fugitive emissions.
- Reductions in waste emissions.
- Increased storage or removals of CO^2 by biological processes."

- **CRANE tool (PRIME coalition)**

This framework works fundamentally with a full life cycle approach of the solution. It accepts, however, the exclusion of certain phases if that exclusion is appropriately justified and documented.

- **Drawdown project**

The Drawdown project defines the boundaries depending on the sector that is addressed in each case. For instance, LED lights included direct grid emissions and production indirect emissions; Smart thermostats, on the other hand, only include grid emissions ("*electricity and fuel consumption average values with grid emissions factors and natural gas emissions factors using data from the Intergovernmental Panel on Climate Change (IPCC)*")

- **Addressing the avoided emissions challenge – WBCSD (Chemical sector)**

This framework addresses both reduced emissions and avoided emissions during the full life cycle of the product. In the case of avoided emissions, there is an acknowledgement of the importance of secondary enabling effects. Chemical substances are often just a component of a product, which means that there is a potential to influence and avoid emissions on the use end-user level.

- **EIB – Project carbon footprint methodologies**

This framework mainly addresses scopes 1 and 2 according to the GHG Protocol, this is, direct and indirect emissions of the use phase of the project. Scope 3 is to be included only in the case of having significant associated emissions which can be estimated. Normally scope 3, and emissions in the use phase in general, are not to be included. Emissions related to Scopes 1, 2 and 3 of the commission, construction and decommissioning of the project are to be excluded, except of specific cases of the upstream or downstream emissions (Scope 3) which would not take place or be saved without the existence of the project.

- **Evaluating the carbon-reducing impacts of ICT – GeSI**

The scope includes direct emissions from the entire lifecycle of the elements included in the ICT system and the entire set of potential enabling and rebound effects resulting from implementation of the ICT system. Certain secondary enabling and rebound effects can be excluded if they are not considered significant. Primary enabling effects and direct ICT emissions should always be considered relevant.

The 2017 guidelines acknowledge the fact that some processes have so little impact that they can be excluded for the sake of simplicity. This would be the case of all those processes that can be estimated to account for less than 5% of the emissions. This way, the assessment focuses on the processes where the impact can be bigger.

- **Guidelines for assessing the contribution of products to avoided Greenhouse Emissions – The Institute of Life Cycle Assessment – Japan**

This framework is open to any scope or boundary, as long as it is clarified when the calculations are undertaken. However, in the case of assessing components instead of final products, the assessment must include the enabling effects that would allow other final products to avoid the emissions.

- **Accounting and reporting protocol for avoided emissions along the value chain of cement-based products**

This framework has a comprehensive scope as in a full lifecycle LCA. This implies the assessment of the future emissions along the value chain of the product solution, its entire life cycle (production, application of the product, use and end-of-life) and quantified at the end-use level.

- **PAS 2050:2011**

Product life cycle processes to be included:
- Energy use (direct and indirect)
- Combustion process
- Chemical reactions
- Loss to atmosphere of refrigerants and other fugitive GHGs
- Process operations
- Service provision and delivery
- Land use and land use change
- Livestock production and other agricultural processes
- Waste management.

- **IFI Framework: Renewable energy projects**

This framework addresses mostly direct emissions. In addition to that, the following considerations must be acknowledged if appropriate or applicable:

- "Construction emissions for renewable energy projects may be excluded, where forms of renewable energy are generally acknowledged to have low construction/lifecycle emissions.
- Include GHG emissions from large reservoirs associated with hydropower projects.
- Include biomass feedstock-related life-cycle emissions.
- Include geothermal fugitive emissions."

- **IFI Framework: Energy efficiency**

This framework would only take into consideration the mere energy gains from the use-phase. However, secondary effects that related to the project such as behavioural changes can be considered as well. In any case, upstream and other downstream activities, GHG emissions from construction and leakage should be excluded unless clearly significant.

- **IFI Framework: Transport**

This framework deals mostly with emissions originated in the use phase and related to the Scope 3, as mentioned in the previous chapter.

- **Estimating and reporting the comparative emissions impacts of products – WRI**

The document recommends an LCA approach to the scope of the assessment. Consequential approach is preferable, but considering the complexity to retrieve certain information, an attributional approach to LCA (Material acquisition and pre-processing, production, distribution, and storage, use and end-of-life) is accepted. That means that for the boundaries of an assessment following the attributional approach we would consider only direct and indirect emissions of the manufacture and the supply chain, whereas the consequential approach would also deal with the secondary effects related to the use phase.

- **Conclusions**

There is not a single way of addressing the boundaries of a system. Depending on the framework, a specific boundary is defined, or it is left to the consideration of the assessor. Even when there is a definition of the boundary as per the framework, the criteria are not always consistent across the frameworks.

7. Secondary effects

Every solution has a direct effect in terms of GHG emissions: its life cycle has a series of direct or primary impacts that allows for simpler study and accountability. It can also have some primary enabling effects that are directly related with the solution, for instance, the addition of a new component to a pump mechanism that increases its efficiency. The component by itself does not do much, but its inclusion is what makes the pump become efficient.

However, solutions, projects, and products have secondary effects that extend beyond those direct impacts. Those effects are related to the system in which the solutions operate and are much more difficult to measure and study than those primary, direct effects. The secondary effects are related to the changes in society or consumption patterns that are related to the existence of the solution. It is common to refer to positive secondary effects as "secondary enabling effects" and the negative effects as "rebound effects"

- Secondary enabling effects: these effects refer to the changes in society, be it in terms of technology deployment, implementation or even consumption patterns, that are indirectly attributable to the existence of a specific solution. For instance, virtual meeting software allows to avoid the negative impacts of travelling for meetings. However, virtual meeting software would not exist without the internet. So those savings, although not directly attributable to internet, are possible (enabled) by the existence of a technology that allows for them to exist.
- Rebound effects: we consider rebound effects the backlash in savings in GHG that can happen precisely because of the existence of a solution or technology. For instance, an energy saving mechanism that is designed to balance the electricity network and therefore save energy by shifting the consumption to the off-peak hours can lead to an increase in energy consumption during off-peak to the point of increasing the overall electric consumption and potentially also the emissions.

However important these effects are on a practical, real level, there are many frameworks that do not include them in their assessment methodologies. In fact, only the *Avoided Emissions Framework*, the PRIME framework (in which the *CRANE tool* is based) and the *GeSI* framework on the impact of ICT, do deal with secondary effects properly as will be discussed below.

The rest can be divided in two groups: those who acknowledge the existence of secondary effects, either enabling, rebound or both, and those who do not even mention them. The first group would encompass the *WBCSD framework for the chemical sector*, the *EIB's project carbon footprint methodologies*, the *IFI Framework for Energy Efficiency* and the *WRI's draft on estimating and* *reporting the comparative emissions impacts of products*. The second group would include all the others: *GHG P for products and projects*, *Drawdown project*, *the Guidelines by the Institute of Life Cycle Assessment of Japan, Accounting and reporting protocol for avoided emissions along the value chain of cement-based products, PAS 2050:2011, and IFI Frameworks for Renewable energy projects and transport.*

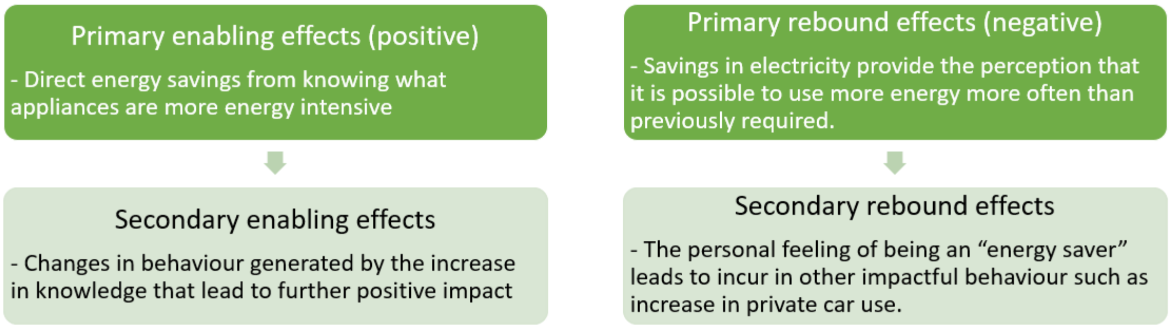


Figure 5. Secondary effects

- **Avoided Emissions Framework**

- *Enabling effects*:

This framework refers broadly to the avoided emissions that result from using the solution. The specific case of the enabling effects as secondary effects are called "secondary or longer-term enabling effects". They are "those expected to reduce emissions relative to the BAU system, but which occur over a longer timeframe or as a result of increased scale of adoption". This longer timeframe means that it is more difficult to establish the actual relation between the solution and the effect. The forecasted enabling effects from a solution can potentially end up being rebound effects.

Since the effects that are included in the assessment need to be clearly stated, there must be a criterion to stablish the cut-off between what is included and what it is not. This framework recommends excluding longer terms secondary enabling effects "due to the greater uncertainty relating to these, and that these typically relate to infrastructure changes such as reductions in building infrastructure or transport infrastructure"

- *Rebound effects*:

Rebound effects are an increase in emissions that "may be caused by related consequential or by unrelated (and sometimes unintended) effects [of a solution] and are often related to human behavioural changes in demand for carbon-intensive goods or activities". They subdivide it among immediate and longer-term rebound effects. They are generally hard to identify. That is why they are often left out of the calculations. "Forum for the Future for example encourage the estimation of rebound effects by conducting 'new research or by making an allowance based on existing complementary research'."

To assess whether the rebound effect has the potential to outweigh the positive impacts of a solution, a sensitivity analysis should be undertaken.

  - If the rebound effect is likely to be small, it should be enough with its acknowledgement

- If the rebound effect is too difficult to calculate, it is best to identify the potential rebound sources and investigate ways to counteract them.

More research is required in this area.

- **CRANE tool (PRIME coalition)**

- Enabling effects

The key challenge is to estimate the additional deployment of low GHG products that result per-unit of new system-enabling product deployed. This can, in practice, be very challenging to estimate. **Counterfactual modelling techniques** may be better suited for this type of analysis. Counterfactual analyses model the system level emissions with and without the enabling technology and compare the results. However, the modelling tools required to perform such an analysis may not be available to all investors. In the absence of such sophisticated techniques, the suggestion is to make a simplifying assumption about the per-unit increase in low-GHG product deployment associated with the system-enabling solution.

- Rebound effects

The rebound effects are defined as the increase in emissions that stem from the implementation of a "higher performing technology". As it is acknowledged in other frameworks, they can stem from "unexpected behavioural or systemic responses". In this case, however, the theoretical framework behind the platform recommends taking one of two approaches: either to consider that the implementation of the new technology will not increase the sales or the use due to its performance (in relation to the baseline) or to estimate a reduction on the avoided emissions that can be reached.

- **Evaluating the carbon-reducing impacts of ICT – GeSI**

- Enabling effects

This is one of the main aspects of this framework. Due to the relatively low direct impact of ICT systems but their high potential to enable different solutions that can save a high amount of emissions, the focus of this methodology is to ponder the importance of the ICT systems in the way other systems save emissions. It is similar to the FW "Addressing the avoided emissions" from the chemical sector, but this framework is a much more vocal about it. In fact, their methodology in this paper is called "ICT Enablement Methodology".

Their definition of enabling effects is: "those [effects] that reduce emissions in non-ICT sectors", including those that are aimed at manufacturing devices for ICT systems.

There are two types of enabling effects:

- Primary enabling effects: "immediate reduction of BAU system emissions occurring as a result of ICT system implementation". There are three types:
  - Reduced energy consumption, via enhanced efficiency or reduced operations
  - Reduced or eliminated travel/shipment as vehicles are used less frequently to move people or distribute goods.
  - Reduced or eliminated materials
- Secondary enabling effects: "non-immediate reduction of BAU system emissions occurring as result of ICT system implementation; occur over time as either duration or scale of implementation increases". There are many potential secondary enabling

effects, and the decision to include them or not depends greatly on the scale of adoption. There is no established methodology to assess whether to include them or not, since they are bound to bigger uncertainty and rely more on assumptions.

- Rebound effects

Definition of rebound effects: "those that increase emissions, thus offsetting the emission reductions. Rebound effects are typically changes within the BAU system, though may also result from increased use of the ICT system above its intended use to mitigate non-ICT sector emissions."

There are also two types of rebound effects:

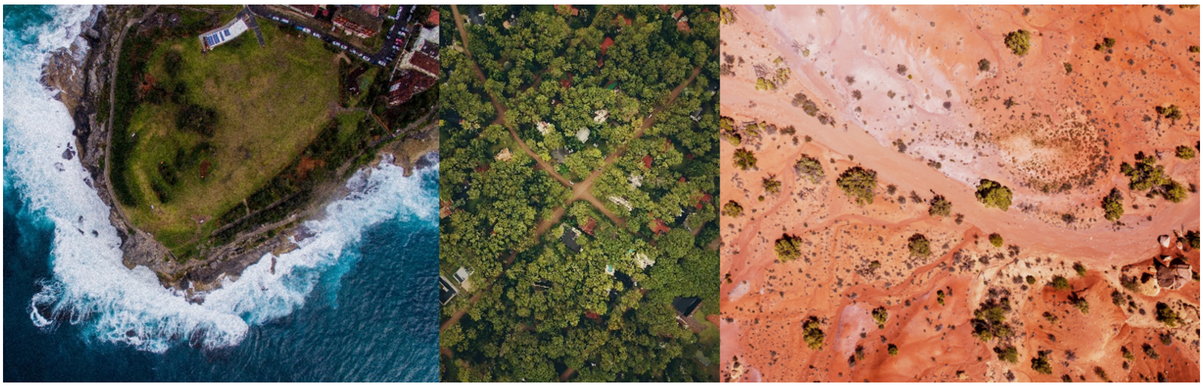
- Primary rebound effects: "occur immediately after and as a direct result of implementation of ICT system. They can take three forms:
  - Increase energy consumption
  - Increase travel or shipment
  - Increased materials"
- Secondary rebound effects: "those occurring later in time, often as a result of the cumulative impacts of larger—scale adoption. These can take one of four forms:
  - Increased use of goods/vehicles
  - Increased productions of goods/vehicles
  - Increased use of infrastructure
  - Increased development of infrastructure."

  Similar issues to the secondary enabling effects apply in terms of scale of adoption and exclusion. Sensitivity analysis are recommended to assess secondary effects. It requires greater levels of proof to exclude a secondary rebound effect than a secondary enabling effect.

  It does not address the issue on how to deal with them in the calculations.

- **Conclusions**

Most frameworks acknowledge the existence of the secondary effects. However, the difficulties to quantitatively estimate them lead to many of the methodologies to disregard these effects which can be, in total, quite significant. In some cases, they are addressed barely in a qualitative fashion through descriptions; in some others there is a rough general estimation of how much those effects could quantitatively influence the outcome of the study.



8. Geography

GHG emissions have global impact; this means that emissions will globally affect the planet regardless of where they originated. Unlike other types of pollution, such as PM, their effects are not local, and they spread all around the globe. However, the quantity of an initiative's emissions is potentially dependent on the location of the geography where any of the product-related activities take place. The processes that intervene in the lifecycle of a product, project or activity will have higher or lower emissions depending on where they take place. For instance, electronics used in Poland have a different in-use carbon footprint that if they were used in Sweden because the electricity mix has very different emission factors. Similar situations can occur in other phases within the lifecycle.

Figure 6. Example of geographical differences: grid carbon intensity 2016. Source: European Environment Agency

Different frameworks address the geographic aspects in different ways, but some of them can be grouped.

- For the **GHG Protocol Project**, the geography is determined not only by the area where the project is going to be built, but also by the baseline definition; the number of data points for defining the baseline for the solution should be high enough for it.

Geography can be determinant on the baseline definition. "The most important criterion in defining the geographic area and temporal range is that they should contain a sufficient number and diversity of baseline candidates to allow a credible analysis and estimate of baseline emissions."

It can also affect the valid time length for different baseline scenarios, depending on technology and economic trends.

Rules of thumb to defining the geographic area:

1. "Where the baseline candidates reflect a mature technology or practice that is similar across regions or is rapidly converging, a regional or global geographic area may be the most appropriate geographic area.
2. Where the baseline candidates vary because of human-influenced factors, some form of jurisdictional/Administrative boundary may be the most appropriate geographic area. Human-influenced factors may include legal factors; socio-cultural factors; or economic factors.
3. Where the baseline candidates are constrained by the availability of physical infrastructure, such as supply networks for electricity and fuels, and area that represents the extent of infrastructure may be the most appropriate geographic area.
4. Where the baseline candidates vary according to biophysical characteristics, such as climatic variation or geological variation, some form of representative ecological zone may be the most appropriate.

A number of factors may influence the choice of geographic area. The principles of transparency and relevance should be used to weigh the importance of these factors."

- In the case of **CRANE tool (PRIME coalition)**, geography does not seem an important element for this case. Instead, they evaluate different markets, but the reach that they are assuming is global.

- The **WBCSD's** framework for the **chemical sector** and **PAS 2050:2011**, both consider the geography as the places where the sourcing and the production happen, as per their cradle-to-gate boundary.

- **Addressing the avoided emissions challenge – WBCSD (Chemical sector)**

"Companies shall specify the geographic region chosen for the study. This includes the geographic region where the product is produced as well as where it is used. The reporting company should consider trade-offs that are relevant for the geographic regions chosen for the study, e.g. water depletion"

- **PAS 2050:2011**

PAS 2050:2011 also considers the importance of geographical representativeness for the selection of data sources to be used for the calculations. "For geographical specificity (e.g. geographical area from which data are collected such as district, country, region); data that are geographically specific to the product being assessed shall be preferred." All the while identifying primary activity data and secondary data for use in GHG emissions and removals assessments.

- In other cases, geography is defined specifically for the scope of the project, such as in the case of ***GeSI's framework on ICT impacts*** and ***Lafarge-Holcim's framework on cement-based products***:

- **Evaluating the carbon-reducing impacts of ICT – GeSI**

GeSI considers geography as one of the potential criteria to define the system boundary due to the existence of valid and reliable emission data or lack thereof.

"Differing geographical, behavioural and temporal conditions in the scope of a study can lead to varied effects, even where the ICT solution is the same. Availability of existing data or requirements for conducting research to generate data will also vary. Therefore, assessment of life cycle processes requires careful planning and execution that is tailored to the goal and scope of each study undertaken."

"Regarding potential uncertainty in the net enabling effect, the company may want to explore how emissions reductions from ICT implementation would vary in buildings of different ages, or in different geographies or climates."

- **Accounting and reporting protocol for avoided emissions along the value chain of cement-based products**

According to Lafargue-Holcim, geography can have an important influence on the results via data sets.

"Geographical coverage: A good geographical coverage is essential to receive adequate results. Especially for data sets with a significant impact (product composition, energy data) country-specific data shall be used."

"Extending the geographical scope by additional countries requires data collection for all three levels [primary data collection, secondary data collection for life cycle of product solution and secondary data collection for use stage of the building]. In some cases, it might be possible to partly use existing data by extending a country cluster."

- In the case of the **Guidelines for assessing the contribution of product to avoided Greenhouse Emissions – The Institute of Life Cycle Assessment – Japan,** the spatial scope of the assessment is included only on the functional unit definition.

The frameworks related to the IFI deal mostly with infrastructure project. For this reason, their geography definition is the project's local context:

- **IFI Framework: Renewable energy projects**

Assessments following this framework should be using country-specific data and factors. In the case of international electrical connections applying for IFI funding, it will be the IFI who will evaluate the emissions, but the criteria are not developed in the document.

- **IFI Framework: Energy efficiency**

Only mentioned in the case of water supply projects: "boundaries should be set according to where the actual project investments are going to be located, who the intended beneficiaries are and where they live, as well as where existing equipment is currently located as long as the baseline conforms to agreed-upon rules for defining baselines."

- **IFI Framework: Transport**

"Factors that inform an appropriate intensity level should be matched to relevant local context"

Some frameworks specifically require that, once the geography is defined, it should be consistent all through the assessment. Therefore, solution, baseline and data used for the calculation should be representative of the places that have been identified as relevant for the solution, be in during production, use or end of life. This is the case for the ***Avoided Emissions Framework, the GHG P Products****, and the* ***WRI's draft for Estimating and reporting the comparative emissions impacts of products*****.**

- **Avoided Emissions Framework**

The AEF addresses the geography in two different ways: considering if sources used to do the assessment are geographically relevant and identifying the limits to the generalisability of the results, depending on geography.

-Sources: "a study providing a specific piece of data might be geographic-specific and therefore not appropriate to use."

- Reporting factors: "Are results and factors transferable – or do they relate to specific boundary conditions (e.g. geography, time, scale)?"

- **Greenhouse Gas Protocol – Products**

The geographical boundary needs to be properly defined to assess the validity of the data sources used for the calculation and the validity of the emission factors both in the production and the use phase.

An important aspect that is acknowledged in this framework is the geographical representativeness. This is a quality data indicator which represents "the degree to which the data reflect the actual geographic location of the processes within the inventory boundary (e.g. country or site)".

The recycling data collected must be representative of "the geographic location where the product is consumed (as defined by the use profile)." Therefore, not only the productive processes' location will affect the result of the calculation, but the location of the final user of the product. This will affect the end-of-life management and, therefore, the future emissions that will be related to it.

- **Estimating and reporting the comparative emissions impacts of products – WRI**

Its main addressing of geography must deal with setting the baseline options, as it is highly dependent on the location, and available data quality.

"…the manufacturer may not know the exact range and distribution of end uses, which may also vary geographically" "In short, there is considerable variation in terms of reference options"

Data quality: "Ideally, data for both the assessed and reference products should be as specific as possible with regard to geography, technology, and time."

- There are also cases in which there is no mention to the geographical boundaries, or these are unclear. It is the case of *Drawdown project* and the *EIB project carbon methodologies*.

- **Conclusions**

The **geographical boundaries** are highly relevant, and therefore it is arguable that unified criteria should be somehow deployed to provide comparability between solutions. Most frameworks would include this aspect in a way or another.

9. Timeframe

One of the most defined aspects of an assessment is time. Over the different frameworks, time can be applied in different ways.

Firstly, those frameworks that have an LCA approach to the estimations need to define the time under the Functional Unit (FU). The FU defines the basic unit of assessment and it allows for comparability between products or services. Sometimes time is not considered, for instance, if we compare two products with the exact same performance. However, when performance differs, it is best to compare amount of service. That often requires to define a basic time unit that will be part of the definition of the FU (for example, the time that a water faucet needs to be open to clean hands considering different flows).

Time also becomes an issue in terms of data quality. The reference data for the study of forecasted impacts should not be too old to avoid obsolete information. Some frameworks refer to this to ensure data quality, but this could be included in the "relevant" aspect of adequate data.

Another consideration is the timeframe during which the service or product is supposed to have an impact. The impacts over time are generally aggregated to obtain a single number of avoided emissions that the solution can directly obtain or enable. The timeframe used to calculate the impacts has several consequences on the calculations. It is not the same to calculate the avoided emissions for a period of 10 years than those calculated over 30. Not only because the avoided emissions are added, or aggregated, over time, but also because there can be a *potential reduction on avoided emissions as time passes*. The general trend in the industry is to increase efficiency and reduce emissions in current and new activities, therefore the business as usual is expected to change as well, either by reducing their own emission or by changing the reference activities or baselines altogether. In addition to this, the actual length of the life cycle of a product can be determinant on the impact. It is useless to analyse the impact in 30 years of a technology that is expected to become obsolete in five.

This chapter will mainly consider time in its meaning of duration of the service or product when we consider the aggregated impacts. As we will see in the case studies, if this parameter is taken as such, all other things equal, the aggregated results would all be just bare products of the yearly impact. Therefore, the higher the number of years considered in the timeframe, the higher the impact. However, that is a conflict in results that is very easy to solve due to the simplicity of the calculation. It is when timeframe is taken in conjunction with Baseline changes or expected life time of the projects or products that things get interesting, and deeper differences between the frameworks can be identified.

- **Avoided Emissions Framework – EIB - GeSI**

The period for reporting is generally one year, although in the specific case of the Avoided Emissions Framework, different periods could be accepted in some cases. These are: new products, when the adoption rate can change rapidly and therefore the impact of year 1 would be different of the impact of year 3. In this case, the inclusion of a life-time emission reduction would be recommended; long-life products' emissions avoidance could also be considered during the entire lifetime. It could also allow for potential lock-ins and benefits of short-life solutions against long-life ones.

It is important to consider that some products in particular can have a especially short life. This is the case of electronic components and appliances, which can be expected to last from 2 (e.g. mobile phone) to 10 years (e.g. routers), depending on the product.

- **Greenhouse Gas Protocol – Products**

The aspects in which the time variable is used are:

1. Time period of the inventory: "amount of time a studied product takes to complete its life cycle, from when materials are extracted from nature until they are returned to nature at the end-of-life or leave the studied product's life cycle." It is very dependent on the waste treatment processes used in the geography where it is set to use.
2. Time is an integral part of the data to be collected, which means that data has to be time representative (as time in history) and has to include length in time of whatever process the data refers to.

- **Greenhouse Gas Protocol – Project**

Time is used for assessing the validity of the baseline or baselines and consequently to define the time period over which GHG reductions are quantified.

Valid time length for a baseline scenario: "a particular baseline scenario or performance standard should be valid only for a finite period of time for the purpose of estimating baseline emissions. After a certain period, either no further GHG reductions are recognized for the project activity, or a new (revised) baseline scenario or performance standard is identified. The length of this period may vary, depending on technical and policy considerations, and on whether baseline emission estimates are dynamic or static"

"Identify the time period over which GHG reductions will be quantified.

- For each project activity and primary effect, identify and justify the valid time length for the corresponding baseline scenario or performance standard.
    - [How quickly are economic conditions changing?
    - How quickly are changes occurring in the technologies or practices providing the same product or service as the project activity?
    - At what point are the criteria and assumptions used to identify the geographic area or temporal range for baseline candidates likely to change?
    - When might the barriers (or net benefits) faced by the project activity or baseline candidates change significantly?
    - If the project activity involves a retrofit, when would the retrofitted equipment have otherwise reached the end of its useful lifetime?
    - Are baseline emission estimates static or dynamic?]

- Quantify GHG reductions for a period of time no longer than the shortest valid time length identified."

- **CRANE tool (PRIME coalition)**

The CRANE tool uses a 30-year time for the measurement of potential impact of a solution. That means aggregating the impacts of a solution for 30 years. For this platform, it is important to account for long-term potential benefits.

- **Drawdown project**

Their only reference to time is the time to reach Drawdown ("the future point in time when levels of [concentration of] greenhouse gases in the atmosphere stop climbing and start to steadily decline") which is the main conceptual goal. This deadline is 2050.

- **Addressing the avoided emissions challenge – WBCSD (Chemical sector)**

This framework only considers time in terms of FU and data quality.

- **Guidelines for assessing the contribution of product to avoided Greenhouse Emissions – The Institute of Life Cycle Assessment – IFI Transport - Estimating and reporting the comparative emissions impacts of products (WRI)**

In all these frameworks, the timeframe to be considered for the assessment of the impacts has to be determined depending on the solution.

In the case of iLCAj, an assessment requires the identification of 1.- the number of products sold during a specific period of time; and, 2.-the time period during which the products will be in use. These would be the referenced timeframes.

For IFI and WRI, it will be defined depending on the project or the lifetime of the product.

- **Accounting and reporting protocol for avoided emissions along the value chain of cement-based products**

The reporting activity requires "specifying the time period that the case study relates to, typically one dedicated period in which the product is sold."

The estimated life of the products (to consider the in-use phase impacts) would be dependent on the specific product and the chosen baseline. Therefore, they are defined on a per-product basis.

- **PAS 2050:2011**

This framework considers that time affects the assessment in as much its impacts occur. Therefore, it includes GHG emissions and removals occurring during the 100 years following the manufacture of the product. It even considers the possibility of evaluating beyond the 100 year-period if there is evidence that a solution can have significant impacts after that.

The calculations should consider the expected average yearly emissions to counter for temporal changes. The results obtained by this system have a validity of maximum 2 years unless there is a change in the life cycle that could invalidate them and, therefore, a new assessment would be required.

- **IFI Framework: Renewable energy projects**

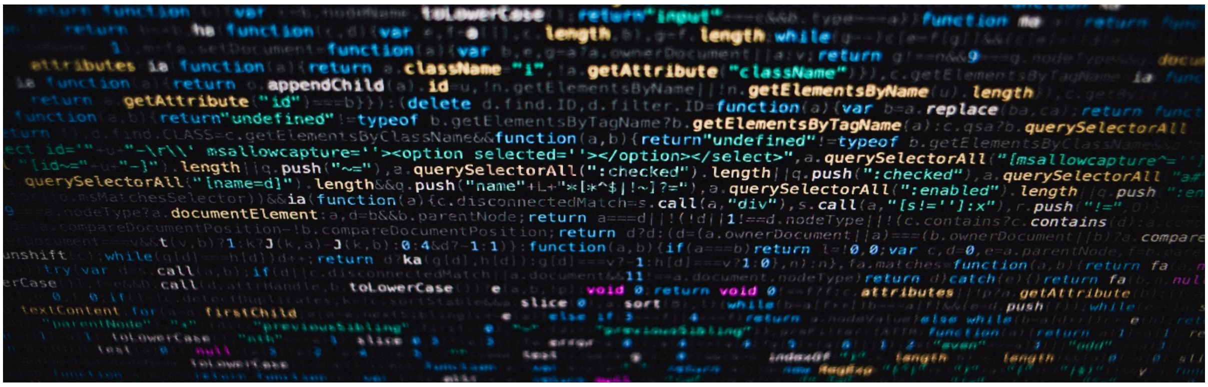
This framework considers time when assessing the prospective or future power plants that will be affected by the renewable energy project. The estimation of that cohort is what it is called the Build Margin (BM). To calculate it, the "common dataset uses an average of the annual emission intensities of new electricity generation projected over the next 8 years".

- **IFI Framework: Energy efficiency**

The time reference is the lifetime of the facility.

- **Conclusions**

In general, when considering aggregated impacts over time, there is a wide range of considerations. Some frameworks would consider only the time during which the solutions are operational, others 1 year, 2, 8, 30 and even 100. It becomes then very difficult to compare different solutions that would compound the life duration of each solution, including end-of-life impacts, during a specific period if that period is not commonly accepted.



10. Technology Readiness Level (TRL)

The Technology Readiness Level (TRL) is a scale that measures the maturity level of a solution. It was first developed by NASA to evaluate the technological systems to be implemented in their operations in the 1970s. Overtime, it was evolved and ultimately adopted by the EU as well.

The TRL scale is composed by 9 different levels depending on the level of development of a technology. They provide a reference for different solutions to be measured in terms of development against a third set of criteria, which provides "a common understanding of technology status" and thus simplify the decision-making processes.

The TRLs in Europe are as follows:

TRL 1 – Basic principles observed

TRL 2 – Technology concept formulated

TRL 3 – Experimental proof of concept

TRL 4 – Technology validated in lab

TRL 5 – Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)

TRL 6 – Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)

TRL 7 – System prototype demonstration in operational environment

TRL 8 – System complete and qualified

TRL 9 – Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

Some solutions are expected to have a certain level of impact, but they are still under development. That implies two different types of uncertainty: 1.- the further in time a solution is introduced in the market, the higher the uncertainty of how that market is going to be; 2.- The less developed a solution is, the higher the uncertainty about its final net performance. In addition to that, the potential impacts can be deferred in time. Therefore, the TRL of an innovation can be crucial to the outcome of the assessment. (Wikipedia, 2020)

However, some shortcomings for this type of measurement of technology have been identified:

- Readiness does not necessarily fit with appropriateness or technology maturity
- A mature product may possess a greater or lesser degree of readiness for use in a system or context than one of lower maturity
- Numerous factors must be considered, including the relevance of the product's operational environment to the system at hand, as well as the product-system architecture mismatch.
- Currently TRL models tend to disregard negative and obsolescence factors.

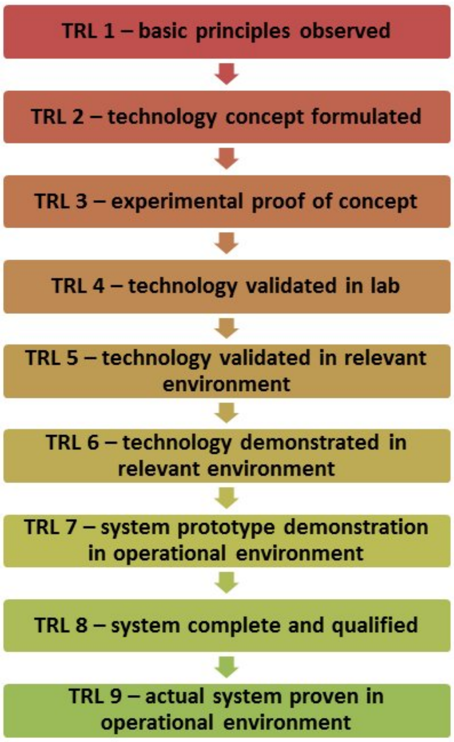


Figure 7. TRL according to IEEE/ACM 2nd International Workshop on Software Engineering Research and Industrial Practice (SER&IP) (2015)

We know from our interview with certain investors, among which Breakthrough Technology Ventures, that they also consider TRL in the assessment of potential investments. However, it is unclear how they are really using them since we do not have any information of their process, only their concepts, and they have always been laid out very ambiguously.

The only framework that deals with TRL is the Avoided Emissions Framework.

- **Avoided Emissions Framework**

The framework works with the TRL in different ways.

Firstly, it helps roughly estimate potential for avoided emissions: all other things equal, a higher TRL solution is considered to have a higher avoided emissions *potential* than a solution with lower TRL

Secondly, the framework can provide direction for development of the solutions themselves. The potential for change can be more fundamental in an early stage TRL solution and more detailed in the case of a more developed TRL solution.

Finally, the FW can help assess different scenarios "in terms of the uncertainty of the solution, and how this might impact the magnitude and timing of the potential emissions reductions".

Regarding the solutions:

"Low TRL solutions may have a significant potential future impact but will likely be many years until the market impact is significant. High TRL solutions might also have impacts in more than one market, where the innovation could apply to other markets.

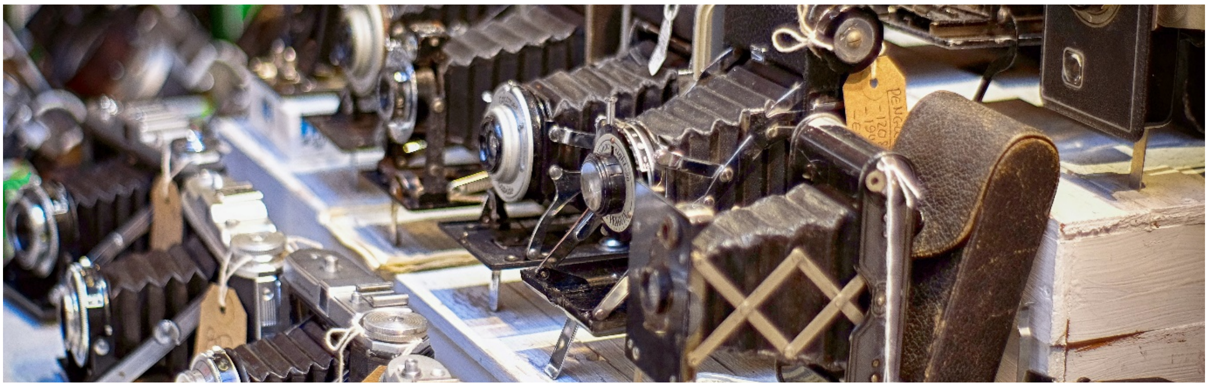
For low TRL solutions, by definition, it is difficult to get reliable representative data, (especially where there is no commercial solution yet available, so no field data available). It is therefore likely that there will be large uncertainty in the result, and it will be necessary to rely on expert opinion.

In these cases it is recommended to follow an approach such as:

1. Test if the solution is 1.5C compatible
2. Research to see if there are studies available that can help the assessment.
3. Use a moderated expert opinion"

Conclusion

TRL is often disregarded in many frameworks, probably due to its dynamic nature over time and the difficulties to quantify them in calculations. It is likely a qualitative aid but offers no computational value.



11. Baseline

The baseline is the product/service that a new solution would be substituting in the market and the one we use to compare the differences in emissions. It is generally the most adopted product/activity that provides the same service to the same market, in the present or in the foreseeable future. The baseline can change depending on the timeframe, according to the development of the market, and depending on the geographical distribution.

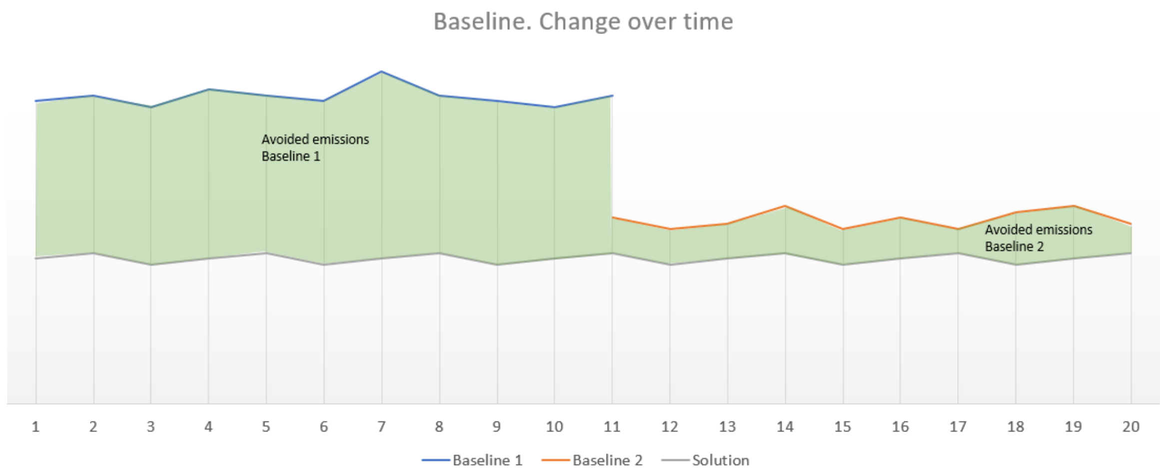


Figure 8. Baseline. Change over time

This complexity potentially leads to choose different baselines if different assessments of the same product are undertaken, or to choose the wrong baseline altogether. The choice of the wrong baseline might offer the wrong results, over or understating the avoided emissions generated by the solution. It seems necessary to establish a set of criteria that will improve replicability of the results (in this case, the choice of baseline) while using different frameworks or assessment processes.

Only one framework considers the past performance of the product as baseline, and that is the **GHG Protocol for products**. However, as we saw, this is a framework that mostly deals with reporting impacts of an existing product and not so much to quantify the avoided emissions of a potential solution. This baseline is mostly used to track carbon inventory improvements. The other reporting protocol, the **PAS 2050:2011**, does not address it at all.

For the rest, most of them consider the baseline the state of the world or the market in the absence of the project or solution under assessment. However, the criteria to choose the baseline or baselines and the depth of the studies vary greatly from one to the other. Below we can see a summary of the different conditions that baselines are subjected to, the criteria use to choose them, and the examples presented to understand what it is, according to each framework.

- **Avoided Emissions Framework**

The BAU (Business as usual) scenario would represent the situation without the enabling solution. It refers to the "before" scenario, the one before the assessed technology. It acknowledges the importance of update and review the choice of baseline due to the rapid change in the technologies to keep accuracy of the analysis.

Main questions to be considered when looking into baseline according to the AEF:
- What should the baseline reflect? ("the most appropriate widely used alternative" or "what is most likely to be sold instead of the solution under assessment"?)
- Are there multiple baselines? There might be different baselines or a combination of all of them depending on the assessment's geographic boundaries.
- Will the baseline change over time? Depending on the pace of advance of the technology, it might be necessary to periodically re-assess the baseline. It is recommended to reassess every 5 years
- Future projections for long life products. Changes in market, regulation, etc, will have to be included on the baseline future scenarios.

- **Greenhouse Gas Protocol – Project**

This document presents an extensive explanation of how to select a baseline procedure, identify the baseline candidates and estimate the emissions. We will schematically represent them below.

There are two baseline procedures acknowledged by the protocol:

- Performance standard procedure, preferred when:
    - A number of similar project activities are being implemented
    - Obtaining verifiable data on project activity alternatives is difficult
    - Confidentiality concerns arise with respect to the project activity,
- Project-specific procedure will be preferred when the number of baseline candidates is limited or GHG emission rate data for baseline candidates are difficult to obtain.

There is an option to use both procedures if "the baseline scenario could be represented by a blend of alternative technologies, management or production practices, or delivery systems." In this case, both procedures should be entirely performed.

There are 6 steps that should be taken to identify the baseline:

1. Define the product or service provided by the project activity. Only consider direct, primary effects and outputs.
2. Identify possible types of baseline candidates. Useful questions:
    a. What alternative new or existing technologies, management or production practices, or delivery systems would provide products or services, similar to the project activity?
    b. What alternative management, production or delivery systems of others use to provide the same product(s) and/or service(s) as the project activity?

   c. What is the production, management, or delivery system most used to serve the same market as the project activity?
   d. If any, what is/are the status-quo technologies, management or production practices, or delivery systems?
3. Define and justify the geographic area and the temporal range used to identify baseline candidates.
   a. Geographic area: the geographic area is influenced by several factors. It is supposed to start on national level and then move to larger or smaller regions, depending on: the maturity of the technology the baseline candidates represent, and if their variation depends on human-influenced factors, presence of infrastructure and biophysical/ecological characteristics, the location of the baseline can influence the choice to make it more relatable to the project under assessment
   b. Temporal range: "The temporal range defines the appropriate time period from which to select the relevant baseline candidates, and is based on installation, implementation, or establishment dates of the various technologies, equipment, or practices." It is recommended to start with 5-7 years. Rules of thumb to choose the temporal range are: longer if market hasn't changed over time and a practice dominates the sector; longer if there are several and varied potential technologies or practices to make sure that the baseline candidates are representative; shorter in a sector of quick changing technology; if the sector has suffered a relevant policy or legal change, then the temporal range has to correspond with that point in time.
4. Define and justify any other criteria used to identify baseline candidates: Other criteria can refer to legal requirements and common practice.
5. Identify a final list of baseline candidates: "Those that fall within the defined geographic area and temporal range and provide the same product or service as the project activity." In the case of a large number of baseline candidates, statistical sample may be used to define the final list.
6. Identify baseline candidates that are representative of common practices (project-specific baseline procedure only). For performance standard procedure it is not necessary because the rates of market penetration for different baseline candidates will be directly reflected in the baseline emission rate derived using that procedure.

There are two different systems to estimate the baseline emissions, depending on the use of project-specific procedure or performance standard procedure. These processes not only help determine the emissions but give an initial idea of the viability of the project itself.

In the case of using the project specific procedure (fewer cases), the steps to follow to define a baseline and calculate baseline emissions are:

- Comparative assessment of barriers of the alternatives, including the 'do nothing' alternative. This should be mainly quantitative, but a qualitative analysis could be used as well
- Identify and justify the baseline scenario by the analysis of the projects' barriers and how to overcome them, and later choosing the most conservative viable alternative or the one with greatest net benefits.
- Then use the GHG emissions rate of the baseline to calculate the emissions during the chosen time. In the case baselines changing overtime, there can be two periods of time for reference or a combined emission rate.

In the case of standard performance procedure, we can find two different definitions of emission rates, depending on the type of activity. Production-based performance standard refers to projects in energy efficiency, energy generation and industrial processes. The emission rate is expressed in relation to units of production. On the other hand, time-based performance standard is applied in the case of CO2 storage and removals, fugitive emissions, and waste emissions. The emission rate is expressed in relation to time and size or capacity of the plant.

To calculate the baseline emissions, we need to calculate the performance standard as the baseline emissions rate. Considering the emission rates of all the possible baselines, we must define a level of stringency (the best, the median, etc) and justify the choice. That will give us the emissions rate to use in the baseline emissions calculation.

For production-based performance standard, based on unit of production, the baseline emissions are the baseline emission rate times the total production. For time-based performance standard, the baseline emissions are the product of the emission rate times the time (normally 1 year) and the total size of the projected installation.

- **CRANE tool (PRIME coalition)**

The emissions of the product displaced (what we call the baseline) is studied using an LCA approach, this is, considering the product's and the displaced product's emissions during their entire life cycle. This also provides the option to use public databases to obtain data.

The impact estimated should be calculated considering some aspects:

- In the case of long-lived products, the sale of one unit of product would entail the saving of all the emissions of one displaced product on the year of sale. (Note: this implies that both products will be similarly lasting).
- Future progression of the displaced product's emissions: the market and the products are constantly changing. Therefore, the impact of a product that has been displaced will be different now and in the future. Three different scenarios are identified: assume that future trends follow historical trends; assume that industry-specific targets are met; assume there will be no change. However, it does not say how that change should be computed in the calculations, just the different scenarios and the need to justify the choice of one over the others.
- Will the product displaced today be the same one to be displaced in the future?
- Product emissions need to be translated to displaced emissions per unit of product deployment (or service provided, such as in the case of PV panels, that should be expressed as emissions displaced by unit of energy provided)

- **Drawdown project**

The baseline assumed in this project is a world in which no new climate action is taken.

- **Addressing the avoided emissions challenge – WBCSD (Chemical sector)**

The baseline is a solution or product which delivers the same function to the end user as the product under analysis. It also must be well established in the market, with a high market share, or the weighted average in shares of all the products providing said function.

"Solutions to compare shall:

- Be at the same level in the value chain
- Deliver the same function to the user
- Be used in the same application
- Be distributed/used on the market, and not in the process of being banned, in the reference time period and geographic region. For the solutions to be compared at a specific level in the value chain this implies:
    - If the study is conducted at the chemical product level, any alternative established product(s) with a high (combined) market share, based on sales volume in the reference year, shall be used. A sufficiently high market share is normally considered to be 20% and above.
    - If the study is conducted at the end-use level, the weighted average based on shares of all currently implemented technologies for the same user benefit (including the studied end-use solution to which the chemical product contributes) shall be used.
- Be exchangeable for the typical customer in the selected market in terms of quality criteria
- Be as consistent as possible with the solution of the reporting company in terms of data quality, methodology, assumptions, etc.

Describing the solutions to compare:

- The reporting company shall clearly describe how the boundaries of the market and the application have been defined
- Both the solution of the reporting company and the solution it is compared to shall be described in similar levels of detail
- The description shall include the reference flow, i.e. the amount of the chemical product on which the result of the study is based
- The description shall discuss all aspects of all compared solutions which have a material impact on the emissions generated during the life cycle
- If the study is conducted at the end-use level, the description shall detail how the chemical product is used as part of the end-use application."

- **EIB – Project carbon footprint methodologies**

The baseline according to this framework is a theoretical "without project" scenario, the expected alternative that would meet the output offered by the project under assessment.

The baseline alternative must deliver equivalent outputs to the project and be credible in economic and regulatory requirements.

- **Evaluating the carbon-reducing impacts of ICT – GeSI**

This document uses an LCA approach to assess the changes to the Business-as-usual (BAU) system as a result to the adoption of the ICT solution. That BAU is what we are referring to as the baseline for this framework. It is defined as the world as it is before the implementation of the ICT solution. It must be defined but the framework does not really state how.

- **Guidelines for assessing the contribution of product to avoided Greenhouse Emissions – The Institute of Life Cycle Assessment – Japan**

iLCAj defines the baseline as the state of the market where the solution is absent. The "product for comparison" that will be the baseline could be either the final product, if the target product is the final product, or a component. If the target product is a component, then the final product that would be using the component is the baseline. "Functional unit for both systems of final product(s) which achieve the reduction effects and the baseline shall be absolutely identical" (Emphasis added).

Possible choices for the product for comparison:

- Product(s) with highest market share.
- Those publicly assumed as the average of the product category.
- Previous versions of the same product in the same company
- Existing product(s) before the new solution is developed, or
- "Product(s) that can be fitted for standard values that are determined based on legislations or regulation.

- **Accounting and reporting protocol for avoided emissions along the value chain of cement-based products**

The baseline that needs to be specified needs to be uniform regarding all the saving categories that are considered. The baseline solution should be the one that acts as the predominant standard solution in the market segment that has been chosen, while delivering the same user benefit and there will be only one baseline for each market segment.

In the case of some of the saving categories, such as energy efficiency and roads, "Whenever possible country clusters for specific building types shall be defined. For each country/country cluster a typical building shall be defined by a typical composition as well as the key parameters of the energy modelling."

- **IFI Framework: Renewable energy projects**

The baseline is the current energy production for the proposed project. In this case, the baseline would be the emissions of the current electricity mix in a country. However, in the case of a project substituting a specific facility, then assessment of the baseline, or facility to be substituted, can be used.

- **IFI Framework: Energy efficiency**

For this framework, the baseline should be viable for the expected project lifetime.

There are two ways of dealing with the choice of baseline.

- If outputs are similar in the case of the pre-investment condition and the solution, the pre-investment facility would be the baseline until the expected end of its life
- If the output of the post-investment facility increases significantly, the pre-investment condition will be the baseline until that capacity and during its expected lifetime. If that exceeding capacity will be covered by additional facilities to be built in the future, the baseline for it could be considered a no-project scenario or through benchmarking with energy efficiency sources of existing production or for efficient new technologies or the combination of both.
- The increase in production during the lifetime of the pre-investment facility can be "represented by a benchmark comprised of existing sources of energy efficient production". In the case of the production after the end of life of the pre-existing facility, "should in principle comprise energy efficient new technologies or a relevant benchmark of the most energy efficient existing technologies may be used".

- **IFI Framework: Transport**

Baseline is the situation in which the project does not exist and without an alternative new project, "while investments to ensure the integrity of existing infrastructure and cater for demand, if any, would be included"

There is the possibility of having a dynamic baseline regarding demand and the parameters impacting demand.

"Conservatism in terms of assumptions implying emissions reductions within the net GHG emission calculation is an overarching general principle."

- **Estimating and reporting the comparative emissions impacts of products – WRI**

Attributional approach: to claim past impacts in the marketplace, the reference product should represent what would be most likely sold in the absence of the assessed product.

Attributional and consequential approaches:

- The assessed product is a component: use few representatives final products and reference products to ensure representative results.
- Long lived products: account for policy and non-policy drivers that can affect the elements in the system boundary over the assessment period (sinks and sources), such as changes in efficiency standards.
- Other option, in the case of attributional approach, limit the validity of the assessment to one year
- Use "marginal" emission factors in the case of renewable energy product.

- **Conclusions**

Most of the frameworks dealing with forecasted emissions consider a baseline to compare with and claim the amount of carbon saved/avoided/reduced. In the case of reporting frameworks, the baseline would be considered the same organization or process in an earlier year.

12. Market Analysis

The number of units of product or service that are set in the market is fundamental to quantify the potential for avoided emissions. A product or service that has a high reach will have a higher impact than another that reaches half the customers. This analysis can be made either looking offer side of the solution (how much of it will be produced) or the demand side (the market penetration or share that it is estimated to reach). Since the impact will often be allocated to scalable solutions without increase in manufacture, as in digital solutions, and others for which the use phase will have an important effect on the overall impact, we will not consider the offer side of the analysis (production) but by the demand, the market penetration or market share, as a way of estimating the units that can potentially be sold.

The market penetration accounts for the impact aggregation related to the implementation of a product or service across the market. This means the addition of every offer that has the same product or service from every company that does so. *"For example, if there are 300 million people in a country and 65 million of them own cell phones, the market penetration of cell phones would be approximately 22%. In theory, there are still 235 million more potential customers for cell phones, or 78% of the population remains untapped. The penetration numbers might indicate the potential for growth for cell phone makers."* (Kenton, 2019) The higher the market penetration, the higher the positive or negative impact. For this reason, it is important to consider what the market of the proposed solution will be and how much of it the solution will hold in relation to the baseline/s.

Market share would be the share of a specific company's solution of that overall penetration in the general market.

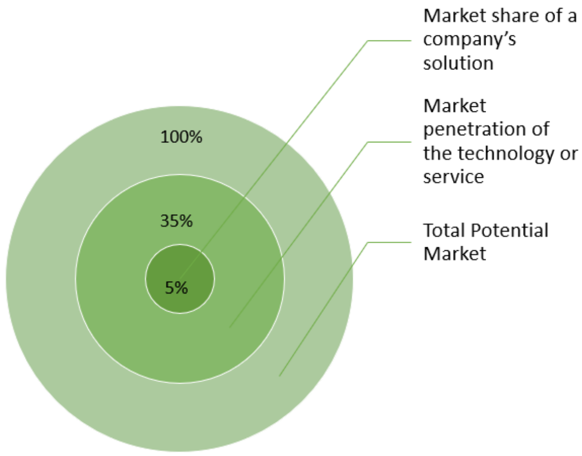


Figure 9. Market size/penetration/share

Most of the frameworks analysed do not consider market conditions at all: market size, penetration, or share. Those would be **GHG Protocol for Products, Drawdown, EIB, GeSI, PAS 2050:2011, IFI Renewable Energy Projects and IFI for Energy Efficiency Projects**.

The most common use of the market conditions is for the choice of baseline. The frameworks analyse what the current market is like to choose a solution or group of solutions as baseline in comparison with other existing alternatives. The frameworks that have this baseline consideration are:

- **Greenhouse Gas Protocol – Project**

It is only considered when looking into the baselines as one of the factors to determine common practice or predominant technology or practice. The protocol establishes that market penetration should be understood regionally and within a specific sector. It is calculated as the percentage of plants or total output that corresponds to each baseline candidate, so it is not a future estimation but a calculation of the current state of the art, so a baseline can be calculated. The future penetration does not seem to be considered. This can also affect the timeframe.

- **Addressing the avoided emissions challenge – WBCSD (Chemical sector)**

Used mostly for the definition of baseline as an ex-post element.

- **Guidelines for assessing the contribution of product to avoided Greenhouse Emissions – The Institute of Life Cycle Assessment – Japan**

Market share is used to define common practice for the baseline definition. When considering the target product, the uncertainty of the market reaction to it is solved by reporting "avoided emissions per functional unit", therefore the market penetration and share are not important factors in this framework.

The rest of the frameworks consider the potential market conditions for the solution or project under assessment in a way or another:

- **Avoided Emissions Framework**

There is no clear reference to market penetration in this framework. What is considered are the concepts *market share* and *market size* of the specific solution that is under assessment. This will require a study for both market size and share, and for behavioural changes as well. These aspects are considered in the calculation of the volumes that would be sold/put in use in the case of the services and the products under assessment. The forecast of this volume would take into consideration the probability of technical success and, most importantly for this part, the probability of adoption, which would be dependent on the market share that the product or service will take. To make this forecast, there are different aspects that can be assessed:

- Some solutions are disruptive and can create new markets and render existing technologies obsolete, which is difficult to predict.
- It is important to consider the existence of other solutions in the same system that might be related to the assessed initiative and perhaps be interdependent with each other, such as in the development of new markets or infrastructure. In that case, the assessment should be made in cluster.
- A key question for future solutions is how to assess what the future market size will be, and what market share the solution will have. A solution may be an *enabler* (e.g. charging infrastructure) that is helping to create a market (market maker) or may be relying on a market to develop *(market taker)*. The projected market share may be based on an extrapolation of existing market developments, or it may be based on the market that the new solution is expected to develop. This will also in turn *depend on whether the market already exists or if it is being developed*. If a solution is not yet developed commercially, then when is it expected that it will enter the market (e.g. is 5 years or 10 years in the future a reasonable assumption?), and *what is the penetration speed expected?* They do not consider specific frameworks or references that could help underpin these perspectives.

- **CRANE tool (PRIME coalition)**

PRIME seems to use Market Penetration as a synonym for Market Share, although it later specifies that it is the entire market for the type of product the company is developing, not only the specific product made by the company.
"Compare several market deployment/penetration business scenarios for a specific venture's product to calculate and forecast multi-year ERP estimates. Scenarios could include:
• A baseline set of scenarios used for all companies to enable comparison across similar and dissimilar companies
• Best/worst/average case scenarios for comparison
• The company's own forecast of market deployment/penetration of its product (which is typically overly-optimistic)"
The standardized methodology to calculate the market penetration of a solution (as an alternative to the calculations undertaken by the company or an investor) is as follows:
Assume a S-shaped penetration curve. This adoption curve requires the definition of three parameters to be developed:

- M: Maximum penetration that a product will be able to achieve (percentage, between 0 and 100%). 100% recommended by the framework for standardization purposes. Here the use penetration to avoid the possible differences between market shares of products that share the market.
- k: factor of speed of penetration. The higher the value, the faster the product penetrates
- x: The year in which the product achieves the 50% of its maximum penetration.

There are two primary paths for estimating x and k. The first involves using an appropriate benchmark such as the rate of penetration of a similar product or venture (using historical data). The second simply involves making an assumption to provide comparability.

$$Penetration\ in\ year\ y = \frac{M}{1 + e^{-k(y-x)}}$$

- **Accounting and reporting protocol for avoided emissions along the value chain of cement-based products**

This framework considers market implications in terms of potential market (market penetration) but does not define how to estimate it.

- **IFI Framework: Transport**

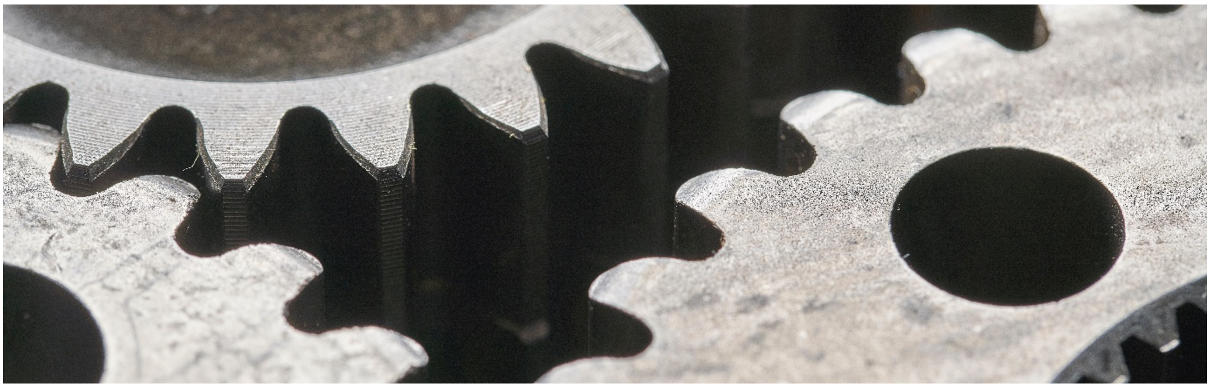
The framework includes a demand analysis on "how transport policies and projects induce changes in transport demands, fossil fuel use, and GHG emissions. This analysis should take account of the main drivers of user behaviour, in particular income, monetary travel cost, and travel time." However, market share and penetration on a broader setting is not considered.

The last framework shows a dual approach. The draft paper for the **WRI** on **Estimating and reporting the comparative emissions impacts of products** suggests two different approaches for the comparison of two different products: the consequential and the attributional approach. Depending on the approach used to undertake the assignment, the treatment of the market conditions will be different.

In addition to the choice of baseline, the analysis of market conditions is only recommended in the consequential approach, since scaling becomes non-representative when using the attributional approach. In the case of the attributional approach, we would only work with existing data and impacts are calculated only at a functional unit level. When using the consequential approach, we can forecast changes in the market size and therefore have a more accurate view of the potential amount of product that can be sold in the future.

- **Conclusions**

Both market share and market penetration will influence the impact that a solution will have in terms of forecasted emissions. It is obvious that a solution with a positive climate impact that is widely accepted will lead to more GHG emissions savings than if a less positive initiative takes that place. However, just a few frameworks consider either of them as a key element in their assessments.



13. Allocation

ALLOCATION/ATTRIBUTION/CONTRIBUTION

When looking at the emissions of a process where different actors are involved, distributing the impacts can be difficult. For instance, a product's avoided emissions can require a specific material that needs to be produced by another party. How much of the avoided emissions should be allocated to either company? It could also be the case between different products or solutions in the same company that share some production processes. If they did not co-exist, the total emissions of each of the products would be different, therefore potentially changing the impact of each of them if taken together.

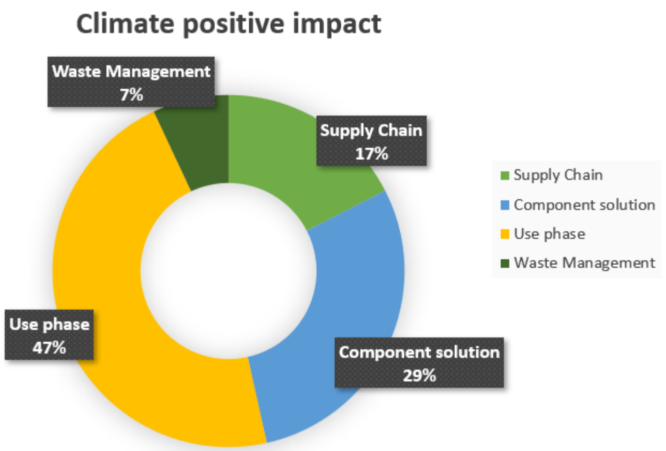


Figure 10. Exemplification of the allocation of a certain impact to different actors/phases within the general process

DOUBLE COUNTING:

Double counting is the fact that the same emissions (avoided or emitted) are allocated to two or more sources. To control this issue, GHG protocol came up with the 3 emissions scopes, in which the emissions are classified according to the source.

Scope 1: Direct emissions. These are the emissions that the company directly emits from its operations. It would include emissions from the company's vehicles or the emissions from the exhaust of a biomass power plant.

Scope 2: Indirect emissions. This scope englobes the emissions that are attributable to a company because of what it consumes in its operations. They would mainly be the emissions from the electricity consumption. These emissions are not produced directly by the company, but they are required for their internal processes. The emissions would be in the Scope 1 from the electricity company. There is no double counting because they belong to different scopes for each company. This is not double counting as understood by the GHG protocol.

Scope 3: Corporate value chain emissions. This scope englobes all the emissions related to the extraction, production, and transportation of all its raw materials and components even if they buy them from other vendors. This scope also comprises the emissions of the use phase and end-of-life of the company's product or solution. This is generally the goal of enabling solutions and avoided emissions, that are trying to reduce the emissions downstream. Double counting is admitted in this scope, that is why it must always be reported separately from the rest.

ADDITIONALITY

The fact that a saving in emissions would not have occurred but for the existence of the solution, product or service that is being assessed. If there is no additionality, the products should not be allocated any emissions savings.

There is a UN Methodological tool for demonstrating additionality which clearly reflects the questions worth asking before claiming additionality.

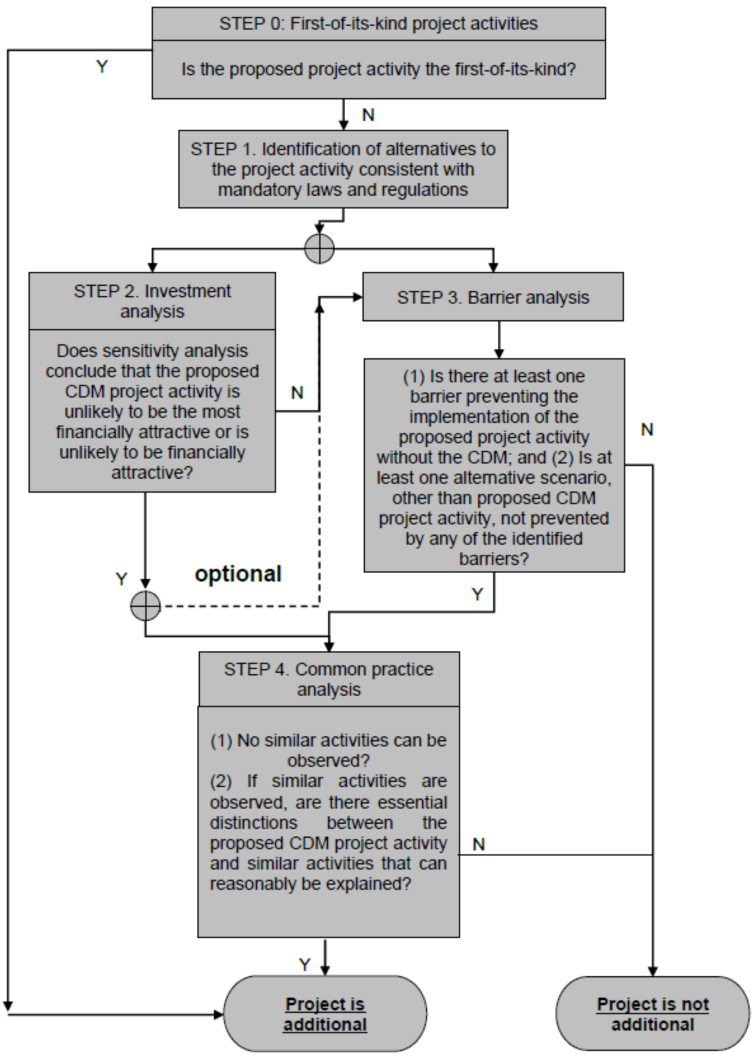


Figure 11. Additionality decision tree. UN

In general, most frameworks consider allocation in a way or another, and they provide a set of rules to disclose the impacts accordingly. However, there are still some of them who do not include this issue at all. We are talking of *GHG Protocol for Projects*, and all the three protocols from the *IFI (International Financial Institutions)*.

The rest of the frameworks, as said, do acknowledge the need for allocation in a way or another.

- **Greenhouse Gas Protocol – Products**

The GHG Protocol for products develops different types of allocation. Some systems work only for allocating between products and co-products in the same life cycle, and others are only used when different life cycles are assessed.

Methods to perform allocation between all the products and co-products (not waste):

- Physical allocation: "based on the underlying physical relationship between the quantity of product and co-product and the quantity of emissions generated"
- Economic allocation: "based on the market value of each"
- Other: in case of existence of other established and justifiable relationships.

In the case of allocation between product life cycles (important in the case of recycling):

- Closed loop: "type of system expansion, accounts for the impact that end-of-life recycling has on the net virgin acquisition of a material"
- Recycled content method: "allocates the recycling process emissions and removals to the life cycle that uses the recycled material"

- **CRANE tool (PRIME coalition)**

They only consider additionality. Additionality is important to avoid an overestimation of the impact of the product/solution. The types of impact that should be included in an analysis of additionality are:

1. Improve the performance of a GHG emitting product. "the impact of the new venture's deployments is equal to the decrease in emissions associated with the increased performance of the incumbent product. "Rebound" can be important for some performance improving technologies. In some cases, rebound effects can result in net increases in GHG emissions. (…) Absent concrete information regarding rebound, make one of two assumptions: first, that there are no increases in sales or use of the emitting product due to its increased performance, or second, assume that only a fraction of the estimated efficiency gains will be achieved (following the conservatism principle)"
2. Improve the performance of an existing low GHG product. "the impact of the new venture's deployment is equal to the increase in displaced emissions associated with the increased performance of the incumbent low GHG product."
3. Increase the deployment of an existing low GHG product. "the impact of the new venture's deployment is equal to the increase in sales that occur due to the increased competitiveness of the product". Extensive knowledge about the elasticity of demand for the product is required.
4. Introduce a new low GHG product into a market without existing low GHG products: "The impact of the new venture's deployments is equal to the displaced emissions of the incumbent product".

- **Drawdown project**

Drawdown project disclaims the importance of avoiding double counting and to consider system and solutions interaction, but they do not really disclose how that is being modelled. Many solutions and systems are studied separately but they do not show how the potential interactions with each other are accounted for. “Model integration ensures that resource constraints are accounted for (e.g., available land for forests or crops), avoids any double-counting of impacts from overlapping solutions (e.g., different modes of transportation), and addresses interaction between solutions where possible (e.g., increasing demand for electricity from electric vehicles or electric heat pumps).”

- **Addressing the avoided emissions challenge – WBCSD (Chemical sector)**

This framework has its own definition of attribution. “Avoided emissions calculated at the end-use level shall always be attributed to the complete value chain”. To clarify this issue and communicate the clear double-counting, the reporting company should report not only the total emissions avoided, but its actual contribution to the end-use solution. This can be: fundamental (enabling), extensive (key to enabler), substantial (doesn’t contribute directly but it is hard to substitute without changing the GHG emissions), minor (doesn’t contribute directly to the avoidance and it is used in the manufacture of a fundamentally or extensively contributing product), too small to communicate (it can easily be substituted without changing the GHG avoiding effect of the solution).

If one of the companies involved in the value chain wants to attribute a specific share as additional information, then all the value chain needs to be assessed and several steps need to be taken. Often attribution of emissions will be based on physical relationships, which is not possible if service providers are not part of the value chain. Companies should refer from comparing avoided and caused emissions, since no prescriptive guidelines have been developed.

- **EIB – Project carbon footprint methodologies**

EIB’s framework only addresses allocation in the example of CHP plants, and to that it references to a tool designed under the GHG protocol.

- **Guidelines for assessing the contribution of product to avoided Greenhouse Emissions – The Institute of Life Cycle Assessment – Japan**

The allocation of the impacts should be based on the level of contribution by each of the components and services in the production of the final product, following the consensus amongst stakeholders or independent evaluators to determine it, which increases the potential for subjectivity.

“In the case where the contribution ratio cannot be quantitatively determined, qualitative explanations about how the target product(s) contributes to the avoided emissions through the life cycle of final product(s) which achieve the reduction effects shall be provided in communication as additional information, along with the calculated results of avoided emissions.”

- **PAS 2050:2011**

This framework describes several instances and how to calculate the allocation in each of them:

- Co-products: The strategies would be in order of preference:
    - Divide the unit processes into two or more and collect input-output data from each of them

  - Expand the product system to include additional functions:
    - A product that is displaced by one or more of the co-products of the process being considered can be identified; and
    - The avoided GHG associated with the displaced product represent the avg emissions arising from the provision of the avoided product.
  - Physical allocation.
  - Economic value

- Waste:
  - Generally, emissions are allocated to the product system that generated them
  - Waste combustion with energy recovery: the emissions are allocated to the generation of energy
- Recycling: Annex D (not especially clear, deals enough with the recycled content on new products)
- Reuse: each part of the process needs to be measured to obtain the total GHG emissions
- CHP: use emission ratios depending on system
- Transport: allocation places on the limiting factor: either mass or volume.

- **Estimating and reporting the comparative emissions impacts of products – WRI**

Allocation in this framework is defined by consensus of all the stakeholders, which would define the contribution rate.

- "If the assessment has been performed with value chain partners, conduct attribution based on a percentage agreed upon with those partners and report the attribution method and percentage.
- Disclose that the total comparative impact reflects the collective effort of the entire value chain."

There are some frameworks that directly relate to ISO certification schemes to define the mechanisms under which allocation should be made within their method. Those are **Accounting and reporting protocol for avoided emissions along the value chain of cement-based products,** which refers to ISO 14040 / 14044 for allocation rules. In addition to that, "A sensitivity analysis should be conducted to identify the impact of any allocation done". At the same time, E**valuating the carbon-reducing impacts of ICT – GeSI,** references ISO 14044 – Environmental Management – Life cycle assessment – Requirements and guidelines, for allocation procedures.

The only exception in this case would be the **Avoided Emissions Framework**. It does acknowledge the need for allocation, but as a default allocates all the emissions to the fundamental enabling solution, instead of allocating it to the entire value chain. That, in turn, is the source of issues, the main ones being double counting and the lack of reference to the real relative importance of the solution in the system.

"It is common practice to attribute all the avoided emissions to a solution where that solution has a fundamental role in **enabling** the avoided emissions (…) The avoided emissions would only be realised with the existing of the solution" (Emphasis added).

Issues:

- Existence of double counting

- The claimed avoided emissions might not be representative of the actual importance of the solution.

Why emissions are not allocated:

- Complex, expensive, and uncertain process.
- Scope 3 allows for double counting and avoided emissions is seen as the "positive side" of scope 3 emissions.
- No obvious solution exists.

In the case an organisation wants to allocate the avoided emissions, different approaches for this are:

- Equal allocation
- Financial cost attribution
- Financial value attribution
- Stakeholder consensus

Ways to avoid double counting:

- Multiple contributors to the same solutions: as explained before, either one contributor assumes all the savings or some of the above approaches are used.
- Accounted for in other GHG scope: emissions should be clearly framed in the proper scope, and emissions reductions in scopes 1 and 2 should not be considered in the avoided emissions calculation.
- Overlapping products of the same company: when two products contribute to the same avoided emissions, those should be accounted for only once.

- **Conclusions**

Most frameworks consider the importance of allocation, attribution, additionality, and double counting, to the point that many of them would device processes to try and quantify them to be included in the calculations. However, in some other cases, they are not at all considered. The fact that there is not an agreement on its use can provide misleading results if aggregated with other solutions in the future. It is important to acknowledge its existence, at least, even when calculating Scope 3 emissions which allow double counting.

In addition to that, many frameworks rely on the agreement by advisors or stakeholders, which would analyse every case independently, therefore decreasing the potential for standardisation and comparability of results.

14. Study case

To analyse the importance of the elements we have previously defined, I have undertaken the analysis of existing solutions following the methodologies of the different frameworks. To study the potential differences, I have defined a scenario analysis in which every element represents a different scenario. These calculations can be consulted on the annexed excel files.

The development of the process is as follows:

- Firstly, an initial set of data is defined for each project.
- Secondly, a few scenarios are defined according to the relevant elements, one scenario per each.
- Thirdly, the initial set of data is modified only regarding the relevant element in each scenario, therefore obtaining the influence of such scenario considering all other things equal.
- Fourthly, the ranges and the percentual change in results is calculated for each of the scenarios.
- Finally, the quantitative results are reported here along qualitative considerations.

The goal of this section is to quickly pinpoint the potential of variability of assessments and the areas where we can expect to find most of the issues. The parameters under quantitative study are the following ones:

a. System boundaries
b. Geography
c. Timeframe
d. Secondary effects
e. Market effects
f. Allocation

There are a few limitations to this methodology, mostly considering the complexity of the systems under study. For a deeper study it would be positive to develop a mathematical model that could take into consideration complex interactions among all the defined elements (o parameters). However, the scope of this project is not to provide a highly accurate account for differences, but to point to the existence of the differences for which we understand that the current method is sufficient.

A second limitation is the fact that not all frameworks will be applicable to a specific solution. One of the clear ones in the study case below on bioplastics for feminine products is IFI Transport. However, whenever possible, the considerations from the frameworks have been taken into account.

Another limitation is the lack of information in some of the updated versions of the frameworks, such as in the case of the framework on ICT impacts by GeSI and the final algorithms used in the CRANE tool. However, we consider that the current report does represent the main issues that seem to still exist, and that are the different considerations and approaches existent in terms of forecasted emissions of products, projects and solutions and their influence in society in technological and social levels.

Bioplastics for feminine products (Next period)

Next period is a start-up that is in the process of developing a bioplastic that can be used in feminine products, such as sanitary napkins, to reduce the use of fossil fuel plastics. Feminine products are used by women aged roughly 12 to 52 on a monthly basis in most of the world. The impact in terms of production and waste related emissions has a potential to be significant. Therefore, the solution proposed can help avoid emissions if we compare it with the traditional products.

The initial calculation used in the study considers the following data:

Baseline	Mainstream tampons (with applicators) and sanitary pads
System Boundaries	Cradle to grave
Geography	Global
Time Frame	10 years
Secondary effects	None considered
TRL	Low (TRL 3 Assumed)
Market penetration	Potential for a 5% *market share*. No information on market penetration.
Allocation	100% of savings allocated to solution

The results of the calculation lead to 54,000 tons saved each year, therefore 540,000 during the entire period under consideration (see excel).

BASELINE

The baseline has not been analysed from a quantitative perspective but only from a qualitative one. In the base scenario, only the feminine products that are currently mainstream from a commercial perspective are considered, which are sanitary napkins and tampons with applicator. However, there are alternatives that are overlooked: tampons without applicator, reusable cotton napkins, menstrual underwear, and menstrual cups.

Some of these alternatives seem to be marginal in the current market conditions, but others such as menstrual underwear and menstrual cups seem to be gaining terrain. That means that there is a potential shift in the market balance in the years to come, and therefore a change in baseline. The fact that the component is substituting only parts of the sanitary napkins and the applicators of tampons does not mean that the use of plastic in them should necessary be the baseline: if the change happens in products that have a very small penetration in the market, the potential impact will be smaller than expected, so that is what we could consider. In the case of the GHG Protocol for Projects, the baseline would not be the same one that has been chosen. Therefore, we can say that there are potential of variations under different criteria. As stated before, the criteria can be very well defined, as in the case of the GHG Protocol for Projects or be left to the assessor's criteria such as in the case of Evaluating the carbon-reducing impacts of ICT.

In addition to the consideration of baseline, we must factor in the influence of time and how to manage it. The frameworks that require a review of the baseline every certain amount of years, such as the Avoided Emissions Frameworks, or those that analyse in depth the trends in the technologies that can be considered baseline, such as the GHG Protocol – Projects, will potentially have more adaptable or accurate results respectively than those that consider the baseline as an static element, such as the WBCSD and its framework on chemical components and the Project Carbon Methodologies by EIB.

TRL

TRL has also been addressed only from a qualitative perspective. As described in the chapter about Technology Readiness Levels, only the Avoided Emissions Framework considered TRL as a factor to take into consideration. TRL does not affect the amount of GHG emitted or avoided, but the potential for success and for the technology to deliver what it is said to do. Considering that the assumed TRL of the solution is 3, the potential for delivery of the avoided emissions is still uncertain.

SYSTEM BOUNDARIES

The system boundaries that are considered in most frameworks are cradle to grave or an explained account of what the boundaries should be, which already creates a wide potential for variability that is difficult to quantify. However, in addition to that, there is a framework, EIB, which would not be applicable in regular circumstances, only considers scopes 1 and 2 of emissions, and not scope 3. As the main difference between the chosen baseline and the solution deals with the end-of-life due to being biodegradable, there is no reason to assume that baseline and solution will have different results in those scopes. Therefore, the avoided emissions from EIB is near null.

The variation in this case can be close to the 100%.

GEOGRAPHY

The base calculation assumes the geography is global. None of the frameworks except for CRANE explicitly states that the market should be global, so that is already a source of variation.

In addition to that, the results of limiting the geographical reach of the solution do create variation. If we consider the Nordic countries, that have a very small population, the total avoided emissions are reduced to 53 tons of CO_2-e per year. On the other hand, India, which is a very large country, has the potential to reduce 1,264 tons of CO_2-e per year. To run the calculations, I used national data on feminine product usage, but not different end-of-life practices, which should also be taken into consideration and that can affect the final result.

The percentual change from the Nordic region to the global impact is of 99%.

TIMEFRAME

As explained in the corresponding chapter, timeframe has been used considering the length of the final assessment. Considering this, we have a range from 1 year of savings, such as in the case of Avoided Emissions Framework, EIB and GHG Protocol for Products, to 100 years, which is the case of Defra's 2050:2011. Therefore, we are talking of a 99% of difference of the final impact from the framework of the shortest timeframe to the one of the longest.

Other aspects, such as reduction in savings overtime and changes in baseline, as addressed above, have not been considered in this analysis but would clearly have further influence on the result.

SECONDARY EFFECTS

Most of the frameworks recognise the existence of secondary effects but few provide rules or guidance on how to quantify them. Since they have a systemic component, it is difficult to do. Since no basic rules are applied in any of them, the potential for variability is large since it is dependent on the assessor. I did not include any variability because I think it is unnecessary to convey the potential for divergence.

However, I did follow PRIME's recommendation of, in absence of better judgement, reduce the future positive impact due to rebound effects. The reduction is arbitrary, so I used a 10% reduction on the final impact during the ten year long basic timeframe. Therefore, in this case, the aggregated impact for ten years would be 486,000 tons instead of 540,000.

MARKET

Market size, share and penetration, can change the final result of an avoided emissions assessment. We got a glimpse of this during the analysis of the Geography above and the study of the baseline. The basic calculation assumes a potential market share of 5% of the market, being that the specific market for sanitary napkins and tampons which is considered unmovable.

However, as we saw before, not all the frameworks look into market share, but some do take a look into market penetration. The case of the GHG Protocol for Projects used it to choose the baseline, and as we saw, we are not calculating the differences based in this type of criteria. However, we can use the PRIME methodology approach in which the importance is not so much the advance of the particular company that is presenting the solution, but the technology itself. According to the PRIME methodology, for the sake of simplification and comparability, it is assumed that the technology will have a 100% of market penetration in the end of the assessment period, which is 30 years for them. PRIME methodology uses an S-shaped adoption function with different variables. Since we are keeping the timeframe in ten years, we will roughly approximate the penetration assuming that the adoption rate is in average a 4% and the time to reach 50% of the penetration is 15 years. The result is a 45% of market penetration on year 10. This would give us a non-aggregated result of 486.000 tons of avoided CO_2-e on year 10, which is nine times more than we would expect with a market share of 5%.

It is clear that here we are measuring two different things: avoided emissions from the specific market share of the solution of a company and the avoided emissions from the market penetration of a technology, regardless of how many people are behind it. However, it is fair to wonder to what extent these variations are necessary and, if so, why not use both of them.

ALLOCATION

If we stick to the simplest approach, the impact is fully allocated to the solution. This is a possibility, but in many cases the need to allocate to different actors, most likely the entire value chain, is recommended if not required.

There are different ways to allocate according to the literature, but the main systems are through physical characteristics, such as mass, economic weight of each actor, expert opinion, or agreement among the actors. Agreement among the actors is often unviable, and the expert opinion has a variability component based on different people approaching different instances that is difficult, although not impossible, to avoid. The most objective ones would be the physical and economic weight of the different components and actors.

In this specific case, I have used the physical allocation in terms of mass. If the component that is under assessment is only 13% of the weight in the case of tampons and 86% in case of sanitary pads, then the impact that can be allocated to that solution is less than previously estimated, a total of 444.000 tons of CO_2-e. That corresponds to a, 18% lower result than before, mostly attributable to the high proportion of plastics in the sanitary pads.

RESULTS SUMMARY

As we can see in the table below, there is a large potential for variation in the results depending on the criteria that we are following. Acknowledging these variations can provide room for discussing how we could reduce these ranges.

Aspect	**Range of results (ton-CO_2-eq)**	**% of change**
Boundaries	540 132 [0, 540 132]	100%
Geography	539 600 [532, 540 132]	99.90%
Timeframe	5 347 307 [54 013, 5 401 320]	99%
Secondary Effects	54 013 [486 119, 540 132]	10%
Market	4 321 056 [540 132, 4 861 188]	89%
Allocation	96 513 [443 619, 540 132]	18%

15. Conclusions

This report has analysed different frameworks for the study of the avoided emissions of projects, initiatives, products, and solutions in general. Although the main procedure is clearly similar from one framework to the other, they are not all the same and that variability can be a source of confusion or misrepresentation of impacts. As main takeaways from this analysis we can mention:

- There are many frameworks and most of them follow a similar assessment process. As previously said, most of them would consider the importance of establishing boundaries in terms of the productive system, the geography, the timeline and the effects or scope of the assessment. Most would compare the solution to a baseline to study how much it is being saved in terms of emissions. They would use emission factors to calculate how much each product or project emits and what the difference is, if any.
- Nevertheless, the parameters to define the calculations vary from one framework to the next, hindering comparability. Some would be very strict in what can be considered a baseline, for instance, and some others would not provide much guidance. Some consider important to address secondary effects while others disregard it or do not present them in depth.
- Even when the parameters are similar, each framework gives them different relevance. That generates structural differences on the reports that make it costly to compare them even when the information and parameters are relatable, since re-calculations need to be made.

This study is not aimed at suggesting that a very stringent model needs to be implemented. The high variability and development rates require a certain level of flexibility. However, it would be good for every actor involved in these processes to agree on what the most important elements are and how to deal with them. This way, we might be able to avoid high levels of discrepancies. Ideally, a joint effort can assist in building a standard framework where the foundations for this main elements or parameters are agreed upon and settled to simplify the comparison of assessments from different sources and hopefully the mainstreaming of the forecast of emissions.

This is a key aspect on the future we are building all together. Reliable and sound data creation is fundamental. The only way to know where we are going is to be able to grasp the direction of our impacts and, in the specific case of the climate crisis, the future climate impacts of our activities, especially those that are under development. We at Cleantech Scandinavia wish and hope for a productive collaboration with each other in this direction.

Annex I: Main elements in each Framework

GAP - CTS	All of them	Mission Innovation	GHGP products	GHGP projects	CRANE	Drawdown	Bilan Carbone	WBCSD	EIB	GeSI	GRI 305	ILCAJ	Lafarge-Holcim	IFI	WRI
	Approach		Approach (attributional or consequential)										Approach (LCA)		Approach (attributional or consequential)
Scope	Scope	Scope and impact	Scope						Scope	Goal and scope	Scopes	Scope			
	Organizational scope						Organizational scope								
	Scope - all GHGs	Scope - all GHGs													
	Direct solutions emissions	Direct solutions emissions													
	1.5 C compatibility	1.5C compatibility													
	Target product											Target product			
	Emissions Model - Methodology					Emissions Model		Methods	Methodologies		Methodologies, assumptions and tools	Calculation Method	System model		
	Functional Unit	Units/metrics						Functional Unit				Functional Unit	Functional Unit		
	Trade-offs												Trade-offs		Trade-offs
	Assumptions	Assumptions													
	Emission factors	Emission factors													
	Sources of emission													Sources of emission	
	Effect of induced traffic (in transportation)													Effect of induced traffic	
	Primary effects			Primary effects (under boundary)											

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	Secondary effects	Rebound effects		Secondary effects (under boundary)					Enabling and rebound effects						Extraboundary effects (e.g. rebound effects)
Boundaries	Boundaries		Boundaries	Boundary			Operational scope	Boundary setting	Project boundaries	Limit assessment			System boundaries - Life stages		System boundary (life cycle stages)
Geography	Geography			Geography (under baseline)				Time and geographic reference						physical boundaries	
Technology readiness levels	Technology readiness levels	TRL													
Timeframe	Timeframe / service life		Time period (under boundary)	Temporal range (under baseline)			Time frame	Service life					Service life estimation	Length of assessment period	
Baseline	Baseline	Baseline		Baseline	Emissions of the product displaced				Baseline emissions	Business as Usual		Baseline	Baseline		Baseline
	Baseline candidates			Baseline procedure											
	Baseline procedure			Baseline candidates											
	Barriers			Barriers (under baseline)											
	Financial Model					Financial Model									
	Total Addressable Market				Porential product deployment	Total Addressable Market							Market segments		
	Scaling results to product's market size														Scaling results to product's market size
Market Penetration	Adoption scenarios/Market penetration			Market reaction/penetration		Adoption scenarios									
	Upscaling												Upscaling		
	Integration					Integration									

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	Cut-off criteria												Cut-off criteria		
Allocation	Contribution ratio		Allocation									Contribution ratio?	Attribution / Allocation		Attribution
	Double counting												Double-counting		
	Additionality				Additionality										
	Data quality												Data quality		Data quality
	Data sources	Data sources												Source of data	
	Cross-check	Cross-check													
	Sense checks	Sense checks													
	Uncertainty	Uncertainty	Uncertainty												Uncertainty analysis
	Independent review	Independent review													
	Performance tracking		Performance tracking				Annual review								
	Action plan						Action plan								
	Reporting of results	Reporting of results	Reporting		Tracking emissions post-investment		Report						Reporting		
	Assurance		Assurance												
	Reporting of factors	Reporting of factors													

Annex II: Studied elements in each framework

CTS Report	Scope	System B.	S. Effects	Geography	TRL	Timeframe	Baseline	M. Penetration	Allocation
AEF	X		X		X		X		
GHGP Products	X	X				X			X
GHGP Projects		X		X		X	X	X	
CRANE			X				X		
Drawdown								X	
WBCSD		X	X	X		X			
EIB	X	X					X		
GeSI	X	X	X				X		
GRI 305	X								
iLCAj	X						X		X
Lafarge-Holcim		X				X	X		X
IFI				X		X			
WRI		X					X		X

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