# Tool for ex-ante assessment of green research and innovation initiatives

Final report from the expert group on the significance of research for the green transition

November 2024
Expert group on the significance of research for the green transition

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| Published by | Expert group on the significance of research for the green transition |
| Layout | Secretariat for the expert group |

The publication is a translation of the report "Redskab til vurdering af grønne forsknings- og innovationsindsatser".

ISBN (electronic publication): 978-87-93807-76-1

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# Preface

The green agenda has become a ubiquitous part of everyday life for us all, and politicians have set high ambitions for tackling the challenges of climate change. This is reflected in the Danish climate targets and in the Danish government's manifesto *Taking responsibility for Denmark,* which raises the bar even higher.[1] Denmark is to be climate neutral by 2045 and is to have annual net removals of around 8 million tonnes $CO_2e$ by 2050. In other words: There's no time to waste!

The public sector is responsible for providing the necessary framework for the green transition, in which research and innovation play a key role. This is reflected in developments in public research funding and in recent political decisions to increase the level of funding significantly. In 2020, the level was increased by DKK 1.2 billion, resulting in a total of DKK 2.5 billion being allocated to green research and innovation. It was also agreed to keep investments in green research and innovation at the 2020 level up to 2025. Most recently, it was agreed to earmark a minimum of DKK 15 billion to green research and innovation up to 2030.

In light of the ambitious political targets and the high level of investment in public research and innovation, it is paramount that we know more about how public funds are being prioritised, so that society can get the most out of our investments. In other words, improving the knowledge base and the decision-making basis for policy prioritisation of green research and innovation investments remains an important task. For this reason, the government set up an expert group tasked with improving the knowledge base about the effect of green research and innovation, given that a solid knowledge base provides for well-founded policy decisions. The expert group was also tasked with developing an analytical framework to qualify how publicly funded research and innovation can best help reduce greenhouse gas emissions. The analytical framework should be considered as a tool for assessing future public research and innovation initiatives.

The work of the expert group builds on existing knowledge, and the expert group has carried out analyses and surveys, all of which contribute to improving the knowledge base for research and innovation. Furthermore, the expert group has developed an analytical framework that can help systematise the assessment of public research and innovation initiatives targeted at greenhouse gas emissions reductions.

This is the final report from the expert group, and the export group would like to thank everyone who contributed to their work, including external experts, researchers, stakeholders and other actors involved. Their input and commitment have been crucial to the group's work, not least work on developing the assessment tool.

**Members of the expert group**


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The expert group was set up in June 2022 and completed its work in November 2024 Other publications by the expert group and other relevant information can be found on the expert group's website.

[1] Regeringen (2022), *Regeringsgrundlag: Ansvar for Danmark*, https://fm.dk/udgivelser/2022/december/regeringsgrundlag-ansvar-for-danmark/

# Target group and reading guide

This report is aimed at policy actors responsible for setting priorities for investment in green research and innovation, although the report is also relevant for other actors who set priorities for and fund investment in green research and innovation. The report presents an assessment tool (an analytical framework), which is the expert group's proposal for a systematic approach to assessing how research and innovation initiatives contribute to reducing greenhouse gas emissions. The tool is designed to provide a consistent basis for assessing and comparing research and innovation initiatives across different areas and types of initiative. The tool aims to support the decision-making process for prioritisation of research and innovation initiatives by encouraging consistent assessment across initiatives and by helping to ensure that the important parameters and conditions for the potential of an initiative are assessed on the same basis.

The report has been structured so sections can be read independently. Readers can identify sections of relevance specifically to them and skip others.

The introductory **summary** provides an overview of the main conclusions of the report. **Section 1** describes some of the rationales behind public involvement in green research and innovation and why it is important that the public sector sets the direction for climate action. **Section 2** describes the task performed by the expert group and explains the rationale and reason for improving the knowledge base and developing an assessment tool. This section also includes a description of the principles applied by the expert group in its work. **Section 3** takes an in-depth look at the improved knowledge base. This includes a comparative analysis of decision-making on research and innovation initiatives in other countries. This is followed by a description of technology outlooks and roadmaps, which are relevant for the expert group's work. Furthermore, this section highlights points from some of the expert group's own work and analyses.

**Section 4** presents the concept of the assessment tool developed by the expert group. The tool is described as a systematic approach to investing in research and innovation, and the section provides a detailed overview of the tool as well as an explanation of steps and parameters in the assessment process. **Section 5** highlights some of the considerations that have gone into developing the assessment tool, including the limitations of the tool and how it can be applied most appropriately. **Section 6** focuses on use of the assessment tool in practice and presents possible ways to apply it, with examples of indicators and data. The section describes the different steps in the process, including the reduction potential (step 1), assessment of conditions (step 2) and important considerations (step 3). Furthermore, the methodological challenges of using the tool are highlighted. This description of the assessment tool is rather technical and is therefore accompanied by examples.

# Summary

Research and innovation play important roles in generating new knowledge, developing green technologies and solutions, and in providing a deeper understanding of climate change, all of which are crucial for the green transition. There is great optimism and confidence that the potential of research to contribute to climate action can be enhanced, and this is stressed by recent years' significant public investment in green research and innovation. While research can be crucial, the path from research in a laboratory to concrete greenhouse gas reductions is often very long, and many factors need to come together for research results to be realised and have an effect in practice. The solutions will only have a significant impact when they have been scaled up and implemented commercially and by society. It is therefore important to assess the degree to which conditions are in place for this to happen when deciding on research and innovation initiatives, such as research missions or targeted research and innovation programmes. Take wind turbines, for example. Despite well-established wind-turbine research communities and the technology's potential to substitute fossil energy sources and significantly reduce greenhouse gas emissions, there is no real effect until the technology has been implemented on a large scale. Scaling up wind turbines from pilot projects to broad deployment requires significant investment, political support, infrastructure development and local-community backing. The potential greenhouse gas emissions reductions promised by research and innovation are not achieved until the wind turbines have been manufactured by businesses, installed on land or at sea, and integrated into the energy system.

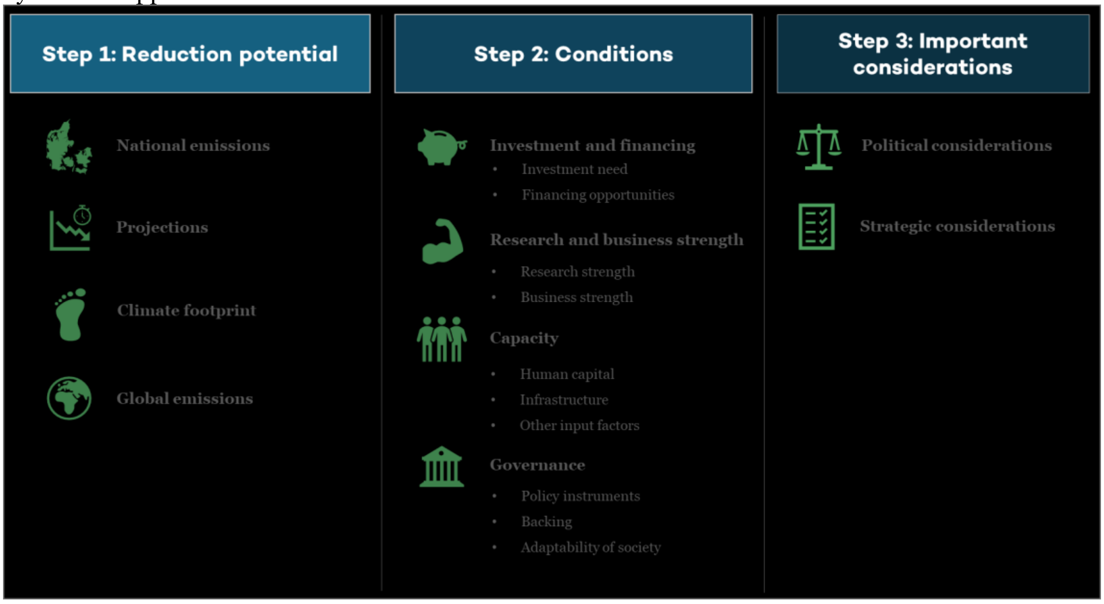
The great optimism about what can be solved through research and innovation is not just a Danish phenomenon. Across the world, businesses, countries and global actors are increasingly focussing on combatting climate change through research and innovation. And much of the knowledge and many of the solutions to advance the green transition will be developed outside Denmark. We can therefore learn from the rest of the world and adapt out effort accordingly. However, Denmark can also contribute new knowledge to the global green transition.

We assess that green research and innovation will continue to be allocated a great deal of public funds in the future. There is therefore a real potential in applying a systematic approach to investment in research and innovation to better assess different initiatives and their potential to reduce emissions. The Danish Council on Climate Change agrees with this and also stresses the importance of a structured and systematic assessment of research and innovation initiatives targeting climate challenges.[2]

As part of our work, we looked at how other countries approach the challenge of assessing research and innovation initiatives. We can see that the issues are addressed by other countries, but we have not been able to identify any systematic approach that can be transferred to a Danish context. We have therefore developed our own proposal for approaching the task in a structured and systematic way. Distributing green research and innovation investments in a structured and systematic way is not an easy task. We had many considerations how best to do this, what to include and how much to include. In the end it was out choice, but experts, stakeholders and others, provided invaluable into the process. In this report, we present our proposal for an assessment tool to systematise assessment and prioritisation of green research and innovation investments, see the figure below.

[2] The Danish Climate on Climate Change (2023), *Danmarks globale klimaindsats*, https://klimaraadet.dk/da/analyse/danmarks-globale-klimaindsats, The Danish Climate on Climate Change (2024), *Kommentering af global afrapportering*, https://klimaraadet.dk/da/analyse/kommentering-af-global-afrapportering-2024 & The Danish Climate on Climate Change (2024), *Forskning og innovation målrettet klimaomstillingen*, https://klimaraadet.dk/da/analyse/forskning-og-innovationmaalrettet-klimaomstillingen

**Figure 1.1**
Systematic approach to assessment of research and innovation initiatives




*Source: Expert group on the significance of research for the green transition*

Since the objective is for research and innovation initiatives to help reduce greenhouse gas emissions, the first thing to do is to look at the potential for this. **The first step** is therefore to assess the reduction potential of the initiative. This first step is in line with the objective of prioritising investments in initiatives aimed at the largest emission sources. This is primarily an assessment of the potential of initiatives to reduce national emissions, but the assessment also looks at Denmark's total climate footprint and total global emissions. This provides a holistic picture of how the different initiatives can contribute to reducing emissions, nationally as well as globally, and where green research and innovation funds are best spent. While the reduction potential can tell us something about an initiative's potential for reducing emissions and thereby about the possibilities for realising the relevant climate targets, there are also a number of conditions that determine the likelihood of an initiative being able to realise this potential. The **second step** therefore involves determining the likelihood of the reduction potential being realised by assessing a series of parameters considered the most important for the initiative to realise its full reduction potential. Investment and funding include an assessment of whether sufficient private funds are likely to be available to implement the initiative and meet the investment need, or whether public involvement is likely to be required. A specific area of attention here is to ensure as far as possible that private investment is not displaced by public investment. Research and business strongholds are about the existence of relevant research environments and industries. Capacity is the resources required by the initiative, such as human capital and infrastructure. Governance is about the structural conditions needed to support development of the initiative. Assessing these conditions will provide a better understanding of the likelihood of the initiative being implemented successfully and its full reduction potential being realised. However, there are other important considerations besides reduction potential and factors determining whether the initiative can succeed. The **third step** therefore looks at important considerations that are not directly related to the reduction potential of the initiative but provide a picture of the wider societal and environmental implications of the initiative. This includes social, economic/financial, and environmental or strategic considerations required to form a holistic assessment of the initiative.

The approach outlined above can be used as a tool to systematically assess research and innovation initiatives aimed at reducing greenhouse gas emissions. Structuring the assessment into the three steps described above, with each step focussing on different parameters in relation to the initiative, provides for a complete and nuanced assessment, allowing for manageable and acceptable use of administrative resources and time. This ensures the best prerequisites for prioritising research and innovation investment into the areas where the potential and the likelihood for success are greatest. The approach can also help identify barriers and reasons why some initiatives should not be prioritised, and this, in turn, may help shed light on restrictive or alternatively conducive policy measures. This in turn will help ensure more efficient allocation of public funds and increase the likelihood of research and innovation delivering on the promise of contributions to climate action and climate targets. Ultimately, this should benefit the goal of Denmark reaping the most from its investment in the green transition.

# 1. The role of the public sector in the green transition

The expert group was tasked with examining the effect of research and innovation on the green transition, and the group has therefore looked at public research and innovation, including how public research and innovation can best help realise Denmark's climate targets. In this regard, it is important to take a holistic perspective and consider public research and innovation as a portfolio of measures and initiatives. It is also important to consider not only the development of new green technologies but also research and innovation initiatives of a more general societal nature, such as behavioural research or research on how to design effective policy instruments. Looking at public research and innovation as a portfolio is helpful in terms of risk spreading and investment diversification. It can also be conducive to taking account of different time horizons for different climate targets. All of this should ensure a more robust and long-term approach to research and innovation and to meeting the climate targets.

## 1.1 Rationales for public involvement

Realisation of the green transition and Denmark's climate targets will not just happen by itself. For society to achieve these goals, the right conditions must be in place. This is a political responsibility, and the public sector has several rationales for getting involved, for example through support for research and innovation. The expert group's first report, which dealt with the background for setting up an expert group on the significance of research for the green transition,[3] explains some of these rationales, including their limitations. Some of the main points of the report are summarised below.

Rationales for public involvement stem from a number of complex conditions and challenges that will not be resolved on their own. These are also referred to as market failures and structural system failures and transformative system failures. They describe situations in which the market fails to exploit the resources of society efficiently without intervention, and in which the market is characterised by sluggish innovation and transition processes. The general focus has been on correcting market failures and increasing incentives for innovation in the overall economy. However, this approach has failed to sufficiently solve large and complex societal challenges such as climate change.

**Firstly**, production and consumption are still extensively based on technologies that emit greenhouse gases. Even though climate-friendly alternatives are available, many of them are unable to compete with established technologies. This is because they are not sufficiently mature or competitive, the established technologies are advantaged by subsidies, there are barriers to shifting to new technologies or similar. Even small differences in productivity can obstruct new technologies from gaining momentum, and manufacturers of established technologies, whether knowingly or not, may contribute to impeding deployment and uptake of the new technologies. Without major benefits for end users, there will be no incentive to shift to more climate-friendly alternatives. **Secondly**, there are mutual interdependencies between technologies and other necessary components, such as infrastructure, regulation, complementary technologies, etc. The mere existence of a technology with potential to contribute to the green transition is no guarantee

[3] Ekspertgruppen om forskningens betydning for den grønne omstilling (2023), *Publikationer*, https://ufm.dk/forskning-og-innovation/radog-udvalg/andre-udvalg/ekspertgruppe-groenne-omstilling/publikationer (only available in Danish).

for its deployment in the market. Deployment of the technology can depend on availability of resources, such as well-functioning infrastructures, or compatibility with existing systems. Furthermore, it can depend on the existence of financial incentives to support implementation. If such components are not in place, the development and ultimately deployment and uptake of the technology will be limited. **Thirdly**, the green transition needs a broad array of instruments, and only the public sector has the capacity to coordinate this on any large scale. For example, taxes and regulation can be used to reduce greenhouse gas emissions by motivating businesses to implement existing climate-friendly technologies and solutions or to develop new ones. They can also encourage consumers to change behaviour. However, standalone measures are not enough, and a broad portfolio of policy instruments is needed, especially because technological developments are uncertain, and the market often focuses on short-term solutions[4]. Therefore, more comprehensive public action is needed to coordinate instruments and ensure a more effective transition.

Research and innovation investment is an important policy instrument in this regard. Public funds can be a decisive factor in facilitating the required development if the market and businesses are unable to establish the incentives required or fund long-term solutions. Besides this, there are several arguments in favour of public investment.

**Firstly**, research and innovation can lead to societal benefits beyond those accruing to an individual business. This is referred to as positive externalities. For example, other actors can benefit from knowledge and research results they did not invest in themselves. Because the individual business does not reap all the benefits resulting from its research and innovation investment, this may lead to underinvestment in research and innovation relative to what is optimal from a society perspective. In these situations, public investment can provide the desired socio-economic return and utilise positive externalities in the form of knowledge diffusion. **Secondly**, businesses may find it hard to attract sufficient risk capital, because they often have more knowledge about their research project than investors and this lack of knowledge makes the investment uncertain for investors. This is also referred to as asymmetric information and can make it difficult to obtain private research and innovation funding, especially within the green transition where large and uncertain capital investments and follow-on investments are often necessary. **Thirdly**, new knowledge is only valuable if the skills, funding and incentives needed to apply the knowledge are in place. Successful innovation therefore requires more than just knowledge; it requires coordination of resources and demand. Government measures can play a role in supporting this coordination, for example by ensuring a qualified workforce, such as PhD graduates, to avoid shortages of scientific personnel. Similarly, the public sector can affect demand by establishing an appropriate price structure and incentives, for example through taxes. All of this can help feed demand for new solutions. **Fourthly**, some industries, those characterised by many small businesses and entrepreneurs in particular, may lack the capacity to manage research and innovation activities on their own. Although businesses can come together to establish private institutions for sharing knowledge and resources, in certain situations the public sector will have to contribute with aid and expertise to support collaboration and innovation, and to generate value for society.

Thus, there are many arguments for public involvement and investment in research and innovation. However, public involvement is not without challenges, and there may be issues with inefficiency and coordination. These issues are dealt with in more depth in the expert group's first report, with a thorough review of the pros and cons of public investment in research and innovation. This review includes an important area of attention, namely ensuring that public investments in research and innovation as far as possible do not displace similar investments that

[4] Rosenbloom, D.; J. Markard; F.W. Geels; and L. Fuenfschilling. (2020). Why carbon pricing is not sufficient to mitigate climate change and how 'sustainability transition policy' can help. Proceedings of the National Academy of Sciences 117:8664-8668.

the private sector would otherwise have made anyway. In other words, not every promising initiative should be afforded public funding. Public funding should only be provided where the private sector is unable to deliver and where the initiative is of interest for society. Similarly, even if the private sector does not invest in a specific initiative, this does not automatically mean that the public sector should step in. There will be initiatives that are simply not promising enough, and this stresses the need for a systematic assessment and priority-setting process.

## 1.2 Strategic publicly funded research and innovation

Publicly funded research and innovation therefore play a crucial role in realising Denmark's ambitious climate targets. To ensure the best possible effect from research and innovation, it is important to set strategic directions for research and innovation. Research missions are an effective tool for this. They are specific and ambitious targets aimed at key societal challenges. Missions represent a selection of the challenges that politicians want to prioritise without pinpointing any specific solutions in advance. This is referred to as 'picking the challenges'. This allows for flexibility in organising the initiative, which is important as it is rarely transparent from the start what solutions will be most effective.

However, setting direction for research and innovation is not straightforward. Selecting missions and initiatives requires a process of prioritising some areas while rejecting others. Furthermore, identification of the missions and initiatives with the greatest potential for helping achieve the climate targets is rarely clear from the beginning. The expert group believes there is a potential for informing this decision-making and selection process by applying a more systematic approach to assessing research and innovation initiatives. The need for a more systematic approach to assessing research and innovation initiatives is particularly relevant for research activities aiming at generating new solutions where applications are immediately apparent. For example, this includes research aimed at solving concrete problems and developing new knowledge that can be translated into specific applications. This includes research based on existing knowledge and experience and research aiming at creating or improving products, processes or methodologies and that can be applied commercially or by society in general. However, the need to facilitate a systematic selection process is less relevant for research activities that focus primarily on basic research. This type of research often aims to generate new knowledge about phenomena and observable facts, but without necessarily focussing on a specific application of this knowledge. Basic research is essential for forming new ideas and is more about expanding the general knowledge base than about creating solutions to achieve climate targets.

Strategic selection of research and innovation initiatives is relevant until research activities reach the stage of commercialisation and market deployment. When research results, such as technologies and solutions, reach this stage, the business sector will play a greater role in further development, implementation and scale-up. In other words, market forces will take over at this stage, although this does not necessarily mean that public involvement is no longer needed. At this point, however, publicly funded research and innovation is probably no longer the most relevant and appropriate policy instrument. Instead, the role of the public sector is now to boost consumer and business demand through other instruments, such as taxes and regulation, to incentivise and facilitate further transitioning to a resource-efficient and sustainable economy.

The expert group's work can be a used to identify research and innovation initiatives with a significant reduction potential as well as the best conditions for realising their potential. This can provide for a more robust basis for policymaking and facilitate selection of the most promising initiatives, so that Denmark can garner the most from its investment in the green transition.

# 2. The task of the expert group

The expert group was tasked with improving the knowledge base about the effect of public research and innovation and with developing an analytical framework to facilitate in assessing how public research and innovation can best help reduce greenhouse gas emissions. In its first report, the expert group described the task in more detail. The following sections provide an updated description of the task and how the group has approached it.

## 2.1 Improving the knowledge base

According to its mandate, the task of the expert group is to:

> ”[...] *strengthen the knowledge base about the effect of research and innovation. Work by the group can build on existing literature on the effectiveness of green research and innovation with relevance for Denmark and analyse the effect of previous green research and innovation initiatives, from research at universities to innovation by businesses, as well as across public sector authorities. The expert group is also expected to examine the basis applied by other countries in their assessment of research and innovation initiatives.*"

As the expert group pointed out in its first report, a robust knowledge base contributes to well-founded policy decisions. The knowledge collected can inform society about the role of research and innovation in the green transition. Therefore, the expert group chose to concentrate on improving the knowledge base about the significance of research and innovation initiatives. This was done through literature reviews and case studies of other countries' approaches to research and innovation initiatives with the purpose to identifying the basis against which they prioritise different research and innovation initiatives. Furthermore, the group examined historical research and innovation initiatives, as well as the literature already available and part of the existing knowledge base. This literature includes reports and analyses from actors that have contributed to the existing knowledge base, such as researchers, the Danish Council on Climate Change, stakeholder organisations, ministries, commissions, expert committees and others. Besides this, the expert group prepared its own supplementary analyses where the existing knowledge was weak or missing. This resulted in a number of analyses of the significance of PhD graduates for the green transition, barriers to the green transition experienced by businesses, as well as the diffusion of green knowledge and green ideas from Denmark to other countries. The expert group also held a series of meetings with external experts and stakeholders to collect input for the group's work on developing the analytical framework.

## 2.2 The analytical framework

According to its mandate, the task of the expert group is moreover to:

> "[...] *establish an analytical framework (model) that, based on objective criteria, can estimate the effect of investments in research and innovation on the reduction of greenhouse gas emissions.*"

As described earlier on in this report, part of the background for establishing the expert group was a desire to improve the assessment and decision basis for setting priorities for investment in green research and innovation. This is important to help ensure that society reaps the most from its investment in green research and innovation and so that research contributes to realising the Danish climate targets. This is described in the expert group's mandate as an analytical framework to be considered as a tool to structure and facilitate systematic assessment of research and innovation initiatives aimed at reducing greenhouse gas emissions. A large amount of work has already gone into current and historical policy-making decisions, and the expert group has included this work in its development of the assessment tool.

In defining the level of ambition and in preparing the assessment tool, the group has followed a set of guiding principles. These are described below and in more detail in the expert group's first report.

**Mission-oriented research and innovation investment** is an important means to achieve Denmark's climate targets. Missions should address overarching societal challenges, such as climate change: what is referred to as 'picking the challenges'. Furthermore, missions should set the direction for public investment but without pin-pointing specific technologies: what is referred to 'tilting the playing field'. The purpose is therefore not to assess individual technologies or projects, but to look at research and innovation funding from a more overall perspective and based on a systematic approach.

**The path from research to implementation is long**, and it is important to look at the entire innovation value chain, as many factors need to come together for research results to be translated into real greenhouse gas emission reductions. Research results will not harvest their full potential until they have been **rolled out in society, fully scaled-up by businesses, and implemented in Denmark *and* globally**.

The expert group has **engaged external actors** in its work in general, and in its work on developing an assessment tool, in particular. The actors provided input and qualified work an ongoing basis. Many different stakeholders with important roles within green research and innovation were involved in the work on an ongoing basis.

The expert group's task was to **develop a tool; not to give recommendations** about prioritisation of investment in green research and innovation, for example by identifying specific areas or technologies.  The tool's raison d'être is to promote a **systematic approach** by facilitating consistent comparative assessment of different research and innovation initiatives aimed at greenhouse gas emission reductions. An important element in this is to facilitate assessment of the parameters with significance for the expected reductions and to ensure a uniform data basis for use in the assessment.

# 3. An improved knowledge base

As described above, part of the task of the expert group was to improve the knowledge base about the effect of public research and innovation initiatives on the reduction of greenhouse gas emissions. Work by the group centred on three key themes: Research and innovation initiatives in other countries, relevant existing knowledge, and possible knowledge gaps. Based on its work, the export group found that:

– In Denmark and in other countries, research and innovation policy today is more mission-oriented than previously and research and innovation are expected to provide a social return on investment, such as contributing to achieving climate and sustainability targets. This places new demands on how we measure and assess the potentials of research. It has not been possible to identify other countries that have found a systematic and structured way to do this.

– Knowledge about technical reduction potentials (which is also important in the context of the government's other climate action work) plays a key role in assessing the potential of existing technologies. However, this type of data is limited to individual technologies and is not suitable for identifying the future development of technologies that are currently at a low level of maturity. This type of data is useful as input for the expert group's work, but cannot stand on its own.

– Private businesses are central to the green transition, as large part of transitioning will be through developing and implementing new solutions in Danish businesses. The expert group therefore examined the barriers and incentives experienced by businesses, the type of highly specialised workforce they use, and whether the knowledge of Danish businesses is applied outside Denmark. The group also consulted and obtained additional knowledge from a number of private businesses and in addition public and private foundations and publicly owned businesses.

## 3.1 Research and innovation initiatives in other countries

The expert group's identification of research innovation initiatives in other countries shows that many countries historically have aimed their initiatives at retaining a certain level of innovation with a view to achieving productivity growth. General focus has been on correcting market failures and increasing incentives for innovation in the overall economy. However, this approach has failed to sufficiently solve large and complex societal challenges. This has led to increased focus on mission-oriented research and innovation policies to address major societal challenges. The research missions introduced under the EU research and innovation funding programme Horizon Europe are a good example of this.

This shift towards more mission-oriented research and innovation policies has sharpened focus on assessing and measuring research potential. In this context, it is relevant to examine how other countries organise research and innovation initiatives and identify strategies and approaches to improve and support Danish initiatives. However, the expert group has not been able to identify other countries with a systematic and structured approach that can be directly transferable to a Danish context.

### 3.1.1 Mission-oriented research and innovation policy

Denmark is not alone in promoting and investing in research and innovation initiatives to reduce greenhouse gas emissions. Several countries, in the EU in particular, along with global actors, are investing in the generation of new knowledge and technological development with a climate agenda. It is therefore relevant to examine whether other countries have developed and use tools that could serve as inspiration for a similar tool in Denmark. Such an examination should not focus exclusively on initiatives to reduce greenhouse gas emissions. Initiatives, to solve e.g. other UN Sustainable Development Goals may also be relevant. The SDGs include societal challenges that cannot be solved exclusively through productivity growth (e.g. eradication of poverty and gender equality), and therefore initiatives aimed at these other areas may inspire the work of the expert group. The expert group looked at the existing literature on research funding and research policy and examined the basis applied by other countries when assessing research and innovation initiatives. The overarching purpose of examining other countries was to collect input for further work by the expert group. The literature on research funding and research policy illustrates a strong movement towards the use of mission-oriented research and innovation policies as a tool to address major and complex societal challenges such as climate change[5].

Mission-oriented innovation policy is to a certain extent a buzzword for a range of different policy approaches. However, it is inspired by the mission-oriented policies in the 1970s and 1980s, applied in the defence and space industries, in particular[6]. As opposed to early mission-oriented policies, in modern mission-oriented policies technological innovation alone is not enough to meet the objective of a research mission. There is more complexity, and the solutions have to be implemented and scaled up commercially and at household level, which can be a problem if the existing structures are unfavourable and prevent this. Therefore, a more holistic approach is required when drafting research and innovation policies.

### 3.1.2 Research funding as a management tool

A special focus within a mission-oriented approach is how funding is used to direct research towards solving societal challenges. Governance and public management play a key role in mission-oriented research and innovation policies, and can be crucial for realising established goals. A recent study by Norn et al.[7] shows how in Norway, the Netherlands and Denmark funding instruments are designed and implemented with the aim of directing research towards solving complex societal challenges. The study categorises research orientation according to three dimensions: Specific themes, assessment of socio-economic impact, or requirement for collaboration. The 'assessment of socio-economic impact' dimension is particularly relevant for work by the expert group. The three countries in the study share a focus on socio-economic impact that is broader than just productivity growth, but what differentiates these two goals is defined only vaguely in all three countries. All three countries are therefore more or less inclined to use an already existing impact based on research and innovation aimed at maintaining productivity growth at a certain level.

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[5] Mazzucato, M. (2019). Governing missions in the European Union. Independent Expert Report, Wohlert, J., & Norn, M. T. (2023). Fra forskning til forandring: Hvordan kan universiteternes innovationsindsats bidrage til udviklingen af forskningsbaserede løsninger på store samfundsudfordringer? Janssen, M. J., Torrens, J., Wesseling, J. H., & Wanzenböck, I. (2021). The promises and premises of mission-oriented innovation policy—A reflection and ways forward. Science and public policy, 48(3), 438-444, Hekkert, M. P., Janssen, M. J., Wesseling, J. H., & Negro, S. O. (2020). Mission-oriented innovation systems. Environmental innovation and societal transitions, 34, 76-79.

[6] Foray, D. (2022). The Economics of Incomplete Plan - on Conditions, Procedures and Design of Future Mission - Oriented Innovation Policies.

[7] Norn, M-T, Aagaard, K, Bjørnholm, J & Stage, AK. (2024). 'Funder strategies for promoting research addressing societal challenges: Thematic, impact, and collaboration targeting', Science and Public Policy. https://doi.org/10.1093/scipol/scae033

### 3.1.3 Structured and systematic research and innovation

The expert group examined whether, other countries apply a systematic approach to prioritising green research and innovation investments. The group was able to identify parallels to its work by looking at the OECD's Mission-oriented Innovations Policies (MOIP)[8], for example. This publication gives an overview of the mission-oriented policy initiatives of OECD countries, referred to as MOIP projects. These projects provide insights into the criteria used by other countries when selecting specific missions. The MOIP projects cover missions within many different areas, while the expert group focussed on green MOIP projects addressing climate challenges. In continuation of this, an in-depth analysis of Germany was performed examining Germany's assessment basis across different societal challenges such as health and demography.

Mapping green MOIP projects across the mentioned countries and examining German MOIP projects provided valuable insight but did not reveal examples of approaches sufficiently systematic to satisfy the demand for a tool as described in the expert group's mandate. Rather, the expert group found that the assessment process was characterised by many subjective considerations. For example, criteria for assessment included wordings such as *"description of the relevance of the problem," "the quality of the project idea"* and *"the implementability of the project idea."* On the other hand, the approach to research and innovation initiatives in the OECD's Committee for Scientific and Technological Policy (CSTP) is more systematic, for example in the committee's Mission Action Lab (MAL) initiative launched in 2021. The focus of MAL is the development of practical tools and methods to operationalise missions. The Mission Action Lab mission self-assessment tool[9] is particularly interesting and has therefore informed the work of the expert group, as it shares the group's objective to inform policymakers about research and innovation initiatives and the likelihood of their success, or, in other words, inform them about how to ensure that initiatives realise their objectives. MAL discusses topics such as resources, policy instruments and backing, topics that are also addressed by the expert group. Their self-assessment tool, however, requires identification of the actors relevant for the mission, and these actors must respond to a questionnaire that forms the basis for the self-assessment.

## 3.2 Technology outlooks and roadmaps

There are many sources of knowledge, data and descriptions of expected developments, including expected emissions with known technologies and these are incorporated in the government's annual climate status and outlook report, for example. This includes the Danish Energy Agency's technology catalogues and the IEA's Energy Technology Perspectives (ETP) reports, which form the basis for projecting expected emissions for specific technologies. As the expert group is looking at initiatives of a more general nature, often encompassing several technologies, solutions, etc., this type of data will often be too specific. Furthermore, there will be initiatives that do not focus on technologies but rather on behavioural research, for example, and in these cases the Danish Energy Agency's technology catalogues will not be useful. Knowledge about technological potentials and developments are important but other data is needed as well. Other sources of knowledge exist, for example roadmaps in green mission partnerships. These contain descriptions of specific research and innovation activities.

### 3.2.1 Technological reduction potentials

Historical data and historical technologies do rarely provide a good basis for informing about which future technologies require research and innovation initiatives to be realised. Due to a relatively

[8] OECD (2024), *Mission-Oriented Innovation policies online toolkit*, https://stip.oecd.org/moip/
[9] OECD (2024), *Mission Action Lab*, https://oecd-missions.org/

large difference between technologies and due to an unstable development over time, historical technologies can only contribute marginally to describing future technology trends. Therefore, expert knowledge is key to understanding technological developments and technology potentials within specific areas. Available expert knowledge, in the form of analysis reports about green technology development in Denmark is somewhat limited, too specific and is only updated as needed. Some of the expert knowledge available is described below.

The Danish Energy Agency's technology catalogues are an example of expert knowledge on green technology development. These reports are prepared and updated on a regular basis and are divided into eight categories. The eight different technology catalogues provide detailed information about different energy technologies and their respective potential for helping Denmark achieve its climate targets. The catalogues cover a broad array of technologies in areas such as renewable energy, energy efficiency and energy storage. The purpose of the technology catalogues is to provide policymakers, researchers and industry actors with a solid basis for assessing and implementing energy technologies that help propel the green transition. The reports include assessments of the maturity level of the technologies described; that is, an indication of the degree to which the technologies are ready to be implemented on a large scale. This is essential to identify the technologies that are ready for use in the short term and those that need more research and development. The technology catalogues also provide insights into the potentials and limitations of each technology, and this is useful when prioritising between different research and innovation initiatives[10]. The technology catalogues are not directly applied in the assessment tool. This is because they present detailed technology analyses and descriptions and this does not align with the general purpose of the assessment tool, which is more about the overarching societal aspects of technological development. Nevertheless, the technology catalogues are useful background knowledge for this kind of work. For example, the technology descriptions in the catalogues can be useful.

Various technology foresight reports within different technology areas, including climate, were prepared in the early 2000s[11] Technology foresight reports are systematic reviews of specific fields of research and innovation, drawn up in dialogue with researchers and experts. This type of collaboration work typically involves many meetings and spans over longer periods of time in an effort to reach consensus on likely specific developments and, thus, opportunities for prioritising policies. The work that goes into these reports is relatively extensive, and there is no longer a systematic technology foresight report relevant in the context of the expert group's assessment tool.

### 3.2.2 Green mission partnership roadmaps

The four green, mission-oriented research and innovation partnerships established by Denmark are key initiatives in efforts to advance the green transition through targeted research and innovation. These partnerships focus on specific areas within climate and environmental technologies and are designed to tackle some of the largest challenges of the green transition. Each partnership is underpinned by a roadmap outlining the strategic goals, concrete initiatives and milestones for achieving the desired results.

The roadmaps contain a description of the research and innovation activities deemed necessary by the parties in the partnership, along with the expected results and time frames. They also describe the required investments, as well as the collaboration structures that need to be established to facilitate efficient implementation of the planned initiatives. Therefore, some of the elements from

[10] Danish Energy Agency (2024), *Teknologikataloger*, https://ens.dk/service/teknologikataloger
[11] Ministry of Higher Education and Science (2003), *Grønt teknologisk fremsyn om perspektivrige grønne teknologier med erhvervspotentiale*, https://ufm.dk/publikationer/2003/gront-teknologisk-fremsyn-om-perspektivrige-gronne-teknologier-med-erhvervspotentiale

these roadmaps overlap with the work of the expert group. However, there is no common systematic framework directly applicable to the expert group's assessment tool.

## 3.3 The expert group's own work

Through various methods, the expert group collected knowledge with relevance for the green transition in order to expand existing knowledge base for public research and innovation. This work involved preparing technical analysis reports, holding stakeholder meetings and procuring analyses from external experts.

### 3.3.1 Main report and technical analysis reports

In August 2023, the expert group published their first main report about the background for setting up an expert group on the significance of research for the green transition. In this report, the expert group explains some of the rationales for public involvement and presents some of the fundamental principles of its work. In addition to this, the expert group prepared three studies of areas of special relevance for public research and innovation initiatives to identify different aspects of barriers and incentives for green research and innovation. This work resulted in three technical analysis reports.

**The contribution of PhD graduates and businesses to the green transition:** The first technical analysis report examines a central element of the green transition, i.e. education of the scientific workforce, especially PhD graduates. PhD graduates carry out green research at universities, and they contribute to the understanding of international research and knowledge, which they incorporate into their research. In the final analysis, they bring this knowledge with them to businesses, where they help translate it into concrete solutions. The report therefore focusses on identifying the contribution of PhD graduates to the green transition, and findings of this analysis include the following.

- Businesses involved in green research and development employ a higher percentage of personnel with a PhD in technical sciences or in natural sciences than businesses that carry out research within other areas.

- The percentage of personnel with a PhD in technical sciences or in natural sciences who were involved in green research during their PhD is higher in green research businesses than in other research businesses.

- The analysis reveals no correlation between having PhD graduates employed and carrying out green innovation. Nor does it reveal a correlation between having PhD graduates from specific academic disciplines and carrying out green innovation. However, the analysis did reveal that personnel with a PhD in social science or technical sciences who carried out green research during their PhD are more likely to be employed in businesses within green innovation.

**The green transition of businesses, including drivers and barriers:** The second technical analysis report examines another central actor in the green transition: private businesses. Businesses play a central role, both with regard to reducing their own emissions and in particular with regard to the development of green solutions and technologies to reduce greenhouse gas emissions elsewhere. To learn more about the drivers and barriers experienced by businesses in relation to carrying out research and innovation within the green transition and adopting green technologies and solutions, the expert group conducted a questionnaire survey among private businesses in Denmark. Amongst other things, the survey found that:

- The greatest barriers facing businesses are high start-up costs, other priorities, lack of technological maturity and legislation and regulations.
- The greatest drivers for businesses are reputation, voluntary green measures and customer demand.

**Patents and knowledge diffusion:** The third technical analysis report examined the diffusion of knowledge and ideas. Diffusion of knowledge and ideas from Denmark to other countries plays an important role in the green transition as it helps to develop and expand Danish research and commercial strengths within specific areas. Furthermore, it contributes to global efforts to reduce greenhouse gas emissions. The analysis looked at patents and citations as a measure of knowledge diffusion. The objective was to identify the climate change mitigation technologies within which Denmark is strongest. In addition to this, the analysis looked at knowledge diffusion from Danish patents to foreign patents through patent citations.

These analyses have helped to underpin that the content of the assessment tool is not just relevant theoretically but also in practice. For example, the PhD analysis illustrates the need for human capital, and the examination of the barriers faced by businesses in the green transition describes the issue of high costs and the need for continuous funding. Finally, the patent analysis shows that knowledge diffusion is an essential part of the green transition, and that Denmark is operating in a global context. The analyses can be found in their full length (in Danish) on the website of the expert group[12].

### 3.3.2 Stakeholder meetings

During 2023 and 2024, the expert group engaged with a broad array of stakeholders, experts and actors to ensure a comprehensive as well as nuanced approach to its work. The expert group held meetings with both internal and external actors, with each meeting tailored to the participants in terms of topic and content. For example, the meeting with representatives from Danish universities focussed on research and knowledge generation, while the meetings with public and private foundations contributed insight about criteria, selection processes and evaluation of research projects. In addition to this, several experts gave presentations on specific specialist topics. All in all, these meetings provided valuable contributions that the expert group has integrated into its work, and the actors consulted were generally positive about the expert group's work, and they contributed input to the work and to development of the assessment tool. The appendices below include an overview of meetings held and information about the actors involved.

### 3.3.3 External analyses

The expert group also used various external analysis consultants in its work. The objective was to make sure the assessment tool could be made operational. The analysis consultants provided their assessment of how to operationalise measurement of whether there is sufficient labour for an initiative to be successful. External consultants were asked to perform analysis for the following three underlying parameters and indicators in the assessment tool: (1) Human capital, (2) Investment and funding, and (3) Research and business strongholds.

[12] Ekspertgruppen om forskningens betydning for den grønne omstilling (2023), *Publikationer*, https://ufm.dk/forskning-og-innovation/rad-og-udvalg/andre-udvalg/ekspertgruppe-groenne-omstilling/publikationer

# 4. Concept for the assessment tool

This section presents the expert group's concept for a systematic approach — an assessment tool — to assess research and innovation initiatives for greenhouse gas emissions reductions. The objective is to create a systematic tool to identify and prioritise the most promising initiatives, so that public funds are invested where they have the highest expected impact.

## 4.1 A systematic approach to assessment of research and innovation investment

Green research and innovation receive substantial public funding. A systematic approach is crucial if society is to reap the most from these investments in the green transition. To facilitate this, the expert group has developed a systematic approach, or a tool, to structure assessment of research and innovation initiatives. The tool represents the group's understanding of the most important factors to assess when determining the greenhouse gas emissions reduction potential of initiatives. The tool also represents the group's understanding of how best to structure assessment of these factors. The assessment tool can be used in political control of mission-oriented investments to identify areas that require policy intervention to remove barriers, which is described in section 5.5.

According to the expert group it is not possible (nor appropriate) to develop a model able to calculate an unambiguous result in million tonnes $CO_2$e. A computational model about research and innovation is impossible, because results from research and innovation are by definition uncertain. If it is possible to make a valid estimate of the costs, implementability and emissions reductions of an initiative, it is unlikely that this initiative will meet the definition of a research and innovation initiative. In lieu of a model, the expert group therefore developed an assessment tool designed to be directly applicable to different types of research and innovation initiatives.

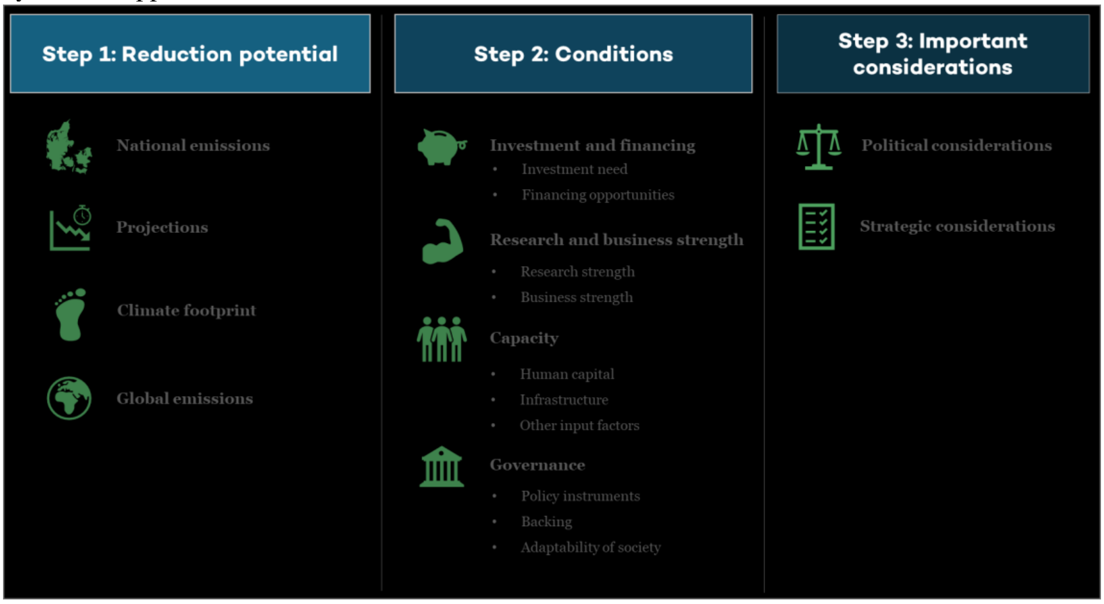
Effective use of the tool requires understanding of what is meant by initiatives in the context of the tool. In the context of this tool, initiatives are specific research and innovation programmes or initiatives aiming to reduce greenhouse gas emissions through development and implementation of new technologies, products or solutions. This includes everything from grand research missions to standalone research programmes, such as the four research missions in Denmark's *Green solutions of the future - Strategy for investments in green research, technology, and innovation* from 2020[13], or thematically earmarked funds from public-sector research foundations. As a rule, these initiatives are broader, unlike specific and standalone green projects, for which the tool is neither considered relevant nor suitable.

## 4.2 Structure of the tool

The assessment tool is structured into a series of steps, with each step focussing on specific aspects and including a number of parameters relevant for assessment of the research and innovation initiative in question. The tool consists of three steps: *reduction potential*, *conditions* and *important considerations*, see figure below. The reduction potential is about the emissions that an initiative is likely to influence and reduce. The conditions are parameters that determine the likelihood of an initiative being able to realise this potential. Important considerations are other conditions and aspects of relevance to assessment of the initiative at hand.

[13] Ministry of Higher Education and Science (2020), *Grøn forskningsstrategi sætter klar retning for den grønne forskning og styrker samspil med erhvervslivet*, https://ufm.dk/publikationer/2020/fremtidens-gronne-losninger-strategi-for-investeringer-i-gron-forskning-teknologi-og-innovation/gron-forskningsstrategi/opgorelse-af-gron-forskning-i-danmark/bibliometrisk-analyse-af-danmarks-gronne-forskning.pdf

**Figure 4.2**
Systematic approach to assessment of research and innovation initiatives




*Source: Expert group on the significance of research for the green transition*

Before beginning assessing the individual steps, for an initial overview, users of the tool should prepare a thorough description of the initiative to be assessed. **The description of the initiative** should include an overall presentation of the initiative for communicating across different types of keyplayers. This includes a description of how the initiative is expected to reduce emissions, as well as whether there are any obvious, relevant areas of attention for the initiative.

**Step 1** contains four parameters, each of which provides insights into where and how the initiative can potentially reduce greenhouse gas emissions. This includes national emissions, i.e. emissions from production within Danish borders, and how these emissions are expected to develop. The step also looks at the climate footprint, i.e. emissions from Danish consumption within as well as outside Danish borders. Besides this, the step looks at global emissions, i.e. the scope of global emissions in the area addressed by the initiative.

**Step 2** includes four conditions and a number of underlying parameters. The first condition concerns the investment need and associated funding opportunities. Research and business strongholds are about Denmark's research and business stronghold in the area. Capacity looks at potential bottlenecks for realising the reduction potential. For example, insufficient labour to scale up an initiative or a lack of test facilities to develop a technology. Governance is about the structural conditions to which an initiative is subject. For example, whether there is public and political backing for a technology or whether a technology is in high public demand.

**Step 3** looks at other aspects and considerations associated with an initiative or that an initiative can influence (besides greenhouse gas emissions). For example, other political considerations, such as maintaining biodiversity, or strategic considerations, such as whether the initiative fits into the existing portfolio of initiatives.

## 4.3 Detailed description of steps and parameters

This section describes the steps in more detail, including the underlying parameters, to give a broader understanding of their content.

### 4.3.1 Step 1: Reduction potential

The first step in the assessment tool is to assess the reduction potential of the initiative. This step helps prioritise investment towards initiatives that aim at reducing emissions from the largest emission sources. Focus is on reducing national emissions, but Denmark's total climate footprint and global emissions are also considered. The assessment provides an overall picture of how different initiatives can contribute to reducing emissions, nationally as well as globally, and how they can help to ensure the best return on green research and innovation investments.

**Reduction potential as a measure**

In the context of this assessment tool, the reduction potential is the amount of greenhouse gas emissions a research and innovation initiative has the potential to reduce.

First of all, this is the potential to target specific emissions sources, which means it must be possible to attribute the emissions reduction to a specific area, industry, product or similar. For example, if an initiative is about research within household energy-efficiency, and the initiative therefore has a potential to impact household electricity and fuel consumption, then the reduction potential for the initiative corresponds to the consumption-related emissions. The assessment of the reduction potential also includes negative emissions. Negative emissions are when the total amount of greenhouse gases that are already in the atmosphere is reduced, resulting in a lower concentration of greenhouse gases in the atmosphere. Emissions reductions by initiatives that contribute to negative emissions cannot necessarily be attributed to a specific emission source. This includes initiatives on research into nature-based methods to address climate change (e.g. afforestation, which involves planting trees that absorb $CO_2$ from the atmosphere), or research into technological solutions (e.g. Direct Air Capture (DAC), which involves capturing and removing $CO_2$ directly from the atmosphere).

Although it is not possible to attribute the potential negative emissions of these initiatives, directly to a source, these types of initiatives are still very relevant for the green transition. They help achieve climate neutrality, and this is important because some emissions are impossible or too difficult to reduce and therefore must be compensated for through other means. Negative emissions will become even more relevant if the political ambition to reduce emissions by 110% by 2050 compared to 1990 is adopted as a climate target.

Step 1 involves an assessment of the initiative's potential to reduce Denmark's **national emissions**; that is, emissions stemming from Danish production within Danish borders and relating directly to the climate targets in the Danish Climate Act. This includes both observed emissions and expected (**projected**) emissions. This is to avoid including emissions in the reduction potential that are already expected to be mitigated by existing measures, technologies or trends. The Danish Climate Act contains several other principles for climate action. One principle is that realisation of the climate targets for national emissions must not lead to emissions abroad instead. Therefore, the potential for reducing Denmark's total **climate footprint** is also assessed, although a reduction in the climate footprint does not necessarily contribute to realising the Danish climate targets, as the climate footprint includes emissions outside Denmark. For example, if an initiative aims to reduce emissions from cement production, but the costs of implementing the initiative lead to production being relocated abroad, then emissions from production in Denmark will be reduced but global emissions will increase. The same applies to initiatives aiming to limit imports of goods from other countries. The Danish Climate Act also states that Denmark must be a frontrunner in global climate action. Therefore, step 1 also includes an assessment of the initiative's potential for contributing to reducing **global emissions.** Global emissions in this context means emissions that are related to neither Danish production nor consumption, and that have neither a direct nor an indirect relevance for Danish emissions. For example, Danish development and export of new and more effective and efficient solar PV panels can contribute to reducing global emissions by making renewable energy accessible and attractive globally, even if these activities do not directly affect Denmark's national emissions.

To provide a more nuanced assessment of the reduction potential, several parameters are considered as a supplement to the assessment of national emissions, projected emissions, the climate footprint, and global emissions.

- **Time horizon:** The time horizon is a description of when the effect of a given initiative is expected to materialise. The time horizon can be divided into short-term, medium-term or long-term, for example, and could be defined on the basis of the targets set out in the Climate Act or specified into time periods of 5, 15 and 25 years. The objective of this assessment is to ensure an equal distribution between long-term and short-term research and innovation initiatives, so that the benchmarks in the Danish Climate Act can be met.

- **Complexity:** To nuance the assessment of the reduction potential, it is also important to consider the complexity of abating the emissions. This involves assessing the technological complexity in relevant industries; in other words, are the emissions easy or difficult to abate? This is an important aspect, because the complexity of some technologies can make them extremely expensive. For example, for purely technical reasons, emissions from the concrete industry are very difficult to reduce. In such cases, higher-than-usual costs relative to the reduction potential may be acceptable.

- **Obsolescence risk:** Finally, it should be considered whether there is a risk that the elements and activities related to the initiative are surpassed by other solutions and therefore become obsolete. This is particularly important for initiatives targeted at technology-rich areas. For example, electric cars have now become so widespread that climate solutions to optimise combustion engines have become less relevant.

### 4.3.2 Step 2: Conditions

The second step involves assessing the likelihood of the reduction potential being realised. This involves assessing a series of conditions considered as most important for realisation of the potential. The step identifies the most important factors and helps determine whether the initiative can realise its reduction potential. Aspects considered include investment and funding, research and business strongholds, capacity and governance. The assessment provides an overall picture of the likelihood of the initiative being implemented successfully, its reduction potential being realised and thus the effect of public investment in green research and innovation being maximised.

#### 4.3.2.1 Investment and funding

Obviously, funding is crucial for realising research and innovation initiatives. Insufficient funding to cover the investment needs of initiatives can lead to delays, scaling issues, etc. Furthermore, the financial condition can reveal potential private and public investors' willingness to take risk and any need for public involvement to support the required development of the initiative.

Three different types of investing are considered when assessing the investment need.

- **Direct investment:** Direct investments are directly associated with implementing the initiative. These cover the costs of developing the technologies before commercialisation, which is the point at which the technologies are made available on the market. It is important to assess the direct investment needed, because there can be discrepancies between the risk appetite and the time horizon of investors, on one hand, and the risk and time horizon associated with investing in the initiative on the other. If this is the case, the initiative might not obtain the required funding, whether from public or private investors.

- **Expected follow-on investments:** This is the investment need associated with any derived activities from the initiative. For example, this could be investment to establish the necessary infrastructure, or investment in deployment and scale-up. Follow-on investments are typically not needed until the technology reaches a higher level of maturity. It is important to assess follow-on investments because their scope may deter private investors.

- **Investment at the commercialisation stage:** These investments are to support the role of the technologies on the market. It can be difficult for even fully mature green technologies to gain momentum in the market. Investments to support this can include capital investment and production aid. The story of the Danish wind-turbine industry is evidence that such investments can be necessary to consolidate the finances and technologies involved in an initiative, even when the technologies are at high level of maturity.

When assessing whether there are private funding opportunities to meet the investment need, both Danish and international actors should be considered, as investors often have an international outlook. The primary parameters for assessing private funding opportunities should be the risk appetite of investors and the time horizon for their investments. These are important parameters because technologies with a low level of maturity will most often require a higher risk appetite and a longer time horizon than technologies with a higher level of maturity. In other words, the potential for investment depends on whether there is alignment between the level of maturity of the technology (initiative) and the investment profile of investors. If there is uncertainty about private funding opportunities, the state can intervene to create incentives for private investment, for example in the form of tax incentives or aid schemes. For example through a tax on fossil fuels, which would incentivise businesses to turn towards more sustainable sources of energy.

#### 4.3.2.2 Research and business strongholds

Strong research environments are a prerequisite for developing and enhancing the research frontier, just as a competitive business sector is needed to translate and implement research into solutions in practice. The combination of research and business provides the best opportunities to develop new technologies and solutions *and* to scale them up and market them commercially, and this is crucial for realising the full reduction potential of an initiative. For example, Denmark has strong research environments within wind energy and a solid commercial strength in the wind-turbine industry. This combination has enabled Denmark to develop, scale up and market wind farms both nationally and abroad. However, it is important to be aware that investing extensively in established research environments and industries also comes with a risk of restricting the development of new ideas and areas.

- **Research strength:** In order to increase the likelihood of success of research and innovation initiatives, Denmark must have research environments that can help develop and push the research frontier in the area. This requires well-established and sizable research environments with growth potential, which often take time to build. Strong research environments with the capability and capacity to carry out the required research activities are needed throughout the lifetime of the relevant initiatives. Furthermore, Denmark's strength in the area compared to that of other countries must also be considered. As research can be considered a non-rivalrous good, we can potentially draw on the strengths and experience of other countries.

- **Business strength:** In order to promote further development of the results of an initiative, it is relevant to assess whether there is a business sector capable of delivering this further development and facilitating full realisation of the reduction potential of the initiative. An example of this in a Danish context is the shipping industry: Danish shipping companies can help implement results from research and development in green fuels. This example also illustrates the transition from research environments to the business sector, which involves the capacity and potential for collaboration between research environments, businesses, organisations, public authorities, etc. Effective collaboration between these actors will help to ensure that research results from a given initiative are in fact absorbed and further developed when launched on the market and implemented. It is only when the solutions reach the final link in the value chain, that the research will lead to actual emission reductions.

#### 4.3.2.3 Capacity

Limited capacity can be a barrier to an initiative and the effect of an initiative on emissions. Capacity issues can relate to human capital, infrastructure or other input parameters. Without adequate and available capacity in Denmark, research and innovation initiatives cannot be efficiently implemented and this can lead to delays and inefficiency in general with regard to realising and scaling up a solution. For example, development of highly advanced energy systems requires both highly qualified engineers and adequate test facilities. If these input parameters are inadequate or absent, it can lead to delays in developing and implementing new energy solutions and, by extension, fewer emissions reductions. There are three different types of capacities.

- **Human capital:** An initiative requires different types of labour, depending on the nature of the initiative. When assessing whether there is sufficient human capital for an initiative, a distinction should be made between the labour directly involved in the initiative and the labour involved in subsequent activities. Research and innovation initiatives typically require a scientific workforce, including researchers and PhD graduates, while derived activities such as implementation and scaling require a skilled technical workforce. For example, consider initiatives on solutions pertaining to energy systems. Such initiatives will require engineers for research and development in smart grid systems. And the resulting solutions of such initiatives will require electricians to instal the solution. If the required human capital is not available, issues with bottlenecks may impede development of the initiative.

- **Infrastructure:** In some areas, inadequacies related to infrastructure can obstruct research and innovation initiatives. Available and adequate infrastructure can be a prerequisite for translating research results into concrete solutions. For example, lack of test and demonstration facilities is an obvious barrier to PtX development and scale-up, just as lack of pipelines for transport is an obvious barrier to large-scale deployment of hydrogen.

- **Other input factors:** An initiative might require other types of capacity besides human capital and infrastructure. In particular, this includes critical input for the expected solution, such as critical raw materials, land or biomass, or other raw materials. For example, bioethanol development requires large areas of land. If the required land is not available, the solution cannot be scaled up.

#### 4.3.2.4 Governance

Important structural and systemic conditions need to be in place to facilitate that an initiative ultimately contributes to reducing greenhouse gas emissions. Governance embraces some of these conditions, one of which is policy instruments, such as legislation, taxes, regulation, subsidies and standards, to support or regulate an initiative. Another element is backing, such as local-community backing for solar PV installations, EU backing for GMO technologies, or support for nuclear power. Finally, the adaptability of society and people's willingness to adopt new solutions and technologies is important, because initiatives are also propelled by behavioural change. For example, initiatives to convert Danish livestock farming to be more environmentally friendly and improve animal welfare require consumer backing and willingness to change consumption patterns. However, even with this backing in place, increased costs for agriculture and consumers can pose barriers. Governance includes three parameters.

- **Policy instruments:** Policy instruments can play an important role in ensuring the ultimate success of research and innovation initiatives in reducing emissions. Policy instruments include legislation, taxes, regulation, subsidies and standards, each of which plays a role in creating the right incentives and framework conditions for implementing an initiative in society. For example, a tax on greenhouse gas emissions in agriculture can motivate the agriculture sector to convert production and adopt new processes that reduce emissions, and such instruments can therefore be crucial for the success of an initiative.

- **Backing:** Backing can be an important element in ensuring successful implementation of a research and innovation initiative. Examples include local-community backing (or opposition) in Denmark for solar PV installations, backing (or opposition) in the EU for research in GMO technologies, and international backing (or opposition) for nuclear power in the green transition.

- **Society's adaptability:** The adaptability of society is about more than backing for an initiative; it means society's willingness and ability to act and to change old patterns of behaviour. In other words, adaptability is about behavioural change and society's willingness and ability to pay the necessary costs of the green transition. There might be broad public backing for conversion of Danish livestock production out of consideration for the climate and animal welfare, but this does not necessarily mean there is also a real willingness and ability to change traditional consumer habits.

### 4.3.3 Step 3: Important considerations

The third step is about the considerations viewed important to achieve a holistic assessment of the research and innovation initiative. These fall into two categories:

- **Political considerations:** From an overall perspective, an initiative should be assessed on the relationship between its reduction potential, its funding requirement and its likelihood of success. By including political considerations in the assessment, however, it is possible to take account of other political prioritisation or other bottom lines, such as biodiversity or the implications for prioritisation of other initiatives. For example, an initiative less likely to realise its full reduction potential may be acceptable if the initiative is expected to lead to improved biodiversity. On the other hand, initiatives with a high reduction potential and likelihood of success may be discarded if they entail adverse implications for the prioritisation of other initiatives.

- **Strategic considerations:** Besides political considerations, considerations of a more strategic nature can be included in the assessment. A strategic consideration could be whether the initiative complements the existing portfolio of research and innovation initiatives. Another consideration is whether the initiative is reliant on the same capacity and input as other initiatives. This could be land, which serves as input in various domains, such as agriculture, biodiversity, solar PV, etc. Furthermore, a consideration may be whether the initiative supports or amplifies other government measures and strategies.

Note that the outline above of political and strategic considerations is neither static nor exhaustive, as considerations may change over time, just as they may be specific to an individual initiative. Therefore, step 3 is meant to be flexible as to what considerations are included.

# 5. Things to consider when using the assessment tool

This section discusses how and when to use the assessment tool, what to expect in terms of resources needed for the assessment, as well as what to take into account when using the tool to assess research and innovation initiatives.

## 5.1 A flexible assessment tool

The tool has been designed to allow for a flexible and structured approach to assessing different types of research and innovation initiatives, but it is important to be aware that the applicability of the tool will vary depending on the initiative assessed. Not all elements in the tool will be equally relevant for all initiatives, and therefore use of the tool should be adapted to the nature of the initiative in question.

This means that initiatives focussing on societal matters, such as behavioural research on how to reduce household food waste, do not necessarily benefit from an assessment of business strengths. Other parameters, such as public backing and adaptability, will be more relevant in such cases. In the case of initiatives to develop solutions, in the form of advanced energy storage systems for example, an assessment of infrastructure will be relevant. Here, infrastructure such as a distribution system is needed to implement the solution, just as power will be a critical input. Initiatives to develop new solutions or new technology, such as PtX, will require investment in electrolysis plant and distribution infrastructure, both during the development phase and for full scale up of production. In such cases an assessment of the expected investment need will be relevant, along with an assessment of whether private funding sources are likely to be available to cover future costs. Initiatives focussing on research, for example into financial instruments such as tax instruments, have huge potential to advance the green transition but it is less relevant to assess the reduction potential of these initiatives, since there is no direct link between the initiative and emissions reductions. Furthermore, there may be cases in which the initiative is associated with negative emissions which cannot necessarily be linked to a specific emission source, and the proposed approach to assessing the reduction potential of such initiatives will therefore also be less relevant. Such an initiative's potential negative emissions could be an alternative to reduction potential.

All in all, it is important to understand that the tool is flexible, and some parts may be more relevant than others, depending on the initiative at hand. As a user of the tool, it is therefore important to assess what aspects of the tool to prioritise based on the relevant research and innovation initiative.

## 5.2 Limitations of the assessment tool

The assessment tool can support and qualify assessments of how research and innovation initiatives contribute to greenhouse gas emissions reductions. However, the tool also has limitations. Because the tool is not a model providing a specific result, the user of the tool must make more active choices and interpretations when assessing an initiative. Although the tool provides a structured approach to such an assessment, the user still needs sufficient insight to be able to interpret the results correctly. Furthermore, the tool cannot replace the expert assessment that is often essential to better understand the full implications of research and innovation initiatives. The tool also does not capture all potential social, economic and environmental impacts associated with an initiative, and although the tool includes some of these parameters, fully covering all aspects is impossible. Fully understanding such complexity would require resource-demanding in-depth analyses and very specific tools. This assessment tool therefore has its limitations, and should be used accordingly. Active choices and interpretations by users are needed to ensure a sound and nuanced assessment process. However, if used correctly, the tool can improve existing processes by providing a systematic basis for the assessment.

## 5.3 Choices in developing the assessment tool

In our development of the tool, we have chosen to focus on the most important and decisive parameters based on current knowledge and expertise. This scoping is based on a number of important considerations. Firstly, the tool is a management tool, which means it must be easy to use and practicable in an administrative context. This means it cannot be too resource-demanding, because this would prevent it from being used in practice. This consideration was significant for our scoping of the parameters included in the tool. Secondly, some aspects are simply too complex to assess in this context, and therefore too difficult to include in the tool in any meaningful way. One such complex aspect is what would happen if funds were not allocated to an initiative, and whether the initiative would then find funds from other sources. Although this is a very relevant question, clarifying counter-factual scenarios would be associated with too much uncertainty and has therefore been omitted. Finally, some aspects are too extensive to assess, and the results would therefore be associated with too much uncertainty. Evaluating the impact of research, for example, is often characterised by considerable uncertainty, and ensuring an adequately certain evaluation would be an impossible task.

## 5.4 Resource use

It is difficult to estimate how resource-demanding use of the assessment tool is. This is because the breadth and complexity of individual initiatives vary greatly, but also because the conditions and parameters in the assessment tool themselves relate to complex socio-economic conditions, etc., which can potentially require very detailed analyses. In the final analysis, it is up to the individual user to decide on the depth of analysis for the individual parameters, and it is therefore important that the assessment is appropriate for its objective and proportionate to the initiative being assessed. It is therefore important to consider the depth of the assessment of the individual initiative.

The *Using the assessment* section below exemplifies how the tool can be applied in practice. The section presents examples for the individual steps and parameters with indicators and data but does not provide direct recommendations on how to perform the actual assessment. Use of the tool should be flexible, and users are welcome to tailor their use of the tool to the individual initiative being assessed.

## 5.5 Identifying barriers and possible policy measures

The tool has been designed to facilitate the process of identifying, and thus investing in, the research and innovation initiatives with the greatest potential for greenhouse gas emissions reductions. The tool can also help identify possible barriers to realising the reduction potential of a given initiative. Such barriers could potentially be removed by other policy measures. Since the assessment tool can be a help in identifying barriers to an initiative, it can also potentially help identify where there is a need for other policy measures to remove these barriers, if there is a political desire to implement the initiative.

For example, an initiative aiming to develop advanced energy storage systems could face challenges in the form of missing infrastructure or insufficient funding for follow-on investments. In identifying such barriers, the tool can also reveal how a research and innovation initiative is unlikely to realise its reduction potential without interventions to remove these barriers. Some barriers, for example existing legislation, have been introduced to serve a specific purpose, for example to support other societal interests. Consider an initiative aiming to develop and implement green hydrogen plants with the potential to reduce fossil-fuel dependency in the energy storage and transport sectors, for example. An important barrier for this initiative could be existing environmental legislation which regulates the establishment of new industrial complexes and sets strict requirements with regard to noise, contamination and land use. The legislation was designed to protect local environments and communities but can also be an obstacle to scaling up technology such as hydrogen plants.

It is important to emphasise that the assessment tool does not set recommendations for policy measures. It merely presents a systematic approach to identifying potential barriers so that potential policy measures to remove these barriers can be considered to facilitate realisation of an initiative.

# 6. Using the assessment tool

The previous sections described the concept of the assessment tool and some of the considerations that went into its development. This section describes how the tool is intended to be used in practice. There is a description of how to operationalise the different steps and underlying parameters that make up the assessment tool. The aim is to illustrate how the tool can provide a way to structure assessment of research and innovation initiatives. Regular case examples with specific initiatives are given to show how the tool can contribute to a systematic and structured approach to the assessment of green research and innovation initiatives.

## 6.1 Description of the initiative

Before using the tool to assess research and innovation initiatives, it is a good idea to describe the relevant initiative in detail. The purpose of this initial step is to have a basic overview before starting the assessment and to determine whether the tool is appropriate for the specific case. The description will also provide a better outset for assessing the individual steps and parameters of the tool, for example by supporting the necessary scoping, selection of data sources and identification of any relevant areas of attention. This is closely related to step 3, which identifies whether there are other important considerations.

The description of the initiative can be constructed from the following elements:

- **Description of the initiative:** Firstly, it should be possible to draw up a general description of the initiative, containing the most essential information about the initiative. The description should be sufficiently detailed to be understood and communicated across different types of actors and organisational levels. This is especially relevant when assessing multiple initiatives at the same time.

- **The initiative's reduction of greenhouse gas emissions**: Next, it should be possible to give a relatively straightforward description of how the initiative is expected to contribute to reducing greenhouse gas emissions in practice. This does not mean a long technical explanation, but rather a more general description of the technologies, solutions, activities, etc. involved in the initiative and how these are expected to reduce greenhouse gas emissions.

- **Obvious areas of attention:** Finally, it will be a good idea to identify any relevant areas of attention for the initiative. This includes areas of attention directly related to the tool, and which will therefore be revisited later in the assessment process, but also areas of attention not directly covered by the different steps in the tool. 'Land use' is an example of an obvious area of attention. Several different policy objectives have 'land use' as an input parameter. This includes solar PV deployment, afforestation, land cultivation, etc. Since land could become a scarce resource over time, it is an obvious area of attention, see also step 2 on capacity.

## 6.2 Step 1: Reduction potential

This section describes how the first step can be operationalised. The first step involves an assessment of the amount of greenhouse gas emissions that a given research and innovation initiative can potentially reduce. This is referred to as the initiative's reduction potential, and it is the amount of emissions within a sector, industry or similar that a given initiative can potentially affect. The first part of the step is to assess the *national emissions* that the initiative can potentially affect. This includes the initiative's potential for reducing greenhouse gas emissions in different industries, etc. in Denmark. The next part of the step is to assess how the initiative can potentially affect *Denmark's climate footprint*, including emissions from international shipping and similar, which are typically not included in national emissions inventories. The assessment should also look at expected future (projected) reductions from existing measures to avoid double counting. Finally, the assessment should look at the initiative's potential for reducing *global emissions*, including in industries outside Denmark. The assessment of emissions that the initiative can potentially reduce should include parameters such as the time horizon (e.g. short, medium and long term) for when the reduction potential can be realised. To ensure nuance, the assessment should also consider parameters such as the complexity of reducing emissions and the risk of an initiative becoming obsolete.

### 6.2.1 What should the reduction potential be a measure of?

The assessment of the reduction potential of an initiative cannot, by definition, be an exact *a priori* calculation of the effect of the initiative on greenhouse gas emissions, as research results are inherently associated with uncertainty. Therefore, to ensure the assessment is realistic and practicable, the reduction potential should be understood more broadly. The reduction potential should be understood as the amount of emissions within an industry, sector, area or similar which a given initiative can potentially affect. This approach is based on a quantification of the emissions directly or indirectly linked to the industries, technologies or products associated with the initiative. However, the approach does not aim to provide an actual impact evaluation of an initiative's ability to reduce greenhouse gas emissions. Instead, the approach aims to assess the share of existing emissions the initiative is expected to affect. For example, in the case of an initiative on research about fodder composition to reduce emissions from cattle, an assessment of the reduction potential will not be able to assess in detail how or how much the specific fodder composition will affect emissions. Instead, the assessment of the reduction potential should be based on total emissions from cattle today along with projections of their development with existing technologies and solutions.

The primary reason not to make an actual impact evaluation is that research results are uncertain by nature and an impact evaluation would therefore be associated with considerable uncertainty. The uncertainty will be further amplified if the initiative is about immature technologies or solutions, which is usually the case for research and innovation initiatives. Furthermore, some initiatives will be of a more general or overarching nature, and this means they may cover many different technologies and solutions, and these may not always come with detailed descriptions, making impact evaluations even more uncertain. Due to these uncertainties, impact evaluations have to be extremely thorough and well documented to yield any reliable results, and this would require extensive investment in time, expertise and other resources. However, even with the most thorough impact evaluation, the result would be associated with considerable uncertainty, and subsequent use of the tool would be biased towards mature and well-documented technologies or solutions at the expense of ground-breaking research.

That said, there are various ways in which to carry out the assessment of the reduction potential, and the approach described here is just one such approach. Although an assessment of the reduction potential based on a broad quantification may be appropriate and practicable in many cases, there may be other cases in which a more detailed impact evaluation is possible and desirable. It is therefore important to consider whether the chosen approach is the most appropriate for the initiative at hand.

### 6.2.2 Greenhouse gas emissions inventories

When assessing the reduction potential, it is important to remember that greenhouse gas emissions can be calculated and inventoried in different ways. In general, emission inventories can be divided into production-based emissions and consumption-based emissions. In the production-based calculation, emissions are attributed to the production process. The consumption-based calculation on the other hand, which is also known as calculation of climate footprint, covers emissions associated with total consumption of goods and services. The example below illustrates the difference between the two calculation methods (types of inventories). For a more in-depth explanation of the differences between production-based and consumption-based emissions, see the 2023 report from the Danish Council on Climate Change on Denmark's global climate action. [14] Furthermore, see the section on Scoping for a description of how to scope the different calculation methods for the initiative being assessed.

**Example of the difference between production-based and consumption-based emission inventory**

A Danish business produces copper cable. The copper itself is imported from outside Denmark and the product is exported to countries outside Denmark.

**Production-based:** Emissions from production of the copper cable product are attributed to Danish emissions. Emissions associated with producing the copper are attributed to the country where the copper is produced.

**Consumption-based:** Emissions associated with production of the cable as well as emissions associated with extracting the copper are attributed to the country where end consumption takes place. That is, the country to which the cable is exported.

There are several reasons why it is important to consider how emissions are tallied. If the sole basis for assessment is the territorial, production-based inventory prepared by the Danish Centre for Environment and Energy (DCE), initiatives that involve reduction of imported goods, for example, will not be assessed as having any reduction potential, because these emissions only counts as Danish in consumption-based emissions. The territorial, production-based inventory only includes emissions that occur in Denmark. Emissions from international shipping and aviation are not included and therefore the significance for the total climate accounts of initiatives aimed to reduce emissions in this area will not be fairly assessed. Furthermore, if only production-based emissions are included, there is a risk that so-called carbon leakage is not accounted for. Carbon leakage is when a reduction in emissions is due to production having been transferred abroad. The two types of inventories mean it is possible to make the assessment of the reduction potential flexible because it is possible to adapt the assessment depending on where the emissions can be attributed to. The production-based inventory covers Denmark's national emissions, which is useful when looking to prioritise initiatives that directly influence Denmark's national climate targets. The consumption-based inventory, on the other hand, is useful when looking to prioritise initiatives based on a more

[14] The Danish Council on Climate Change (2023), *Danmarks globale klimaindsats*, https://klimaraadet.dk/da/analyse/danmarks-globale-klimaindsats

global perspective by including emissions associated with the consumption of imported goods, which can be decisive for understanding the potential global consequences of an initiative and, thus, achieve a more complete and true assessment of the reduction potential.

### 6.2.3 Data basis

As described above, the assessment of the reduction potential should be understood as a quantification of the emissions stemming directly, or indirectly, from the relevant industries, technologies and products associated with the initiative. Being able to make this assessment depends largely on the data available for assessing the reduction potential of a given initiative. Different data sources exist, the most commonly used are:

- Official statistics from Statistics Denmark, the Danish Centre for Environment and Energy (DCE), Eurostat, the IPCC, etc.
- Scientific studies and reports from the Danish Council on Climate Change, the Danish government, universities, GTS institutes (approved technological service providers), etc.
- Industry and sector reports such as the Danish Energy Agency's technology catalogues, IEA reports, reports from industry associations, etc.

Official statistics is the main basis for assessing reduction potentials as they are considered the most appropriate data source. However, it is important to always use whatever data source is most appropriate for the initiative at hand. table 6.1 shows possible sources of data on production-based as well as consumption-based emissions. In addition to emissions inventories, the table includes Denmark's Climate Status and Outlook reports, which is a technical projection of expected emissions, as well as a source of data on global emissions.

**Table 6.1**
Proposal for data sources

| Contents | Calculation method | Prepared by |
|---|---|---|
| National emissions | Production | DCE[15] |
| | Production | Statistics Denmark[16] |
| Climate footprint | Consumption | Danish Energy Agency and Statistics Denmark[17] |
| | Consumption | Danish Energy Agency[18] |
| Denmark's Climate Status and Outlook | Production | Ministry of Climate, Energy and Utilities[19] |
| Global emissions | Production | UN IPCC (the United Nations' Intergovernmental Panel on Climate Change)[20] |

### 6.2.3.1 National emissions

Production-based emissions, here referred to as national emissions, are used as the first parameter when assessing the reduction potential of an initiative. This is because these emissions are linked directly to Denmark's national climate targets set out in the Danish Climate Act. Data inventories from the Danish Centre for Environment and Energy (DCE) and Statistics Denmark provide good sources for this assessment. The reason that both sources are included is primarily because of their technical differences. The two inventories are based on different nomenclatures (classification systems) and therefore allow for different possibilities for linking to other data sources, such as business statistics. Furthermore, the Statistics Denmark inventory contains data on emissions from international transport by Danish ships, aircraft and vehicles that is not included in the inventory from the Danish Centre for Environment and Energy (DCE). The section on Scoping explains the differences between the two calculation methods in more detail, including how the DCE method offers more detailed insight into climate-related data, while the Statistics Denmark method allows for broader comparison across industries and economic indicators. The possibility to choose between the two data sources allows for flexibility in the use of data and, ultimately, in the assessment of the reduction potential. To illustrate how a production-based emissions inventory can be used, below is a simplified example regarding national emissions within agriculture based on the DCE inventory.

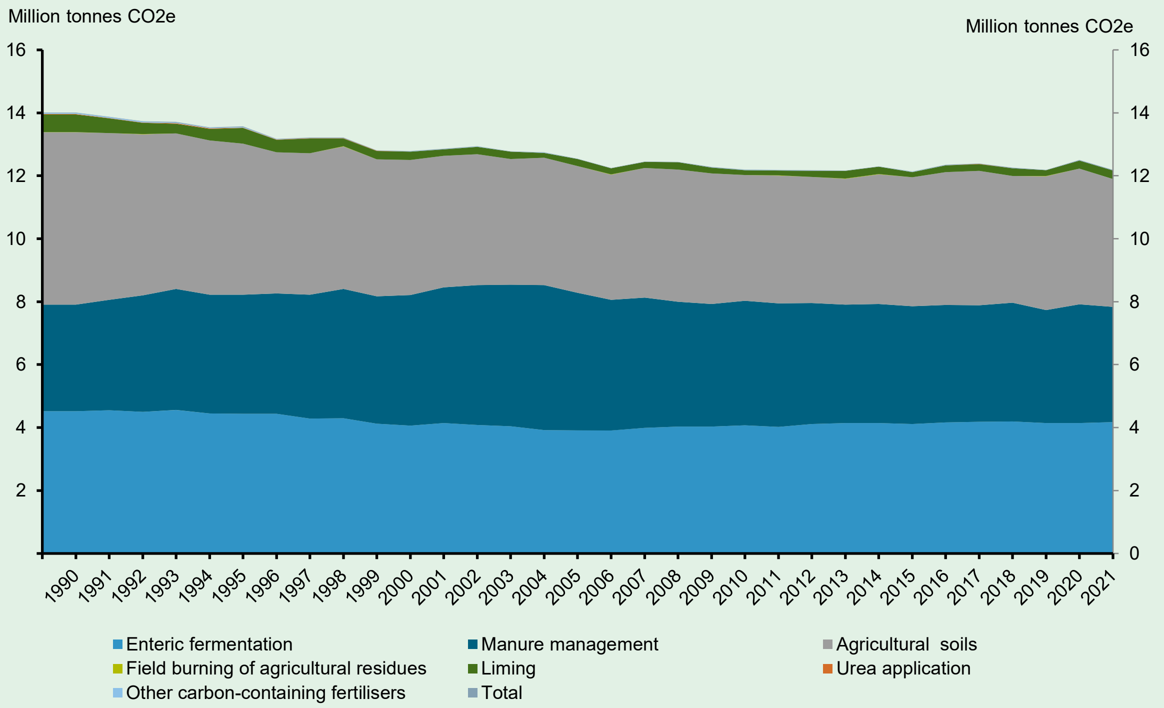
**Example: National emissions from agriculture, 1990 to 2021**

Emissions from Danish agriculture amounted to around 12.5 million tonnes $CO_2e$ in 2021. This could theoretically be considered agriculture's total reduction potential, see figure 6.3. Emissions from agriculture stem primarily from enteric fermentation, agricultural land and manure management, each of which accounts for around one-third of all emissions from agriculture. Selecting the subcategories relevant for the initiative is important, because it provides a truer assessment of the reduction potential. For example, the reduction potential of an initiative to optimise liquid manure management should be assessed exclusively based on categories pertaining to manure management.

[15] European Environment Agency (2024), *European Environment Information and Observation Network*, https://www.eionet.europa.eu/
[16] Statistics Denmark (2024), *Statistikbanken*, https://statistikbanken.dk/statbank5a/default.asp?w=1920
[17] Statistics Denmark (2024), *Statistikbanken*, https://statistikbanken.dk/statbank5a/default.asp?w=1920
[18] Danish Energy Agency (2024), *Danmarks globale klimapåvirkning - Global afrapportering,* https://ens.dk/service/fremskrivninger-analyser-modeller/danmarks-globale-klimapaavirkning
[19] The Ministry of Climate, Energy and Utilities (2024), *Klimastatus og –fremskrivning*, https://www.kefm.dk/klima/klimastatus-og-fremskrivning/klimastatus-og-fremskrivning-2024
[20] UNFCCC (2019), *GHG data from UNFCCC*, https://unfccc.int/topics/mitigation/resources/registry-and-data/ghg-data-from-unfccc

In the event of any doubt as to what categories are relevant for an initiative, see Chapter 8 of Volume 1 of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*[21], which includes definitions of the individual categories.

**Figure 6.3**
Trends in emissions from agriculture, 1990-2021




*Source: Expert group on the significance of research for the green transition's own calculations using data from EIONET*

### 6.2.3.2 Denmark's climate footprint

Looking at the climate footprint of an initiative is relevant for initiatives aiming at Danish consumption and global emissions, even if the initiative does not contribute directly to meeting Denmark's national climate targets. In these cases, an inventory of the climate footprint of Danish consumption by Statistics Denmark and the Danish Energy Agency can be useful. There are many ways to use this inventory. Statistics Denmark has prepared an analysis that exemplifies some of these possible uses.[22] For more ideas, see also the Danish Energy Agency's annual report on Denmark's Global Climate Impact.[23] Possible uses include looking at emissions by country, by industry, or by how the emissions occurred. The climate footprint inventory can be relevant when assessing an initiative about recycling materials in building and construction. Such an initiative will have the potential to reduce the consumption and import of steel in the building and construction sector. The greatest effect of this initiative will be on Denmark's climate footprint and not on Danish national emissions, and therefore the initiative is relevant even though it does not contribute to realising Denmark's national climate targets (see the box below for an illustration of the reduction potential for the metal industry).

[21] IPCC (2006), *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol1.html
[22] Statistics Denmark (2021), *Dansk forbrug sætter i høj grad sit klimaaftryk i udlandet*, https://www.dst.dk/da/Statistik/nyheder-analyser-publ/Analyser/47752-dansk-forbrug-saetter-i-hoej-grad-sit-klimaaftryk-i-udlandet
[23] Danish Energy Agency (2024), *Danmarks globale klimapåvirkning - Global afrapportering*, https://ens.dk/service/fremskrivninger-analyser-modeller/danmarks-globale-klimapaavirkning

### Example: Denmark's climate footprint, the metal industry

Emissions from metal manufacturing in Denmark amounted to 0.2 million tonnes $CO_2e$ in 2021, while the global climate footprint of both the Danish and foreign metal industry stemming from Danish consumption amounted to 3.2 million tonnes $CO_2e$ in the same year, see table 6.2. The reduction potential for Danish metal manufacturing is therefore relatively small compared to the larger reduction potential that can be realised by reducing metals imports or increasing metals recycling. The example illustrates the large difference for the assessment of the reduction potential between production-based and consumption-based calculations and why it is therefore important to identify the relevant inventories for the initiative being assessed.

**Table 6.2**
Emissions by the metal industry in million tonnes $CO_2e$ in 2021, by calculation method

| Calculation method | Greenhouse gas emissions |
|---|---|
| Production-based | 0.2 |
| Consumption-based (climate footprint) | 3.2 |

*Source: Expert group on the significance of research for the green transition's own calculations using data from Statistics Denmark*

The calculation of the footprint of Danish consumption of metal also makes it possible to see where in the world emissions occur and where end consumption of the products linked to these emissions occurs. The climate footprint only includes emissions stemming from consumption of products in Denmark and does not include products that are exported from and consumed outside Denmark. table 6.3 shows emissions from the metal industry by end consumption (place of use) and place of emission. The table shows that a considerable share of Denmark's indirect emissions stem from products produced in Denmark but then exported and consumed outside Denmark (i.e. 4.8 million tonnes $CO_2e$). Of the emissions linked to products produced but then exported from Denmark, as much as 3.1 million tonnes $CO_2e$ (out of a total of 3.2 million tonnes $CO_2e$) occur outside Denmark. The largest footprint from indirect emissions from Danish consumption (totalling 2.1 million tonnes $CO_2e$) was in China, Germany and India.

**Table 6.3**
Emissions by the metal industry by type of use and place of emission, 2021 (million tonnes $CO_2e$)

| | Type of use | |
|---|---|---|
| **Place of emission** | ***Domestic (part of climate footprint)*** | ***Exports (not part of climate footprint)*** |
| Denmark | 0.1 | 0.1 |
| Rest of world | 3.1 | 4.8 |
| *Of which:* | | |
| *China* | *1.5* | - |
| *Germany* | *0.3* | - |
| *India* | *0.3* | - |

*Source: Expert group on the significance of research for the green transition's own calculations using data from Statistics Denmark*

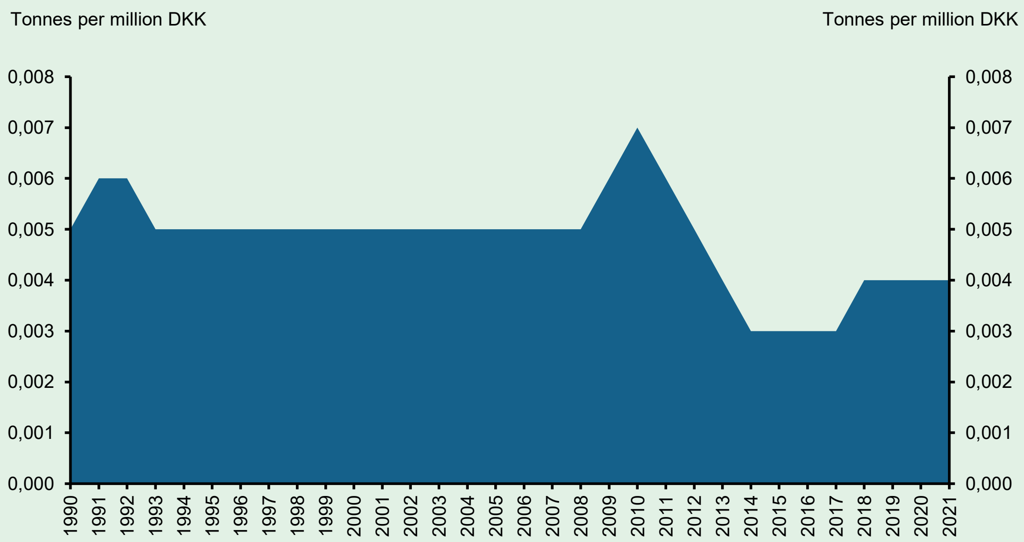
The table also shows that a share of emissions from Danish metal production ends in products that Denmark exports, see the *Exports* column. This column shows that exports of Danish products from the metal industry are linked to a total of around 4.9 million tonnes $CO_2e$, whereas emissions linked to products used in Denmark only account for around 0.1 million tonnes $CO_2e$. Most emissions from the metal industry therefore take place abroad as a result of exports, and Denmark is therefore a transit country in this context.

Finally, the climate footprint inventory can be used to look at the consequence for emissions from changes in production factors in Denmark, as the calculation incorporates a number of environmental multipliers. EXIOBASE, for example, contains figures on emission intensity, which is a measure of the volume of emissions an industry is likely to emit per DKK million turnover. Because it is a ratio between turnover and emissions, emission intensity is less affected by changes in the activity, which means it can be used as an indicator of the degree to which an industry is better at emitting fewer emissions, regardless of changes in activity within the industry.

**Example: Developments in emission intensity for the metal industry, 1990-2021**

This example looks at the emission intensity of the metal industry, which fell from around 0.006 tonnes per DKK million in 1990 to around 0.004 tonnes per DKK million in 2021. This means that the metal industry had a higher turnover per unit of emission in 2021 compared to 1990.

**Figure 6.4**
Emission intensity for the metal industry, 1990-2021




*Source: Expert group on the significance of research for the green transition's own calculations using data from Statistics Denmark*

Emission intensity can be an important indicator of whether an industry has become more 'emission efficient'. However, it is important not to make any ultimate conclusions without a more detailed examination. In some situations, changes can be due to other conditions than a more climate-friendly production, for example data breaches or price changes due to global incidents.

A comparison of activity figures with emissions figures can be an alternative or supplement to emission intensity (see the section about activity dataActivity data). For some industries it may also be relevant to look at the development in energy consumption by type of energy (StatBank Denmark: ENE2HA) to see whether there are any changes in the consumption of greenhouse-gas-emitting fuels.

### 6.2.3.3 Denmark's Climate Status and Outlook

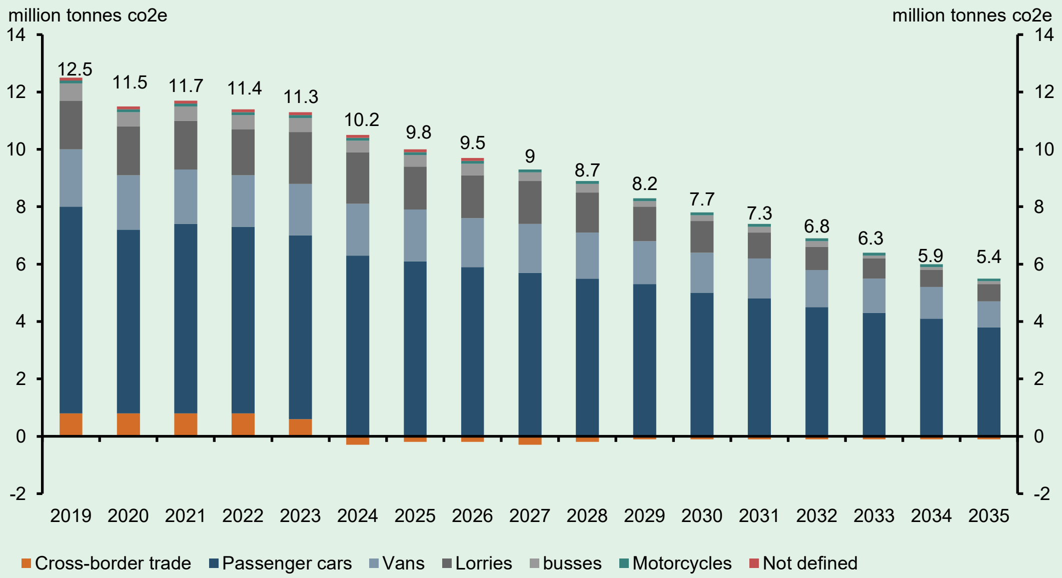
While the production-based and the consumption-based inventories allow us to assess the reduction potential based on historical and current emissions, projections of expected emissions can also be useful. Such climate outlooks calculate expected future emissions trends based on current observable trends. In the context of the assessment tool, climate outlooks can be applied to avoid including emissions in the reduction potential that are already included in emissions that are projected to be reduced by other means.

The most recent outlook report is from 2024 with projections up to 2035. Because the outlook reports are required by the Climate Act, they follow a calculation method in accordance with reporting to the IPPC. The outlook reports can therefore be used to assess whether Denmark is complying with its international commitments. The projections in the reports are based on a frozen-policy scenario; that is a scenario with current climate legislation and existing regulations.

**Example of emissions projection: Expected emissions from road transport up to 2035**

Emissions from road transport are expected to fall from around 11.7 million tonnes $CO_2e$ in 2021 to 5.4 million tonnes $CO_2e$ in 2035, see figure 6.5. This is mainly due to a fall in emissions from cars and vans. When assessing the reduction potential, it is important to look at projected emissions, so as not to overestimate the reduction potential by looking at only at existing emissions. In the case road transport, emissions are expected to fall considerably in the future, and the reduction potential of new initiatives in the transport area is therefore lower after taking projected emissions into account than if only the current level of emissions were considered.

**Figure 6.5**
Expected emissions from road transport up to 2035




*Source: Expert group on the significance of research for the green transition's own calculations using data from the Danish Ministry of Climate, Energy and Utilities*

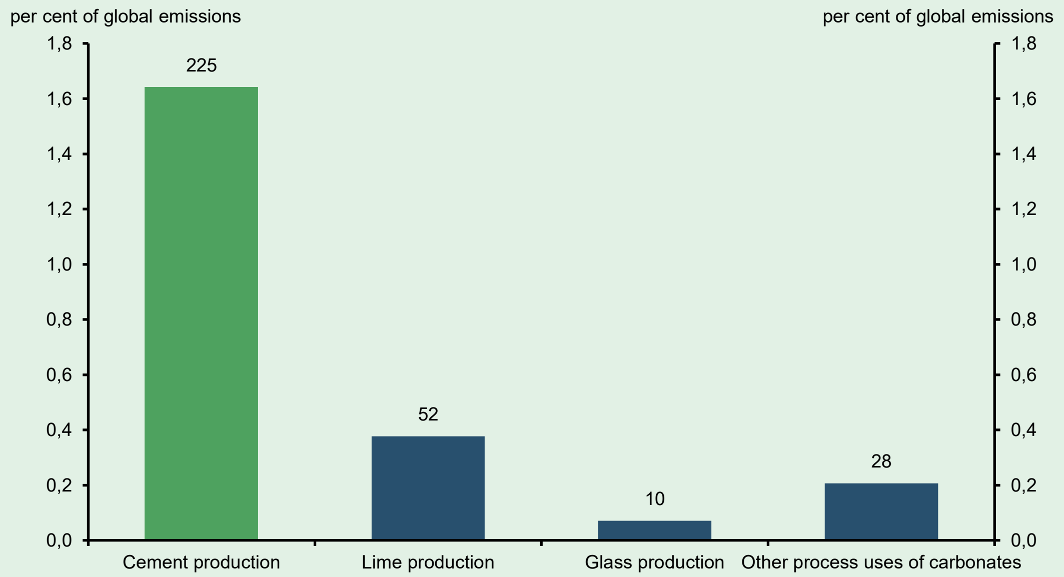
### 6.2.3.4 Global emissions

The emissions in production-based and consumption-based calculations, and in projections, are emissions related directly to Denmark. However, since Denmark aims to be a frontrunner in the green transition, it may be relevant to include global emissions in the overall assessment of the reduction potential. This will make it possible to consider emissions in similar industries and areas in countries outside Denmark, which could be relevant for research areas within which Denmark collaborates with other countries. By considering global emissions, it is possible to assess an initiative's global potential. This could be relevant for an initiative involving a technology with export potentials. Looking at the global potential of an initiative can illustrate the reduction potential if a technology or solution were spread globally. Danish research and development within wind turbine technology, for example, have not only had a positive impact on Denmark's ability to produce renewable energy but have also had a huge global impact.

**Example of global emissions from glass and cement**

Glass and cement are important materials in the building and construction industry, where cement is used to produce concrete, for example. Production of glass and cement is included in the IPCC inventories under the category 'Mineral Industry'. The figure below shows the global emissions related to this category. Cement production is the largest source and accounts for around 1.6% of total global emissions, see figure 6.6. Production of glass accounts for around 0.1% of total global emissions.

**Figure 6.6**
Share of global emissions, 'Mineral Industry', 2021




Note: Including only Annex 1 countries. In million tonnes $CO_2$e.
*Source: Expert group on the significance of research for the green transition's own calculations using data from UNCFF*

### 6.2.3.5 Activity data

Emissions inventories are the main component of the assessment of the reduction potential. However, the activity behind the emissions is also relevant. These activities are measured as tonnes of cement produced or number of kilometres driven by a car (number of passenger-kilometres), for example. In some cases, the inclusion of such activity figures can help to put emissions calculations into context to understand how emissions are related to activity in the area. For example, increased emissions within an area may be due to increased production rather than increased emissions per unit produced.

The primary source of activity data will most often be Statistics Denmark's StatBank Denmark, see Danish data sources in table 6.1 above. However, there are also data appendices to IPCC reports[24] and to Denmark's Climate Status and Outlook reports, which also contain useful activity figures. See Table 6.4 for a list of these activity figures.

Statistics Denmark's StatBank Denmark also includes examples of tables with information about activities within specific areas. For example, there are energy accounts with data on electricity and petrol consumption within an industry. StatBank Denmark also has waste accounts with data on waste production within an industry.

**Table 6.4**
Examples of sources with activity figures

| Source | Contents |
|---|---|
| StatBank Denmark[25] | General activity figures |
| *ENE3H* | *Energy accounts (by energy type and industry)* |
| *WASTE* | *Waste accounts* |
| *BIL5, BIL54* | *Transportation, number of cars on the road, and sales of cars* |
| *BYGV11* | *Building and construction activity* |
| *HDYR07* | *Number of animals in agriculture* |
| Accompanying data for IPCC reports[26] | Activity data related to most of the emission categories |
| Accompanying data for Denmark's Climate Status and Outlook[27] | Projection of activity figures |

Finding global activity data will often be more difficult, as different countries may have different ways of measuring activity. A good place to find global activity data can therefore be the UN's various sub-organisations, as data here will often be processed according to a standardised system. table 6.5 includes examples of UN data sources.

[24] Danish Centre for Environment and Energy, DCE, (2023), *Denmark's National Inventory Report 2023. Emission Inventories 1990-2021*, https://dce.au.dk/udgivelser/vr/501-599/abstracts/no-541-denmarks-national-inventory-report-2023-emission-inventories-1990-2021
[25] Statistics Denmark (2024), *Statistikbanken,* https://www.statistikbanken.dk/statbank5a/default.asp?w=1920
[26] European Environment Agency (2023), *National Inventory Report 2023*, https://cdr.eionet.europa.eu/dk/Air_Emission_Inventories/Submission_UNFCCC/colzdpsvg/envzdps1q/
[27] Danish Energy Agency (2024), *Klimastatus og -fremskrivning*, https://ens.dk/service/fremskrivninger-analyser-modeller/klimastatus-og-fremskrivning

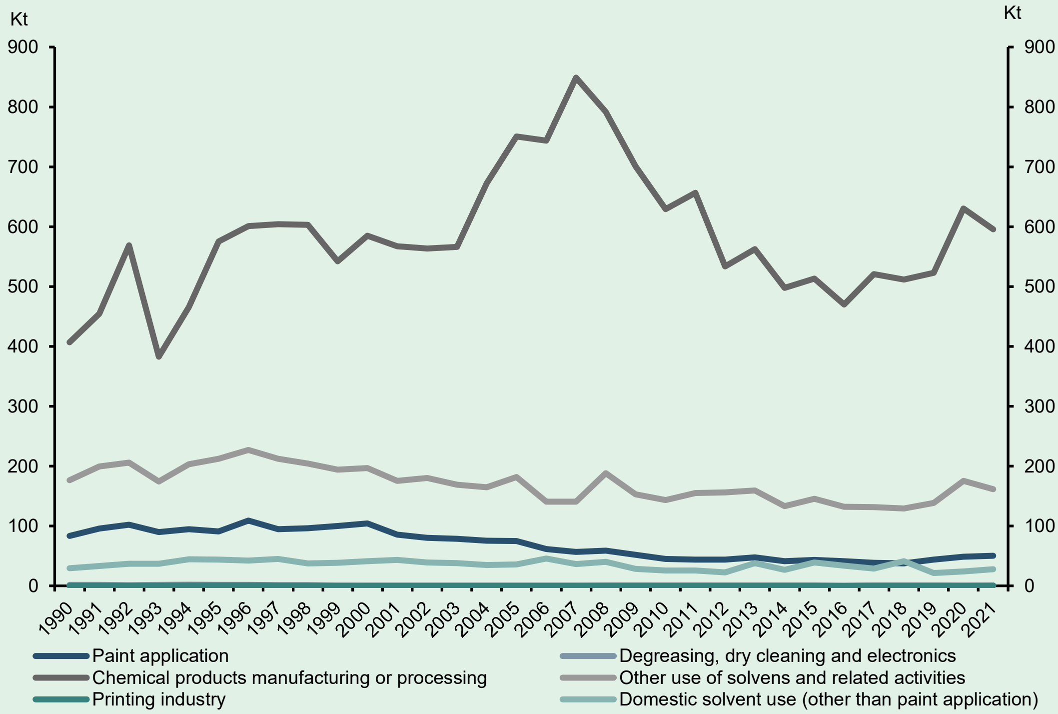
**Table 6.5**
Examples of sources of data on activity from the UN

| Topics | Prepared by |
|---|---|
| Food, agriculture, forestry etc. | FAO[28] |
| Energy statistics, fuels, etc. | IEA[29] |
| UN data bank (goods production, employment, etc.) | UNdata[30] |

### Example of activity figures from national emissions inventories

Danish activity figures from national greenhouse gas inventory reporting to the IPCC contain activity data on major emission sources such as cement production and cattle in agriculture, but it is also possible to find data for smaller emission sources, which can otherwise be difficult to find. figure 6.7 shows developments in the use of solvents from 1990 to 2021. Among other things, the figure shows that for 'Chemical products, manufacture and processing' the use of solvents was substantially higher in the mid to late 2000s but has since been reduced to around the same level as in 1991.

**Figure 6.7**
Use of solvents in Denmark, 1990 to 2021




Note: Including only Annex 1 countries. In million tonnes $CO_2$e.
*Source: Expert group on the significance of research for the green transition's own calculations using data from EIONET*

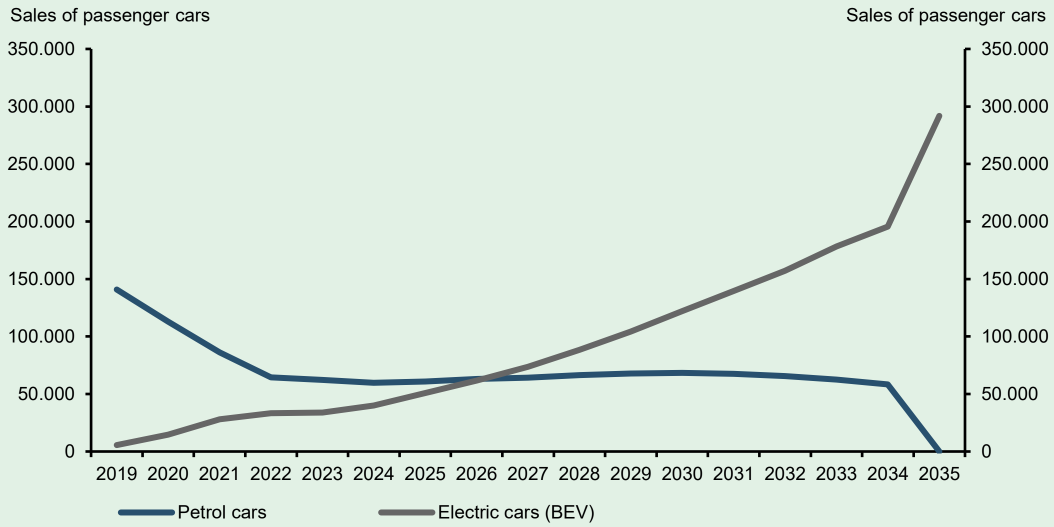
[28] Food and Agriculture Organization (2024), *FAOSTAT*, https://www.fao.org/faostat/en/#data
[29] The International Energy Agency (2023), *Energy Statistics Data Browser*, https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser
[30] United Nations Statistics Division (2024), *Industrial Commodity Statistics Database* , http://data.un.org/Explorer.aspx?d=ICS

**Example of activity figures from Denmark's Climate Status and Outlook**

From 2035, it will no longer be allowed to sell greenhouse-gas-emitting cars in the EU, with a few exceptions. Figure 6.8 shows expected developments in sales of passenger cars up to 2035. It is activity figures like these that form the basis of the projected emissions in figure 6.5 above.

The activity figures provide context for emissions projections, but they can also be helpful when considering other conditions in relation to research and innovation initiatives. For example, the number of electric cars can influence assessments of when related technologies, such as charging stations, need to be in place. Similarly, activity figures can provide an idea about the increasing rate at which electric cars will put pressure on the electricity grid.

**Figure 6.8**
Expected developments in sales of petrol cars and electric cars, 2019-2035




Note: BEV - Battery Electric Vehicles
*Source: Expert group on the significance of research for the green transition's own calculations using data from the Danish Ministry of Climate, Energy and Utilities*

## 6.2.4 Scoping

In order to use production-based and consumption-based inventories, it must be possible to define the initiative's reduction potential; that is, determine in what areas the initiative could potentially contribute to greenhouse gas emissions reductions. For example, if an initiative involves recycling concrete, it is important that only emissions related to this material are included in the assessment of the reduction potential. The difficulty of this scoping exercise depends on the elements involved in the initiative. Scoping is simple for initiatives that relate to a single product or solution. But identifying all relevant areas can be difficult for initiatives that involve several technologies or solutions, or where the technology or solution cuts across several areas.

Scoping strongly depends on the inventories and data sources available (see the previous section). Furthermore, the difficulty of the task is exacerbated because the inventories do not always use the same nomenclature (classification system). This means that the reduction potential of an initiative will have to be scoped differently across inventories. Table 6.6 lists the different nomenclatures.

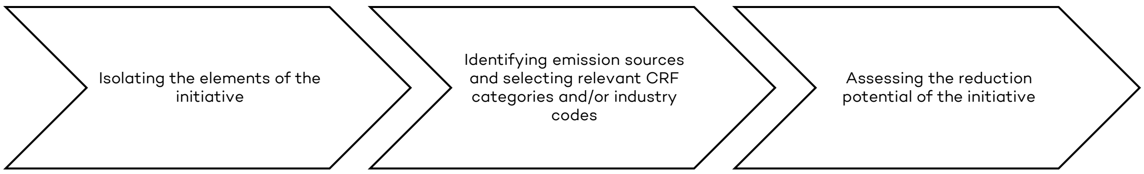
**Table 6.6**
List of nomenclatures

| Contents | Calculation method | Prepared by | Nomenclature |
|---|---|---|---|
| National emissions | Production | Danish Centre for Environment and Energy (DCE) | CRF/SNAP |
| | Production | Statistics Denmark | Industrial classification in the Danish national accounts |
| Climate footprint | Consumption | Statistics Denmark and the Danish Energy Agency | Industrial classification in the Danish national accounts |
| Climate footprint | Consumption | Danish Energy Agency | Industrial classification in the Danish national accounts |
| Denmark's Climate Status and Outlook | Production | Danish Ministry of Climate, Energy and Utilities | CRF/SNAP |
| Global emissions | Production | IPCC | CRF/SNAP |

The inventories from Statistics Denmark use the industrial classification from the Danish national accounts, whereas the inventories from the DCE, the Ministry of Climate, Energy and Utilities and the IPCC use the CRF (Common Reporting Format) categories. Scoping is required for each nomenclature used, and it may not be possible to use both nomenclatures for all types of initiative. Where appropriate scoping is not deemed possible, it should be considered whether the inventories can be used in the assessment at all, as it is important to accurately define what is to be included in the reduction potential. For example, if relevant emissions are overlooked and therefore not included the scoping of the reduction potential (and by extension the final calculation of the potential) could be too narrow . Similarly, the scoping could be too broad if it includes emissions that should not be included. Assessing the scope of what to include in the reduction potential will always be associated with some uncertainty, and the assessment of the reduction potential should therefore not be the only element in the assessment of an initiative.

Initiatives can vary in both extent and elements covered. Therefore, the method of scoping the reduction potential must be tailored to the individual initiative. The figure outlines the fundamental approach to scoping, see figure 6.9.

**Figure 6.9**
Approach to scoping the reduction potential




**The first step is to isolate the elements of the initiative.** The elements of the initiative are the technologies, products, industries or solutions involved in the initiative. If the initiative is about a single technology, there is likely to be only one element, but there will often be several elements involved in an initiative. For example, an initiative about sustainable building materials is likely to include several different building materials, such as glass, concrete, wood products etc. Furthermore, concrete, for example, can be further divided into its material components, one of which is cement. The purpose of identifying the emission sources of the individual elements in the initiative is to identify the correct emission categories in the inventories and to make sure the same category is not included in the calculations twice. This applies regardless of the inventory used.

**The next step is to identify the emission sources** of the individual elements in the inventory used and then select the **relevant CRF categories and industry codes**. This applies regardless of the inventory used. This step is usually straightforward, but it may be difficult in some situations. For example, if the initiative is about a specific activity, and an inventory based on the industrial classification is used, then the industrial classification may be *too* highly aggregated to isolate the activity. Conversely, if an initiative is about an entire industry (e.g. an initiative to make the building and construction industry more sustainable), the industrial classification system may be easier to use than the individual activities in the IPCC inventories. **The final step involves assessing the initiative's reduction potential** on the basis of the scoping arrived at.

#### 6.2.4.1 Scoping based on CRF

CRF (Common Reporting Format) is the UNFCCC's standardised system for collecting and reporting data on greenhouse gas emissions used by member states for their annual national inventory reports. The categories in CRF are generally easy to understand, as the nomenclature is based on emission sources. Overall, the nomenclature consists of six main categories[31]:

1. Energy
2. Industrial Processes and Product Use
3. Agriculture
4. Land-Use, Land-Use Change and Forestry (LULUCF)
5. Waste (excluding waste incineration)
6. Other

Under these main categories are several subcategories representing various activities. These activities represent the final sources of emissions and therefore do not represent actual products. For example, concrete production cannot be categorised under the minerals industry. Instead, information on the content of the product is necessary, and for concrete this is cement. Attributing the emissions to the source also means that the electricity consumption is attributed to the electricity producer. Therefore, an initiative to use less electricity in an industrial process within a specific industry will not manifest as fewer emissions within that specific industry if this type of calculation is used. See the box below for an example of the use of CRF.

**Example of scoping based on CRF: Use of enzymes in fodder**

This example is about an initiative involving the use of enzymes in feedstuff in agriculture. The CRF categories are used to define the scope of the reduction potential of the initiative. Agriculture covers several subcategories, see table 6.7. For the initiative at hand, the scope of the reduction potential can be delineated to subcategory 3A. The EIONET[32] portal also contains the underlying data on livestock composition and enteric emission factors. This allows for further refining the scoping if, for example, the initiative is about a specific type of livestock.

**Table 6.7**
Relevant CRF categories for use of enzymes in feedstuff in agriculture

| Main category | Subcategory (CRF code) | Description |
|---|---|---|
| Agriculture | 3A | Enteric Fermentation |
| | 3B | Manure Management |

[31] Ministry of Climate, Energy and Utilities (2024), *Klimastatus og -fremskrivning 2024*, https://www.kefm.dk/klima/klimastatus-og-fremskrivning/klimastatus-og-fremskrivning-2024
[32] European Environment Agency (2023), *National Inventory Report 2023*, https://cdr.eionet.europa.eu/dk/Air_Emission_Inventories/Submission_UNFCCC/colzdpsvg/envzdps1q/

| | | |
|---|---|---|
| | 3D | Agricultural Soils |
| | 3F | Field burning of Agricultural Residues |
| | 3G | Liming |
| | 3H | Urea Application |
| | 3I | Other Carbon-Containing Fertilizers |

*Source: Expert group on the significance of research for the green transition's own calculations using information from EIONET*

The industrial classification in the Danish national accounts is not used here because all emissions in the agricultural sector are aggregated into a single industry, 'Agriculture and horticulture'. Because enzymes are only related to agricultural emissions stemming from livestock and its digestion, it would not be appropriate to use the industrial classification in this case.

#### 6.2.4.2 Scoping based on the industrial classification in the Danish national accounts

The industrial classification in the Danish national accounts is used to classify economic activities and is based on DB07 (Danish Industrial Classifications 2007). It was therefore not designed for inventorying data on greenhouse gas emissions, and this should be taken into account when using it as the basis for defining an initiative's reduction potential. There are five levels of aggregation, with the most aggregated level comprising 10 categories, of which the six most relevant in this context are[33]:

A: Agriculture, forestry and fisheries
B: Mining and quarrying
C: Manufacturing
D-E: Utility services
F Construction
G-I: Trade and transport etc.

The advantage of using the industrial classification is that it allows for analysing emissions at business and household levels, just as it is possible to make couplings to associated economic activities.

[33] Statistics Denmark (2024), Nationalregnskab, https://cdr.eionet.europa.eu/dk/Air_Emission_Inventories/Submission_UNFCCC/colzdpsvg/envzdps1q/

**Example of scoping based on the industrial classification: Climate-neutral road transport**

This example looks at two initiatives to promote climate-neutral road transport. One of the initiatives target households and the other agriculture. When calculating the climate footprint of something, it is possible to look both at the industry causing the emissions and at the type of consumption causing the emissions. For the two initiatives mentioned above, this combination is necessary to scope the calculations of potential emissions reductions to the two initiatives. The table below shows that transport by households accounted for around 5.22 million tonnes $CO_2$e in 2021, while transport by agriculture accounted for around 0.05 million tonnes $CO_2$e.

**Table 6.8**
Emissions by industry and type of use, million tonnes $CO_2$e, 2021

| Industry | Type of use: Other transport and communication |
|---|---|
| Households | 5.22 |
| Agriculture, forestry and fisheries | 0.05 |

Note: Emissions related to logistics such as transport of food products to factories or shops have not been included.
*Source: Expert group on the significance of research for the green transition's own calculations using data from Statistics Denmark*

Using the industrial classification in the Danish national accounts to define the reduction potential of the initiative can be more challenging than using the CRF categories. There are two reasons for this. Firstly, industry emissions can be aggregated from several different activities. Take emissions from agriculture, for example. It is not possible to separate activities such as fertilizer, livestock digestion, etc. from the aggregated emissions. Secondly, the industry concept is linked to a breakdown by economic activity, which means this classification system contains both categories for emission sources (production) and categories for use (consumption). As a result, households, for example, are included as their own industry. Consider an initiative involving sustainable building materials. For this initiative, the relevant industrial classification is an industry titled 'Construction of buildings'. This industry covers businesses that construct buildings with a view to selling them or as a subcontractor. However, for the initiative involving sustainable building materials, the relevant emissions are not just the emissions from the construction activity itself; the emissions from the production of the building materials used for the activity are also relevant. This means it is necessary to find the industries responsible for producing the building materials. This could be 'Manufacture of concrete products for construction purposes', for example, which covers the manufacture of concrete building materials. Examples include concrete tiles, slabs, pipes and columns, but also larger prefabricated building components made primarily from concrete or cement.

An option to deal with uncertainty and doubt about how to select industries could be to use industry data from the Danish national accounts, which includes tables showing the flow of goods between different industries, see the box below.

**Example of scoping based the flow of goods**

Ttable 6.9 below shows the three industries in which 'Construction of new buildings' has most of its indirect emissions. This includes 'Manufacture of concrete and bricks', which is described as comprising manufacture of refractory products, such as refractory mortar, concrete and bricks. The manufacture of intermediates from sand, gravel, clay and stone is also covered, as are thermal insulation products from fossil silica meals or moler.[34]

This makes it possible to determine that the 'Construction of new buildings' industry uses many greenhouse-gas-emitting products from the concrete industry, and that the concrete industry produces building materials such as mortar, concrete and bricks. This, in turn, makes it possible to find relevant categories from CRF, which in this case would be the production of concrete.

**Table 6.9**

The three largest emission flows from 'Construction of new buildings', 2021

| To | From |
|---|---|
| **Construction of new buildings** | Manufacture of concrete and bricks |
| | Waste management and materials recovery |
| | Production and distribution of electricity |

*Source: Expert group on the significance of research for the green transition on the basis of data from Statistics Denmark*

## 6.2.5 Important areas of attention

It is a good idea to supplement the assessment (based on the above approach) of the reduction potential with other parameters to ensure a more nuanced assessment. These parameters do not need to be operationalised. Instead, they should serve as underlying areas of attention for the assessment.

### 6.2.5.1 Time horizon

As different research and innovation initiatives are likely to be at different stages of maturity, there will be differences between when the individual initiatives are likely to have an effect. This is important because it has significance for the initiative's possibility to help realise Denmark's climate targets in the Climate Act of a 70% reduction in emissions by 2030 relative to 1990, and climate-neutrality by 2050. An important area of attention when assessing an initiative is therefore the question of *when* the initiative is expected to affect Denmark's greenhouse gas emissions. Many green technologies require relatively long implementation periods. This includes not only implementation of the technical solution itself but also the associated societal integration of the technology. For example, it is not enough for electric cars or a pyrolysis plant to be available, they also need to be used in and by society. For electric cars, this requires both a change in consumption patterns and the establishment of support infrastructure such as charging stations, while for pyrolysis, it requires establishing robust logistics chains for feedstock and integration of the plants into the existing infrastructure to allow any surplus heat to be used elsewhere. Ensuring all this

[34] StatBank Denmark's footprint inventories AFTRYK1 and AFTRYK2 use the industrial classification from the Danish national accounts, but this classification can easily be linked to the more widely used industry classification DB07, from which the description above is taken (paraphrased from the Danish original text).

could take many years, and it is therefore necessary to note whether the initiative has a long-term implementation profile. Such a profile may mean that the greenhouse gas reductions from the solution only become relevant after 2050. One way to assess when an initiative will begin to contribute to emission reductions is to ask the party who registered the initiative. Alternatively, an assessment can be based on the assessment of the maturity level carried out under step 2.

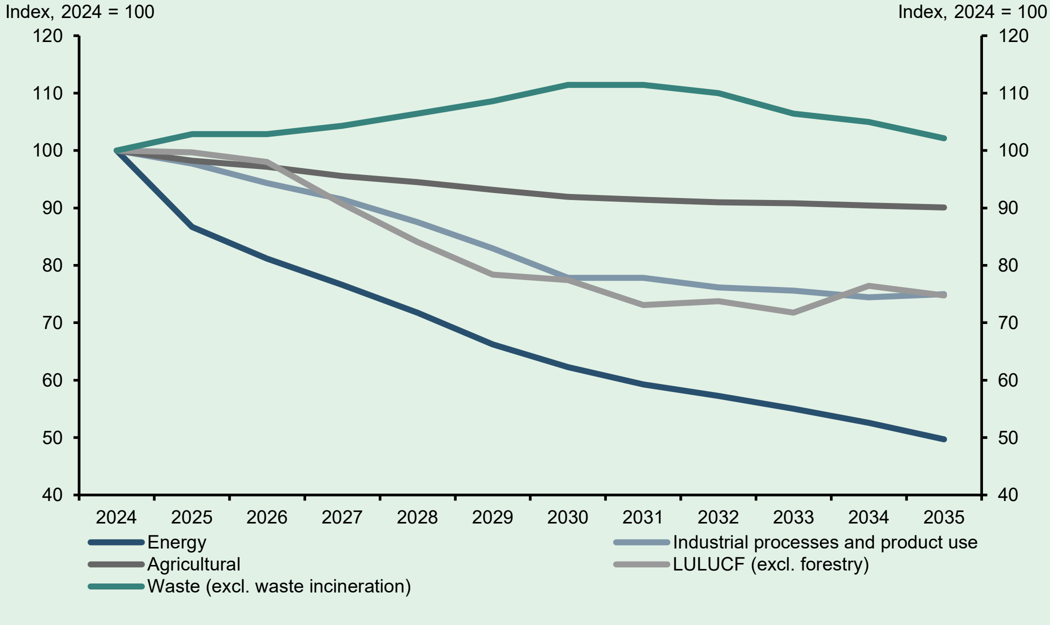
#### 6.2.5.2 Complexity

It may be relevant to consider whether the emissions that an initiative seeks to reduce are easy or difficult to reduce. For example, some initiatives require substantially more technological development to deliver potential reductions. Emissions by the chemicals, concrete and steel industries, for example, are difficult to reduce for technical reasons. These are areas and technologies characterised by complexity, and this should be included in the overall assessment. For help in assessing complexity, refer to the proposed typology by Malhotra and Schmidt [35].

**Example of complexity**

Ultimately, the question of complexity requires a technical assessment of the technologies in an initiative. However, this assessment can be qualified by looking at the climate projections in Denmark's Climate Status and Outlook report. As a rule, emissions from sectors and areas for which projections show a large fall will not be difficult to mitigate. Therefore, it may not necessarily be possible to confirm that an area is technologically complex, but it *is* possible to confirm that an area is *not* complex if substantial emissions reductions have already been projected for the area. The most recent projections show that, by 2035, emissions are expected to decrease for all sectors except for the waste sector, with the largest reductions expected in the electricity and district heating sector, the household sector and the service sector, see figure 6.10. The categories in the figure are aggregates of various activity data, and it is therefore also possible to see projections for more specific activities in each category, which will probably be necessary in many cases.

**Figure 6.10**
Expected trend in Danish emissions by sector, 2024-2035




*Source: Expert group on the significance of research for the green transition's own calculations using data from the Danish Ministry of Climate, Energy and Utilities*

[35] Abhishek Malhotra, Tobias S. Schmidt 2020 'Accelerating Low-Carbon Innovation', Joule, https://doi.org/10.1016/j.joule.2020.09.004

#### 6.2.5.3 Obsolescence risk

The risk of obsolescence is particularly relevant for initiatives expected to run for many years. In these cases, there may be a risk that the technology is rendered irrelevant before it is commercialised. For example, the rapid expansion in the use of electric cars means that technologies related to optimisation of combustion engines in cars risk becoming irrelevant. There is no formula for calculating the risk of obsolescence, but it is important to assess the risk on the basis of the technological landscape. This could be an assessment of competing technologies or whether major changes are expected in the elements that make up the initiative's overall supply chain.

### 6.2.6 Methodological challenges

One of the challenges in calculating the reduction potential is to correctly match the elements of the initiative to relevant categories in the inventories. Some initiatives may be less concrete, and the choices about what to include in the assessment for these initiatives will be less certain. The examples above illustrate why there will always be a need to make choices in the assessment. First, there is the act of identifying the relevant emissions, products or industries in the initiative, but even after this is done, there will still be an element of judgement involved in understanding the chosen categories. In the example about concrete in the previous section, the primary emission source of the product could be identified as cement production. There were categories for cement production in both the SNAP classification (CRF categories) and the industrial classification, but the SNAP classification did not have any subdivision by product type. In some cases, it may therefore be difficult to obtain certainty about the choice of categories. However, with regard to the example about concrete, fitting categories were found in both the industrial and in the SNAP classifications, which makes it possible to compare emissions figures from the two different inventories. If the two inventories provide similar emission figures, this indicates that the correct categories have been chosen.

## 6.3 Step 2: Conditions

Step two of the assessment tool includes an assessment of the conditions needed to support development of a research and innovation initiative and, thus, the likelihood of the initiative realising its reduction potential. This step involves taking account of other factors, besides the reduction potential, which can potentially affect the likelihood of a given initiative leading to emission reductions. The most important conditions relate to: Investment and funding, strengths, capacity constraints and governance. This step includes an assessment of whether the conditions and underlying parameters facilitate the initiative or whether barriers are likely to arise.

The conditions are described along with ways to operationalise them. As with reduction potential, it is important to consider whether the chosen approach is the most appropriate approach to assessing the research and innovation initiative at hand, or whether another approach should be applied.

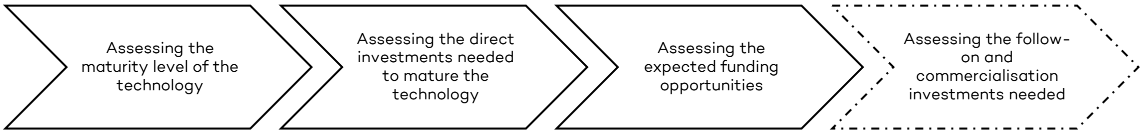
## 6.4 Investment and funding

This section describes how the first condition in step 2 can be operationalised. Here we look at a number of financial factors considered to affect the likelihood of the initiatives being able to realise the expected reductions. The step involves assessing the investment needed to raise the maturity level of the technologies in the initiative, as well as an assessment of the remaining investments needed to commercialise the results of the initiative. There are three different types of investment: Direct investments, follow-on investments and commercialisation investments. Direct investments cover costs associated with developing technologies before they reach a commercial stage, typically funded by public funds and private foundations. Follow-on investments relate to derived activities, such as establishing infrastructure when the technologies are more mature. Investments in commercialisation focus on supporting the market role of the technologies, for example through production aid or taxes, which can be crucial for a technology's success in the market. This step also includes an assessment of the funding opportunities assessed to be needed to cover the expected investment need. Investments are often needed for a research and innovation initiative to deliver actual emissions reductions. It is therefore necessary to assess whether funding is expected to be available to cover these investments, and public intervention may be necessary if there is not enough private funding available. It is important to prevent as far as possible that public intervention replaces private investment. Technological development often entails greater costs and investment needs than initiatives without technology, which is why the following focuses on assessing the investment needs of technology-based initiatives.

### 6.4.1 How to assess investment needs and funding opportunities

This section describes how to structure the assessment of expected investment needs and funding opportunities. To perform this assessment, it must be possible to link the initiative to one or more specific technologies. Furthermore, the aim is not to provide a definitive estimate of the costs of an initiative from start to finish. Instead, the purpose is to highlight any risk of shortages of financing to meet the expected investment need. In other words, the aim is to assess the expected investment need associated with developing and maturing the initiative, and whether there is expected to be adequate high-risk funding to meet the need. See figure 6.11 below outlining an approach to assessing investment need and funding opportunities.

**Figure 6.11**
Approach to assessing investment needs and funding opportunities




*Source: Expert group on the significance of research for the green transition*

**The first step** involves determining the current maturity level of the technology. This can be done using the TRL scale. **The second step** involves determining the direct investments needed to develop the technology to a higher TRL level. **The third step** involves coupling information about the technology's TRL level and the expected investment need to an assessment of the expected funding opportunities. Finally, **the fourth step** involves assessing the expected follow-on and commercialisation investments. In principle, this is not as much an assessment as it is a description of potential financial areas of attention that may arise as the initiative's technology reaches the higher TRL levels and ultimately the commercialisation level.

### 6.4.1.1 Assessing the maturity level of the technology

Assessing the maturity level of a technology can be done in several ways, but one approach is to measure the technology on a scale that determines how close it is to complete market integration. The Technology Readiness Level[36] (TRL) scale is often used for this, for example in the EU's Horizon Europe research programme. This is also used here to operationalise the assessment of the maturity level of technologies involved research and innovation initiatives. The advantage of using the TRL scale is that it is widely used and by a broad array of actors, and it will therefore be easier to find the necessary information when assessing the maturity level of the initiative. However, it should be noted that the TRL scale is not the only possible approach, and it is important to consider whether there are other more appropriate ways of assessing the maturity of a specific technology. The technology's TRL level can be determined through literature studies, by referring to existing assessments of maturity level, etc. Existing assessments of technologies are particularly relevant for the assessment process, and the ETP Clean Energy Technology Guide developed by the International Energy Agency (IEA) is a good reference guide in this respect. It attributes TLR levels to around 550 technologies. Besides TLR levels, the guide also includes descriptions of technologies, relevant sectors, value chains, etc. See the table below for an excerpt of technologies and their TLR levels.

[36] Note that the number of levels in the scale may vary across actors. For example, the IEA's TRL scale contains levels 10 and 11.

**Table 6.10**
TRL levels for a random selection of technologies from the IEA's ETP Clean Energy Technology Guide

| Name | TRL |
|---|---|
| Additive manufacturing for building materials | 7 |
| Battery electric urban transit bus | 9 |
| Charge and injection carbon substitution with biomass sources | 5 |
| Micro-algae and macro-algae (biogas) | 3-4 |
| Potassium-ion battery | 3 |
| Shape-stabilised phase change material (ss-PCM) | 4 |
| Solar tower | 9 |

*Source: Expert group on the significance of research for the green transition on the basis of information from IEA*

The table shows how the IEA's guide represents a broad portfolio of technologies, which makes it suitable for assessing many different types of initiatives and their underlying technologies.

### Example of assessment of maturity level

The following example is based on an initiative about carbon capture and storage. This initiative potentially contains many technologies, as also illustrated when applying the IEA guide, which has a total of 73 technologies related to CCUS (Carbon Capture, Storage and Utilisation). However, in this example, only a small portion of the technologies have been included, divided into the following sub-sectors: $CO_2$ capture, $CO_2$ storage and $CO_2$ transport.

**Table 6.11**
Selected technologies with TRL levels related to the capture and storage of greenhouse gas emissions

| CCUS | Technology | TRL 2023 | Outstanding |
|---|---|---|---|
| $CO_2$ capture | Solid DAC (S-DAC) | 7 | Full-scale commercial demonstration and operation |
| | Liquid DAC (S-DAC) | 6 | Full-scale demonstration and operation |
| $CO_2$ storage | Advanced monitoring technologies | 7-8 | Full-scale commercial demonstration and operation |
| | Depleted oil and gas reservoir | 7-8 | Full-scale commercial demonstration and operation |
| | Dissolved $CO_2$ injections | 5 | Large and full-scale prototype, demonstration and operation |
| | Supercritical $CO_2$ injections | 3 | Full-scale prototype, demonstration and operation |
| $CO_2$ transport | Shipping | 6-7 | Full-scale demonstration and operation |

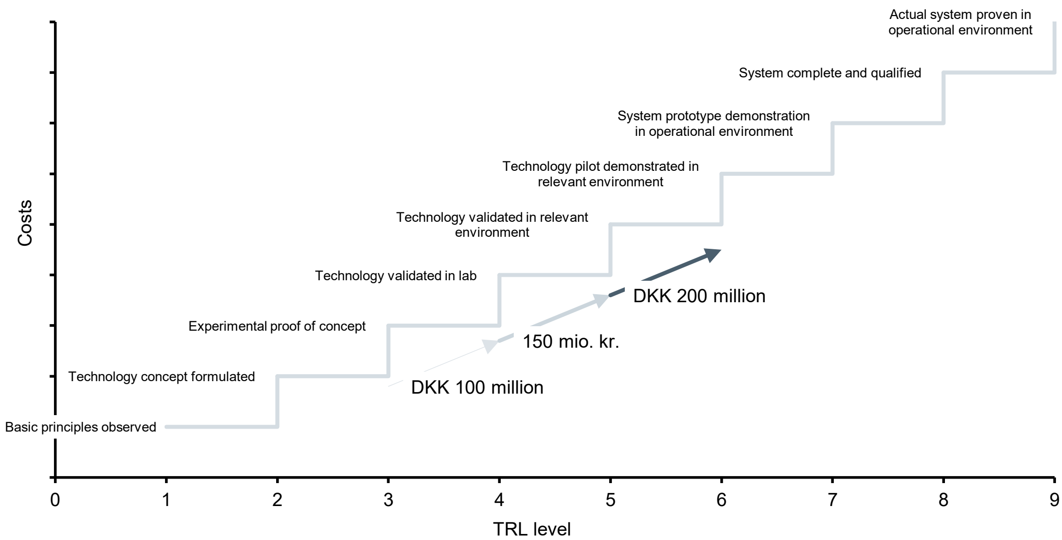
*Source: Expert group on the significance of research for the green transition on the basis of information from IEA*

In some cases, it may be desirable to perform a collective assessment for an area (e.g. the three subsectors above) and of the TRL level. Furthermore, technologies with a TRL level above level 9 have not been included in the overall assessment as they are already on the market and are no longer under development. The next step would be to assess the remaining seven technologies individually to determine what is needed to mature them.

### 6.4.1.2 Assessing the direct investments needed to mature the technology

The direct investments needed to mature the technology to a higher TRL level can involve anything from investments in test facilities, laboratories, prototypes, or similar to salaries for research and development staff, or administrative costs for data collection. figure 6.12 visualises the allocation of the existing TRL level to an initiative's technology and the investment required to raise the technology to a higher TRL level. In the example in the figure, the technology is at TRL level 3, and it is assessed that DKK 100 million is required to raise it to level 4, while DKK 150 million is required to raise it to level 5 and DKK 200 million to level 6. Naturally, there will be more uncertainty associated with assessing the higher levels of maturity, because of the greater number of unknown factors the further away from the technology's current level of maturity an assessment ventures.

**Figure 6.12**
Example: Determining the maturity level of a technology on the TRL scale and assessing the investments needed for its maturation




Note: The costs are fictional examples and not based on any specific assessment.
*Source: Expert group on the significance of research for the green transition on the basis of information from the European Commission*

Assessment of direct investments can be supported by examining already initiated projects, such as projects from the Danish Energy Agency's *Energy Technology Development and Demonstration Programme (EUDP)* or the Danish Environmental Protection Agency's *Environmental Technology Development and Demonstration Programme (MUDP)*. These projects can serve as the basis for finding projects that are similar to the initiative at hand and that can therefore serve as a basis for comparison. This involves looking at the descriptions of the individual project, including funding granted and project budget. Looking at existing and similar projects can thus help assess the initiative's potential investment need. If the projects examined are linked to a business, the projects can also be linked to CVR data. This can provide insight into information about the turnover, business size and industry affiliation of the businesses applying for the projects in question, which, in turn, can be used as a basis for assessing whether the number of businesses is sufficient to allow for allocating the funds linked to the initiative. Furthermore, several international databases can be used to search out various project descriptions, including information about the costs of individual projects. These databases can also be used as a reference work for general estimates of costs etc. See table 6.12 for examples of databases.

**Table 6.12**
Examples of international databases of project descriptions

| Description | Prepared by |
|---|---|
| CCUS Projects Database | The International Energy Agency (EIA)[37] |
| Hydrogen Production and Infrastructure Projects Database | The International Energy Agency[38] |
| Clean Energy Demonstration Projects Database | The International Energy Agency[39] |
| Renewable Energy Planning Database | Department for Business, Energy & Industrial Strategy[40] |
| IEDO Project Database | The U.S. Department of Energy[41] |
| AMMTO Project Database | The U.S. Department of Energy[42] |
| CCU Projects Database | $CO_2$ Value Europe[43] |

A broad array of public foundations and programmes in Denmark allocate funds to projects at different TRL levels. Because these funds are public funds rather than private funds, the application for project funding and other information about the projects are typically available to the public, for example information about funds granted and the overall project budget. Based on this information, it is possible to estimate the typical cost of developing projects with solutions and technologies at earlier stages within the same technology area as the initiative. By looking at similar projects at a lower maturity level, it is possible to get an idea of what the technologies or solutions in an initiative will cost *as a minimum*. For example, if a demonstration plant costs DKK 100 million, it is fair to estimate that a full-scale plant will be significantly more expensive. However, it is important to factor in that private actors may be willing to cover some of the investment need. Below is a list compiling about 7,000 Danish project grants awarded through various public foundations and programmes[44]. The foundations and programmes included in the list are representative of many different levels of TRL, both at the lower and the higher levels of the scale. Because of the size of the list, it will almost always be possible to find projects that are similar, and therefore, comparable, to the imitative at hand. table 6.13 shows the total number of project descriptions with matching keywords. As can be seen from the table, in many cases there will be a suitable number of projects to compare with.

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[37] The International Energy Agency (2024), *CCUS Projects Database,* https://www.iea.org/data-and-statistics/data-product/ccus-projects-database
[38] The International Energy Agency (2023), *Hydrogen Production and Infrastructure Projects Database,* https://www.iea.org/data-and-statistics/data-product/hydrogen-production-and-infrastructure-projects-database
[39] The International Energy Agency (2023), *Clean Energy Demonstration Projects Database,* https://www.iea.org/data-and-statistics/data-tools/clean-energy-demonstration-projects-database
[40] Department for Business, Energy & Industrial Strategy (2024), *Renewable Energy Planning Database*, https://data.barbour-abi.com/smart-map/repd/beis/?type=repd
[41] The U.S. Department of Energy (2024), *IEDO Project Database*, https://www.energy.gov/eere/iedo/iedo-project-database
[42] The U.S. Department of Energy (2024), *AMMTO Project Database*, https://www.energy.gov/eere/ammto/ammto-project-database
[43] $CO_2$ Value Europe (2024), *CCU Projects*, https://database.co2value.eu/
[44] Landbrugsstyrelsen (2024), *Grøn Projektbank*, https://groenprojektbank.dk/ og Danish Energy Agency (2024), *Energiforskning*, https://energiforskning.dk/

**Table 6.13**
Number of projects containing selected keywords, August 2024

| Keyword | Number of projects |
|---|---|
| Concrete | 58 |
| Asphalt | 6 |
| Biochar | 36 |
| Plastic | 37 |
| Polymer | 84 |
| Slurry | 67 |

*Source: Expert group on the significance of research for the green transition*

**Example of assessment of direct investments**

This example uses an initiative for climate-neutral road transport, including vehicle electrification. To assess the need for direct investments to mature the technology, relevant projects were mapped based on a project description including the words electric vehicles, charging stations and charging network. The process involved a simple keyword search, which can be further refined, for example by using language models with synonyms.

In the example about the initiative for climate-neutral road transport, the project budget for relevant projects was around DKK 5-20 million. However, the assessment will almost always require examining the individual project descriptions in more detail to identify and include only the most relevant projects in the assessment. In this case, for example, a project on participation in international cooperation was excluded as it was not deemed to be relevant in this context. The project descriptions will most often be a sufficient basis for determining whether a project is relevant to include in the assessment. However, if a more detailed assessment is desired, the final reports from projects can be included as the basis for determining which projects to include in the assessment. Such final reports contain information about technical results and often also reflections on market perspectives and scale up.

**Table 6.14**
List of projects about: Electric vehicles, charging stations and charging networks

| Project name | Programme | Total budget | Starting year |
|---|---|---|---|
| EASY-E - Easy energy efficiency made available to industry via thermal topology optimisation | EUDP | DKK 19,014,599 | 2020 |
| OpenGIS4ET | EUDP | DKK 4,317,997 | 2021 |
| TOPChargE - Variable topology battery system for optimised network load during high-voltage charging of EVs | EUDP | DKK 19,846,360 | 2020 |
| ACDC - Autonomously Controlled Distributed Chargers | EUDP | DKK 17,376,300 | 2020 |
| Continued active Danish participation in the IEA HEV TCP (electric transport) | EUDP | DKK 595,000 | 2020 |
| WABAT - Workshop Automated Bait Tester | EUDP | DKK 10,139,280 | 2019 |
| *Parker* (demonstration project on grid integration of electric vehicles) | EUDP | DKK 5,412,365 | 2016 |
| IEA Task 28 - extension of 64014-0546 with a view to completing the project together with the remaining countries | EUDP | DKK 210,499 | 2018 |
| The Energy Collective | EUDP | DKK 13,580,000 | 2017 |
| Improved system performance for automotive exhaust cleaning | MUDP | DKK 1,756,236 | 2011 |

Note: Projects were found by searching for project descriptions with one or more of the following keywords: electric vehicles, charging stations and charging networks

*Source: Expert group on the significance of research for the green transition using data from Green Project Bank (data base of green projects) and Energiforskning.dk - information portal for Danish energytechnology research- og development programs*

### 6.4.1.3 Assessing the expected funding opportunities

The assessment of the expected funding opportunities can be based on a list of potential investors, such as private and public foundations, businesses, etc. The investment profile of individual investors can serve as the basis for determining whether the investor is likely to invest in projects at the same maturity level as the initiative at hand. For example, one extreme may be pension companies, which typically have less risk appetite and therefore are less likely to invest in initiatives at a low TRL level; and another extreme may be government and international foundations, which have substantially more risk appetite and therefore are much more likely to invest in initiatives at a low TRL level. Between the two extremes are various other types of investors, such as private equity funds and similar.

The expert group commissioned Deloitte to map the investment landscape linked to the green transition. In their survey, Deloitte assessed the risk profile of selected Danish investor types and the time horizon of their investments. In addition, Deloitte collected information about investors' total managed capital, the share of capital dedicated to the green transition, and whether the investors have a 'green objective'. Applying this type of information can determine whether there will be non-governmental funding opportunities available for an initiative after the initial grant has ended. However, the survey only looks at Danish actors, and it would be recommendable to expand on the information by also looking at international players. In practice, selecting a number of likely investors will need to be supported by desk research on typical investments by the various investors.

#### 6.4.1.4 Assessing the follow-on and commercialisation investments needed

Besides assessing the direct investments needed to bring an initiative to a higher TRL level, it could also be relevant to assess the potential follow-on and commercialisation investments. Follow-on investments refer to major investments in infrastructure, a distribution system, piping, etc, which will often be difficult for private businesses to cover on their own. This is because follow-on investments will usually have a longer time horizon compared to direct investments, and the uncertainty in assessing the investment need is therefore greater. The assessment of the expected follow-on investments should therefore be in the form of an independent qualitative assessment to identify any major follow-on investments. A similar approach can be used to assess any potential commercialisation investments. For initiatives with technologies at a high level of maturity, one basis for assessing this could be to look at the relationship between current expenses and capital expenses for existing technologies and expenses incurred by demonstration facilities. However, because of the low level of maturity of the initiatives, it will probably not be possible to perform such a comparison with the degree of certainty required to use it in an actual assessment.

### 6.4.2 Methodological challenges

Assessing the level of investment needed for research and innovation initiatives can be difficult. This is because the object of the assessment is technologies within a field where there are typically no directly comparable technologies, as the technologies are innovative. An assessment will therefore also be based on estimates, as there will be aspects of the new technologies that cannot be predicted or assessed on the basis of current knowledge.

It should be noted that the project budgets used in the assessment of direct costs only covers research that has received public funding. Extensive research and development take place in businesses, so there is no comprehensive overview or data base for a data-driven assessment of the costs of this type of technology development. This means a built-in bias in the assessment may have to be taken into account. For example, it is conceivable that project budgets in reality underestimate actual costs, as some expenses are hidden by affiliated businesses; for example, the costs of making meters available.

## 6.5 Research and business strongholds

This section describes an approach to determining Denmark's relative research and commercial strengths. Various aspects should be considered when determining research and commercial strengths. Below is a description of how to identify relevant research areas and industries and what indicators to use to assess the strengths. A strong business community can contribute to further developing research results and to ensuring their implementation and scale up. Effective collaboration between research communities and the business community is therefore crucial in turning research results into actual emissions reductions. Finally, it can be relevant to also look at Denmark's position relative to other countries.

**The risk of a restricting effect**

There is an important area of attention to consider when assessing the research and commercial strengths using the approach outlined above. The identification of possible existing well-established research and business communities could involve a risk of a restricting effect. Therefore, it is important to always consider strengths relative to the general investment portfolio to prevent that research investments are not inappropriately one-sided. This is because there will always be a risk that a research area either does not lead to useful results or that it is overtaken by other competing areas.

### 6.5.1 Indicators and data sources

Various indicators can be used in the assessment of research and business strongholds as a condition for the effect of research and innovation initiatives on greenhouse gas emissions. The use of indicators makes it possible to assess individual parameters and make an overall assessment of strengths as a general condition for the success of an initiative. Note that the following is merely a list of possible indicators, and that there are many other ways to identify strengths. It is therefore important to always consider whether the selected indicators are appropriate or need to be supplemented or replaced.

Note also, that time horizon and geographical scope are important areas of attention when using the indicators. That is, how many years are included and what other geographical areas or countries are included in the comparison. For some indicators and variables, it may be relevant to look at an accumulated period with a limited time horizon, for example 10 years for bibliometric research data. In other cases, it may be relevant to look at developments over a period of years to identify any trends for an area. Similarly, it is important to consider the geographical basis of the comparison. Ideally, the assessment of strengths should always be against an international benchmark, so that Denmark is compared with other countries. However, use of the temporal and geographic dimensions will be limited by the availability of data, and this should be taken into consideration when deciding on indicators.

#### 6.5.1.1 Research strengths

The following is a proposal for how to operationalise the assessment of research strengths. The approach is inspired by a number of analyses[45] prepared in connection with the government's *Strategy for investments in green research, technology, and innovation* from 2020. The analyses include a bibliometric analysis of Denmark's green research, as well as analyses of public green

[45] Ministry of Higher Education and Science (2020), *Opgørelse af grøn forskning i Danmark*, https://ufm.dk/publikationer/2020/fremtidens-gronne-losninger-strategi-for-investeringer-i-gron-forskning-teknologi-og-innovation/gron-forskningsstrategi/opgorelse-af-gron-forskning-i-danmark/bibliometrisk-analyse-af-danmarks-gronne-forskning.pdf

research, green research by private businesses, and a survey of green PhD graduates. The purpose of assessing research strengths is to form a picture of Danish green research as the basis for identifying where Denmark has strengths and where Danish research is less strong. Research into the green transition is a complex field, and it cannot be defined precisely. Thus, significant measurement challenges can be associated with inventorying green research, development and innovation. A way to address this is to base assessment of research strengths on a comparison of several different types of data. For example, this can be achieved by looking at research output such as bibliometric data to learn about the amount and impact of Danish green research, and by looking at research input such as PhD graduates and research investments. The number of PhD graduates can be an indicator of current and future research capacity of Danish research environments, while the scope of research investment by public actors and the public funding granted can be an indicator of the economic prioritisation of research areas. table 6.15 summarises the two indicators and a number of variables that can be applied when assessing research strengths.

**Table 6.15**
Indicators and variables for measuring research strength

| Indicator | Variable | Description | Data sources |
|---|---|---|---|
| Research output | Number of publications per million inhabitants | Number of publications for a research area in the last 10 years, converted to per capita (million) compared to other countries. A publication counts once for each institution/country with an author included in the list of authors. | Bibliometric databases like Scopus or Web of Science |
| | Research specialisation | Research specialisation is measured by comparing the share of publications in a research area in a given country with the share of publications in the same research area worldwide over the past 10 years. This can show whether a country is particularly specialised within a specific research area. A Danish research specialisation of 1.00 means that the Danish contributions to publications within this research area are equal to those of the rest of the world, while a value of 1.5 means that Denmark has 50% more contributions within the research area than the rest of the world. | |
| | Top 10% | This indicator shows the share of publications within a research area that falls within the world's 10% top-cited publications over the past 10 years. A share above 10% indicates a share of publications among the 10% top-cited publications above the world average. | |
| | International collective publication | Measures the number of Danish research publications with at least one international co-author for the last 10 years. International co-publication gives an indication of research impact. | |
| | Collective publication with business and industry | Measures the number of publications with authors from both public research institutions and business and industry actors for the last 10 years compared to other countries. | |
| Research input | PhD graduates broken down by green research themes | The share of PhD students who reported that the seven green research themes were included in the research activity during their PhD programme. | Statistics Denmark |

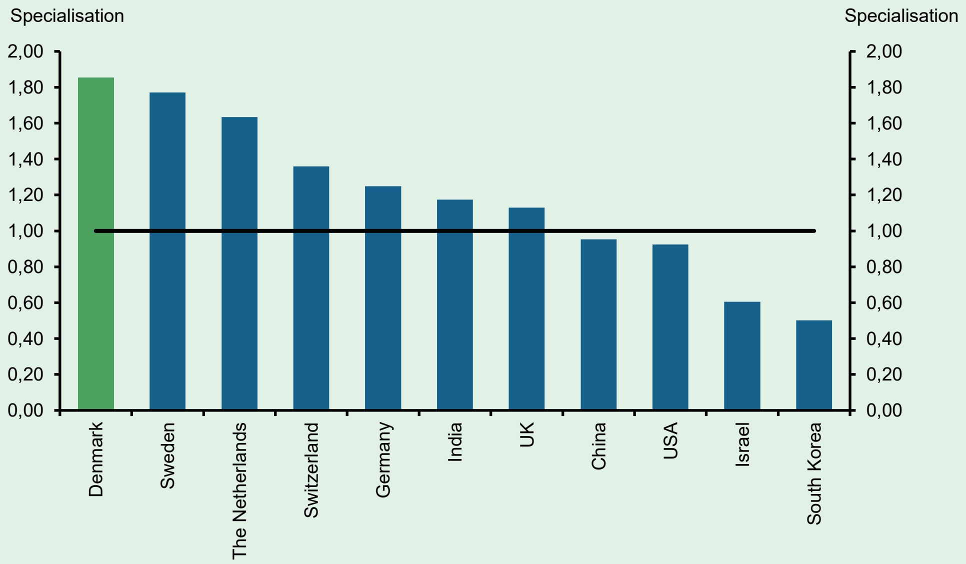
| Indicator | Variable | Description | Data sources |
|---|---|---|---|
| | Public research investment | Total public-sector green research investments by the seven green research themes. The breakdown is derived through an estimated distribution (%) of total research activities by Danish universities. | |
| | Funding granted | Total funding granted by commercial foundations, public foundations and foundation-like associations, broken down by the seven green research themes. | |

### Example of use of indicators: Research strengths

The following example is based on an initiative to reduce emissions from agriculture. For this example, indicators and variables have been selected from the list above. The research area of the initiative has been defined to no. 3, 'Sustainable food production, agriculture and forests'. Note that this delineation is merely for exemplification.

The figure below shows the results for research specialisation in terms of research publications in the individual countries. The figure indicates that Danish research in the area relating to food and agriculture is very prominent in Denmark compared to other countries, with this research area taking up twice as much publication space in Denmark as in the rest of the world output. This indicates that Denmark has a particularly high degree of specialisation in this area.

**Figure 6.13**
Research specialisation within 'Sustainable food production, agriculture and forests' for selected countries 2012-2021




Note: The data are not fractioned. The analysis covers the following publication types: Papers, reviews and conference contributions. Index 1=world average
*Source: Ministry of Higher Education and Science's own calculations using data from Scival*

The figure below shows the results for the share of Danish publications among the 10% top-cited publications. Denmark places well above the world average, but below countries like the Netherlands and Switzerland.

**Figure 6.14**
Share of publications among 10% top-cited publications within 'Sustainable food production, agriculture and forests' for selected countries 2012-2021


Note: Data are field-weighted, but not fractioned. Self-citations are included. Data covers scientific papers, reviews and conference papers. The world average is 10%.
*Source: Ministry of Higher Education and Science's own calculations using data from Scival*

### 6.5.1.2 Business strengths

The assessment of business strengths can be based on a number of different indicators. Several such indicators are often used in different studies and analyses, see for example the 2019 mapping of strengths by IRIS Group[46], and the Ministry of Industry, Business and Financial Affairs' 2023 report on growth and competition[47]. Many of the same indicators are used in this operationalisation, but they are supplemented to give a broader picture of the business strengths. The purpose of assessing the business strengths is to gain insight into the Danish business community and Danish industries to identify whether there is capacity to absorb knowledge and translate research into implemented and scaled up green solutions. Similarly, the purpose is to identify whether there are likely to be good opportunities for spinoff businesses in the area. Finally, the ability to develop and innovate is also included in the assessment of the strengths of an area. This ability is considered particularly relevant for the implementation of green solutions. The following three indicators can be used to assess both established strengths and the ability to develop and innovate: 'Size and productivity', 'International relations' and 'Research, development and innovation'. Information about an industry's share of total employment, value creation, exports, and productivity can be an indication of its size and significance for the Danish economy. Similarly, information about international investments and export intensity can shed light on international relations, while information about number of businesses with activities within research, development and innovation can shed light on the relevant industry's ability to innovate, including the ability to translate research and knowledge into actual green technologies and solutions. table 6.16 below lists the indicators for assessing business strengths and underlying variables.

[46] IRIS Group (2019), *Kortlægning af styrkepositioner*, https://erhvervsfremmebestyrelsen.dk/iris-group-2019-kortlaegning-af-styrkepositioner
[47] Erhvervsministeriet (2023), *Redegørelse om vækst og konkurrenceevne 2023*, https://www.em.dk/aktuelt/udgivelser-og-aftaler/2023/jun/redegoerelse-om-vaekst-og-konkurrenceevne-2023

**Table 6.16**
Indicators and variables for measuring business strength

| Indicator | Variable | Description | Source |
|---|---|---|---|
| Size and productivity | Employment | The industry's share of total employment compared to other countries. | Statistics Denmark OECD |
| | Value creation | The industry's share of total value creation, approximated using total sales by businesses less purchases, compared to other countries. | |
| | Goods exports | The industry's share of total exports compared to other countries. | |
| | Productivity | Productivity is approximated using the industry's average salary level relative to general salary levels (PPP-adjusted), compared to other countries. | |
| International relations | International ownership | Investments flowing into Denmark (inward FDI) within the industry, compared with other countries | OECD |
| | Relative strengths | Investments flowing from Denmark into other countries (outward FDI), within the relevant industry. | |
| | Export intensity | The industry's export intensity (Revealed Comparative Advantage) by product, compared to other countries. | |
| Research, development and innovation | Businesses with research, development and innovation activities | Share of businesses with research, development and innovation activities within the industry, compared to other industries. A business is defined as having RDI activities if it has incurred costs from RDI activities within the year of analysis. | Statistics Denmark |
| | Spinoff businesses | Number of spinoff businesses - i.e. new businesses originating from an existing business - within the industry, compared to other industries. | |
| | Private research investment | Total private-sector green research investments broken down by the seven green research themes, based on an estimated distribution (%) of total research activities between the seven research themes. | |
| | Patents | The industry's patent applications per million capita, compared to other countries | OECD |
| | International knowledge workers | Number of international knowledge workers such as PhD graduates, research managers, etc., compared to other countries. | |

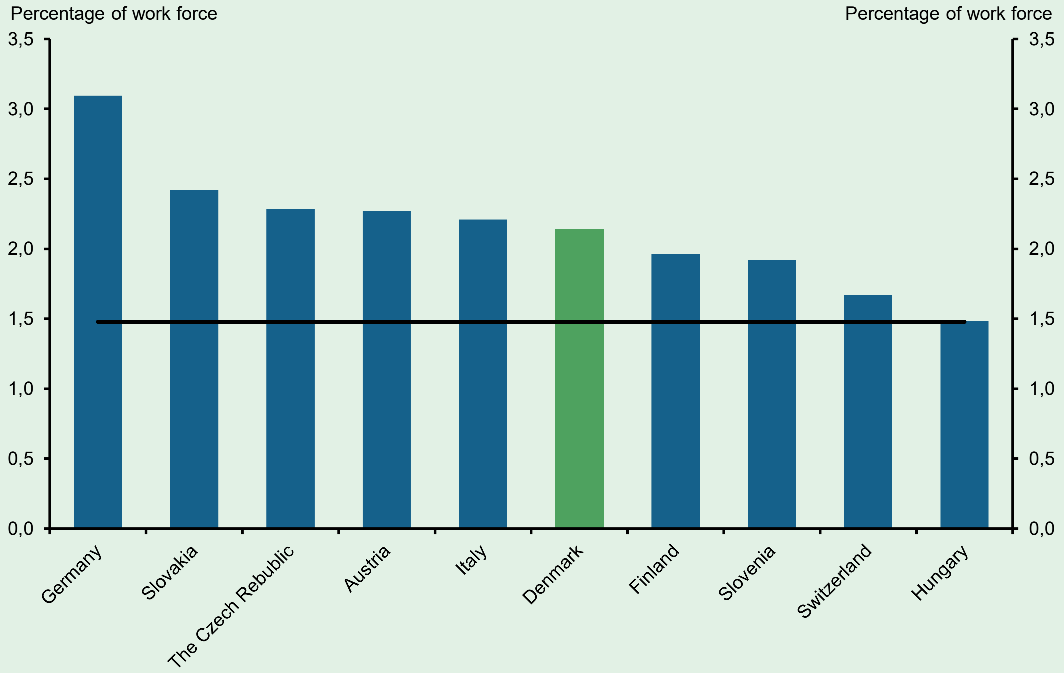
**Example of use of indicators: Business strengths**

The following exemplifies two ways of using the indicators to assess a business strength. The example is about wind technology and the data used includes employment statistics and patent data.

Figure 6.15 shows the share of people employed in the 'Manufacture of machinery and equipment' industry. Employees working within wind turbine manufacturing are registered as employed in this industry. The figure shows that Denmark has a relatively high share of people employed in the industry.

**Figure 6.15**

Top 10 countries with the highest share of people employed in the 'Manufacture of machinery and equipment' industry.




*Source: Expert group on the significance of research for the green transition's own calculations using data from Eurostat*

The table below shows the number of green patents per million inhabitants in Denmark and other EU Member States, respectively, broken down by various technology areas. The table shows that Danish researchers and Danish businesses generally have many green patents compared to the other EU countries. The difference is particularly large in the energy industry. The three italicised sub-categories are the sub-categories in the energy industry where Denmark has most patents. This shows that Denmark has considerably more patents related to wind turbines, biofuels and fuel cells than the other countries. This could be an indication that Denmark has a position of strength within these types of technology.

**Table 6.17**

Number of patents per million inhabitants, by technology classification, 2008-2019

| | Denmark | Other EU Member States |
|---|---|---|
| Adaptation to climate change | 45.7 | 13.0 |
| Buildings | 73.1 | 18.4 |
| Capture and storage of greenhouse gases | 4.3 | 2.3 |
| ICT (aimed at reduction of own use) | 8.9 | 6.1 |
| Production, distribution and transport of energy | 515.3 | 57.8 |
| *(1) Wind turbines with axis of rotation in wind direction* | *399.9* | *8.7* |
| *(2) Biofuels* | *26.0* | *2.9* |
| *(3) Fuel cells* | *15.0* | *4.7* |
| Industry and agriculture | 166.1 | 32.1 |
| Transportation | 24.8 | 39.2 |
| Waste and wastewater | 13.2 | 7.6 |

| | | |
|---|---|---|
| Smart grids | 12.4 | 4.0 |

Note: Figures for other EU Member States are weighted averages. Per capita is calculated in millions of inhabitants. The three most dominant Danish patent types within energy patents have been italicised along with associated figures for per million inhabitants for Denmark and the other EU Member States, respectively.

*Source: Expert group on the significance of research for the green transition's own calculations using data from PATSTAT and the World Bank*

## 6.5.2 Approaches to defining relevant research areas and industries

Assessing the research and business strengths based on the above indicators requires first defining the research areas and industries relevant for the research and innovation initiative in question. This section outlines possible approaches to defining the relevant research areas and industries.

### 6.5.2.1 Research areas

Predefined areas can serve as the basis for defining the relevant research area. The seven green research themes identified in the context of the government's *Strategy for investments in green research, technology, and innovation* from 2020 are a good source for this purpose.[48] The seven research themes, including their descriptions, are presented in table 6.18. In addition, a number of sub-themes can be used to further narrow down the initiative's research area. The approach is therefore to assess whether the initiative can be defined to a research theme and then, potentially, a sub-theme.

**Table 6.18**

Defining the research area: Seven green research themes

| | Theme | Description |
|---|---|---|
| **1** | Sustainable energy technologies and production etc. | This theme includes research, development and innovation in the field of green energy research with a focus on the development of green technologies and production of sustainable and renewable energy, for example, solar energy, wind power, hydropower, bioenergy, geothermal energy as well as carbon capture, storage (CCS) and utilisation (CCUS). The theme also includes storage and conversion technologies such as PtX, Power-to-Gas and fuel cells as well as energy planning and regulation. |
| **2** | Energy efficiency | This theme includes research, development and innovation in the field of energy-efficient construction, infrastructure and building renovation, sustainable building materials and energy efficiency in existing buildings, cities and industry. The theme also includes optimisation of production processes and systems, sustainable and intelligent/smart electricity grids and integrated energy systems, district heating and cooling, refrigeration and heating systems as well as thermostats, heat pumps, ventilation, lighting and technical installations. Finally, the theme includes energy planning and regulation. |

[48] The seven research themes are the result of a mapping of green research needs and potentials. A mixed group of stakeholders were involved in formulating the themes.

| | Theme | Description |
|---|---|---|
| **3** | Sustainable food production, agriculture and forests | This theme includes research, development and innovation in the field of green and sustainable production systems, methods, technologies and solutions within agriculture, food, soils, forests, fishery and aquatic production including research in emissions, capture, sequestration, storage, uptake and cycle of nutrients, $CO_2$ and other greenhouse gases in soils, forests and the aquatic environment. This theme also includes climate friendly as well as more environmentally and nature friendly production systems and management along with climate adaption of production, products and land use. Furthermore, the theme includes research in new and alternative protein sources plus novel foods and other bio-based products. |
| **4** | Climate-friendly transport | This theme includes research, development and innovation in the field of green and climate-friendly transport and logistics of both goods and people by sea, land and air, as well as optimisation of transport capacity, infrastructure and planning. The theme also includes research in sustainable fuels for passenger and freight transport, including electrification, hybrid, e-fuels (PtX) and biofuels with a focus on transition of heavy transport, international shipping and aviation. Furthermore, the theme includes research in facilitating behavioural changes towards more climate friendly transport. |
| **5** | Environmental protection, circular economy and environmental technology | This theme includes research, development and innovation in the field of circular economy and recycling of waste, including plastics, textiles and polymers. The theme also includes research in environmental protection and pollution of air, soil and water with focus on minimising emissions of pollutants in addition to the development of new technological solutions to improve the air, soil and aquatic environment. Furthermore, the theme includes research in sustainable water resources and technologies to ensure the protection of groundwater and drinking water in addition to an improved water supply, water treatment and wastewater utilisation as well as a clean aquatic environment, in both groundwater, surface water and the seas. Finally, the theme includes research in climate adaptation of cities, coastal and rural areas. |
| **6** | Nature conservation, biodiversity and climate change | This theme includes research, development and innovation in the field of conservation, restoration and management of nature and biodiversity, ecosystem services and ecosystem understanding with focus on processes, dynamics, functions and structures. The theme also includes research on the impact of climate change on nature and biodiversity and adaptation to these changes, as well as further development of climate models and climate monitoring, for example, focusing on changes in sea levels and the melting of sea ice, glaciers and the ice cap. |
| **7** | Sustainable behaviour and societal consequences | This theme includes research, development and innovation in the field of sustainable behaviour and societal consequences in terms of both reducing greenhouse gas emissions and improving environmental protection and nature conservation. The theme includes research in climate-friendly and sustainable behaviour, better utilisation of resources as well as regulation, planning and public procurement. In relation to environment and nature, the theme includes research in behavioural change, outdoor activities and nature experiences, public health, multiple land use, ecosystem services, and international conventions and collaborations. |

*Source: Ministry of Higher Education and Science (2020), Definition af grøn forskning, udvikling og innovation i UFM-regi,* https://ufm.dk/publikationer/2020/fremtidens-gronne-losninger-strategi-for-investeringer-i-gron-forskning-teknologi-og-innovation/gron-forskningsstrategi/definition-af-gron-forskning-udvikling-og-innovation-i-ufm-regi

### Example of definition of research area based on research themes

This example uses an initiative for climate-neutral road transport, including vehicle electrification and development of green fuels. The seven existing research themes and their underlying sub-themes were assessed to be an appropriate basis for delineating the research area of the initiative. It was assessed that the initiative could be defined to six sub-themes distributed across two research themes.

Theme 1: Sustainable energy technologies and production etc.

- Sub-themes: Bioenergy, storage and conversion, and Catalyst design for sustainable energy conversion and storage

Theme 4: Climate-friendly transport

- Sub-themes: Climate-friendly freight transport and Climate-friendly passenger transport

A discretionary assessment was made of whether the themes and sub-themes are sufficiently relevant to be included in the delineation of the research area and, thus, in the assessment of research strengths. The next step would be to assess the research strengths of each research theme. Alternatively, only one of the themes could be selected if deemed to be more relevant than the other. In our example, one could consider only using theme 1, seeing that the transport sector (and therefore theme 4) will not be 'most relevant' until the implementation phase of the initiative.

In some cases, it will not be possible or appropriate to use the seven research themes, and therefore other approaches to defining the relevant research area should be considered. For example, an alternative approach could be to define the relevant research area through a qualitative assessment. table 6.19 below lists some of the elements that will typically be included in a qualitative assessment.

**Table 6.19**

Alternative approach to defining a research area: Elements typically included in an alternative approach

| Element | Description |
|---|---|
| 1 | Screen and identify specific methods, concepts and narrow research fields that relate to the initiative. For example, technical terms and relevant keywords can be used to develop search strings. |
| 2 | Use bibliometric data, or similar, to measure Danish and international research activities based on the methods, concepts and narrow research fields identified under Element 1. |
| 3 | Develop indicators based on data inputs identified in Element 2 to assess Denmark's research activity level (within the research area of the initiative), Danish relevant research and Denmark's position compared to international research environments, for example. |

**Example of definition of research area on the basis of an alternative approach**

This example is based on an initiative about regulation and policy instruments about which it was not deemed possible to delineate the research area to existing research themes or sub-themes, because the initiative cuts across multiple areas. A qualitative approach was taken instead to define the relevant research area. Based on the elements presented in the table above, it was deemed most appropriate to select relevant technical terms and keywords for search strings (**Element 1**) based on the description of the initiative (see the box below). Ideally, this method should be supplemented by other methods, but for simplicity's sake, only the search strings method is exemplified here.

TITLE-ABS-KEY("green regulation" OR "environmental regulation" OR "sustainable regulation" OR "climate regulation" OR "regulatory policies" OR "environmental legislation") OR TITLE-ABS-KEY("policy instruments" OR "political measures" OR "government interventions" OR "climate policies" OR "environmental policies" OR "sustainability measures") AND TITLE-ABS-KEY("greenhouse gas emissions" OR "carbon emissions" OR "GHG emissions" OR "climate pollutants") OR TITLE-ABS-KEY("energy sector" OR "renewable energy" OR "energy policy" OR "industrial emissions" OR "manufacturing sector" OR "industry regulations" OR "transportation emissions" OR "transportation policy" OR "vehicle regulations" OR "agricultural emissions" OR "agricultural policy" OR "farming regulations" OR "housing emissions" OR "building regulations" OR "residential sector") OR TITLE-ABS-KEY("sustainable development" OR "climate neutrality" OR "net-zero emissions" OR "carbon neutrality" OR "low-carbon economy")

Next, the search strings were applied to bibliometric data **(Element 2)**, yielding a total of 14,798 observations for the period 2012-2021[49]. Although it is possible to use data to measure 'number of publications per million inhabitants' and 'degree of specialisation', for example, the results should be interpreted with caution due to the limited number of observations **(Element 3)**. Similarly, the results should not be generalised and should therefore not serve as the sole basis for determining whether there is a position of strength. Therefore, if the results are used in the assessment, it is important to use them in combination with other methods.

If an initiative's research area can be defined to one of the seven research themes, there are different options for setting up already available indicators of research strength based on existing analyses and data sources. For example, the seven research themes have been applied to different research output metrics (bibliometric data[50]), just as they have been implemented in different statistical analyses by Statistics Denmark[51], including statistics on PhD graduates, grants from private foundations, public-sector research and development (R&D) and business-sector research, development and innovation (R&D/RDI). The research themes are not likely to be revised anytime soon. This ensures a relatively consistent basis for comparison over the long term for assessing the research strengths for different initiatives across several types of indicators and data.

### 6.5.2.2 Industries

Defining the relevant industry for a research and innovation initiative can be based on industrial classification. Here, industry codes from DB07 (Danish Industrial Classifications 2007) can be used to categorise different types of economic activity in businesses. Depending on how specific an initiative is, the choice of relevant industry can be made against a more disaggregated level, while for more general initiatives, it may be necessary to analyse data at a higher level of aggregation. The first thing is to find the industry or industries deemed relevant to include in the delineation of the relevant industry. To ensure that different types of activities are included, and that the relevant industry is delineated as accurately as possible, a distinction can be made between two types of activity.

- **Research and development activities**: Activities that include the development of a technology or product. This includes businesses that drive the development of new products, services and solutions that can be implemented in different sectors and industries.
- **Implementation activities**: Implementation activities include implementation of technology or products. This includes businesses, organisations and other stakeholders that leverage various forms of innovation to improve their business practices. In addition to technology, this can include implementation of new processes, business models and other types of innovation across different sectors and industries.

[49] Same period chosen as for the exemplification of indicators.
[50] No bibliometric data has been collected for theme 7 (sustainable behaviour) as it was not possible to isolate this area in the statistics. Instead, this theme was integrated into the other research themes.
[51] The seven research themes have only recently been implemented by Statistics Denmark and, due to a time lag, not all data is available yet. This also means it is not possible to extract historical data from before 2021-2022.

An example of this, i.e. of development and implementation of a technology or product across sectors and industries, are biosolutions. It is expected that biosolutions can help reduce greenhouse gas emissions in agriculture and in the food sector, for example through new feed solutions. Biosolutions are developed by businesses within industries such as 'Research and experimental development in biotechnology', while the actual production requires businesses within industries such as 'Manufacturing of compound feed for livestock'. Implementation of a biosolution requires agribusinesses within the 'Livestock farming' industry, which can implement the solution in their production. Thus, several activities and industries are involved, and it will be necessary to include several industries when defining the industry for the initiative.

If it is not readily possible to define a relevant industry, various tools can be applied. One option is to identify businesses that handle the development and implementation activities related to the initiative. Information about these businesses' industry affiliations can then be used to narrow in on the industry for the initiative. Another option, which may become relevant if it is not possible to identify relevant businesses, is to use product codes. Like industry codes, product codes are a classification system that describes the activities of businesses, but at a more detailed level in the form of production outputs. Product codes[52] that are relevant for the initiative can be identified, making it possible to analyse data about businesses and industries[53] that either produce and sell the product or use it in their production. This information can thus be used to define which industry is relevant for the initiative. If neither the industrial classification, businesses or product codes can be used to define the relevant industry, this fact alone may be sufficient to conclude that there is no business strength.

**Example of definition of industries based on product codes and key businesses**

This example uses an initiative concerning the development of battery technologies for storing energy from renewable energy sources such as solar, wind and gas. It was assessed that the relevant industry can be defined based on identified product codes and the identification of a number of key businesses.

*Development activities*

Development activities include the development of battery technologies for energy storage that focus on improving the technologies' energy density, lifetime and safety by using advanced and new materials such as lithium-ion, and on optimising production techniques and integrated systems to efficiently store energy from renewable sources. Industries relevant for development activities were selected by identifying Danish businesses that develop battery technologies as well as the relevant product codes for these technologies. This resulted in a group of industries that were deemed relevant to include when defining the industry for the development activities.

- Manufacture of batteries and accumulators (Nerve Smart Systems A/S, CLAYTON POWER A/S, Viridus Manufacturing A/S, Topsoe Battery Materials A/S)
- Manufacture of electrical equipment (product codes used: Primary cells and batteries V850601, Parts for primary cells and batteries V850603, Parts for electric accumulators V850707)

*Implementation activities*

Implementation activities include integrating battery technologies and systems with existing energy infrastructures and renewable energy sources such as solar, wind and gas to optimise the energy supply. Industries relevant for these activities were selected by identifying key businesses that are relevant for implementation activities. This resulted in a group of industries that were deemed relevant to include when defining the industry for the implementation activities. For example, businesses involved in the production, distribution and trade of electricity

[52] Toldstyrelsen (2024), *Sådan finder du varekoder i eVITA*, https://toldst.dk/erhverv/saadan-beregner-du-din-told/varekoder/saadan-finder-du-varekoder-i-evita og Toldstyrelsen (2024), *Om TARIC (Toldtariffen)*, https://info.skat.dk/data.aspx?oid=2247456
[53] Statistics Denmark (2024), *Nationalregnskabet*, https://www.dst.dk/da/Statistik/emner/oekonomi/nationalregnskab

and gas.

- Electricity supply (Ørsted, Better Energy A/S, Brave Solar A/S)
- Gas supply (NATURE ENERGY BIOGAS A/S, BB Biogas ApS, Ørsted)

## 6.5.3 Methodological challenges

Although an approach based on the research themes is administratively manageable and relatively quick and resource-efficient, it may have inherent problems. Therefore, we list a number of situations to be aware of if they are used to define a research area to be used for a specific research and innovation initiative.

First, it may be challenging to ensure relevant variation between assessments of research strengths for different initiatives. This is in part due to the challenges of dividing a field as complex as green research into broad categories, as it is generally not possible to distinguish between the underlying areas within a theme. That is, a research area can only be divided into seven themes that must accommodate all green research and therefore potentially all conceivable research and innovation initiatives going forward.

Second, organising green research in silos may pose a challenge. This may be problematic in cases in which research spans multiple areas. This is particularly evident when considering the first theme, which focuses on green technologies. Several of these technologies play a central role in the other themes, for example, a storage and conversion technology like PtX, which is used to develop green fuels (theme 4: Climate-friendly transport).

Third, relying on the same seven themes could create an inappropriate bias, where initiatives within the same areas are repeatedly favoured and recommended. Conversely, for some initiatives it might not be possible to define the relevant research area as falling within one of the existing themes. In such cases, the initiative will not be assessed on equal terms with other initiatives where it is possible to define a research theme, which again creates an unintended bias when assessing multiple initiatives. It is therefore important to consider alternative statistics and definitions, as exemplified above, if the existing categories are not suitable for defining a research area.

Using the industrial classifications to define the relevant industry is not unproblematic. Some of the challenges to pay attention to when using the industrial classification are described below.

First, industry codes are based on a classification of business activities that was primarily created to calculate key figures for the Danish national accounts, including GDP aggregates. This is a challenge, because the industries relevant in relation to green research and innovation initiatives will rarely be limited to just one industry. This must be taken into account in the definition process, otherwise there is a risk of creating a skewed and misleading definition of the industry for the initiative, which means the wrong strengths will be assessed.

Second, there may be initiatives involving a technology or product that cannot readily be linked directly to a single industry. This may be because the initiative's possible applications are more cross-cutting in nature, or if the initiative relies on a relatively new technology or product. For example, this could be a technology such as pyrolysis, which only in recent years has been highlighted as a potential key technology for the reduction of emissions in Denmark, and which has not yet been implemented.

Third, there is a risk that businesses with sub-activities relevant to the initiative are not included in the definition of the industry. This is partly because a business's main activity determines which industry it is classified under. On the one hand, it might not be possible to identify businesses with sub-activities of relevance for the initiative. On the other hand, there is also a risk that the definition includes businesses whose activities are not relevant for the initiative, since many different businesses are aggregated within the same industry.

## 6.6 Capacity

Supporting and achieving emissions reductions through research and innovation initiatives requires careful assessment of both the required and the available capacity, as capacity constraints can create barriers and limit progress. Focus is specifically on the capacity available in Denmark, including human capital and infrastructure. Human capital covers the scientific workforce, including researchers and PhD graduates, as well as the skilled technical workforce essential for implementation and scaling of solutions. Insufficient human capital can create bottlenecks that impede initiatives. Infrastructure, such as test and demonstration facilities, is also essential for developing and scaling solutions. Besides human capital and infrastructure, other capacity constraints such as lack of raw materials and land can hinder progress.

### 6.6.1 Human capital

Human capital is a critical capacity area where potential barriers to an initiative can emerge. The primary consideration is to assess whether sufficient workforce with the appropriate competencies will be available to achieve the expected effect of any given initiative. Conversely, there may also be cases where it is relevant to assess whether there is too much human capital available, for example in the scientific workforce. In such a situation, there is a risk of reaching a saturation point, where research productivity begins to decline. While this can be difficult to measure, it can be assessed by examining the ratio of grants to researchers within the relevant field. To evaluate potential bottlenecks, it is important to assess whether pressure in the labour market could delay implementation or increase the cost of the initiative's outcomes. This bottleneck typically occurs when the initiative's increased workforce demands necessitate drawing human capital from other parts of society. Initiatives that require workers with specific technical skills face the risk of short-term labour shortages, creating what are known as workforce bottlenecks. However, over the longer term, multiple market mechanisms come into play to address these imbalances. For example, changes in wage levels or recruitment of international labour. The speed at which these adjustments occur depends on factors such as the degree of workforce specialisation, the number of workers needed, the geographical distance workers must relocate, international demand for similar skills, and opportunities in other sectors. Therefore, it is considered sufficient to assess the short-term demand for labour, as a dynamic labour market is likely to adapt to demand over time. In order to assess human capital, two typical inventories of human capital in the workforce are reviewed here: Education and jobs. These inventories can be used to assess whether adequate human capital exists to support the initiative's planned activities.

#### 6.6.1.1 Education

Assessment of the short-term human capital requirement in terms of training can be based on the knowledge levels and fields of expertise needed to support a successful initiative. Such assessment can be performed by examining the educational qualifications of the current workforce. For research activities, particularly in the early stages of the value chain, focus will be on researchers and PhD graduates[54] as the critical workforce. This means that there is a significant overlap with the parameter strengths, which looks at the scientific workforce, among other things. In this context, the number of PhD graduates who have conducted research within the seven research themes described under 'strengths' is assessed. In the later stages of the value chain, where the results from the initiative are to be implemented and scaled, human capital with a broader competence profile may be needed. This can be assessed by examining the education level of the workforce against the seven themes from the research strategy and by identifying any bottlenecks and mismatch issues, see box below. Another advantage of focusing on education is that the public sector can prioritise certain degree programmes to promote the green transition, for example.

### Model to assess labour market pressure

The expert group commissioned HBS Economics to develop a tool to assess green labour market trends, specifically to identify workforce bottlenecks and skills mismatch that could impact green research and innovation initiatives. The tool is an indicator of high/low labour market pressure, based on economic trends over the past decade. Labour market pressure will change over time, with the calculated mismatches providing a projection of pressure levels up to approximately 2028. In the longer term, the labour market will adapt, and the model will need to be supplemented with population projections, developments in the educational composition of the workforce, etc. The categorisation of education programmes across the seven themes is based on a mapping from the Danish Agency for Higher Education and Science.[55] An education programme is considered relevant to a theme if that theme appears in both the programme description and in at least one mandatory course.

**The workforce can be divided into**
8 themes (the 7 green themes included in the research strategy, and a non-green theme)
6 education levels
15 specialist areas
3 links in the value chain from research to scaling

In total, there are 2,160 data points for labour market segments.

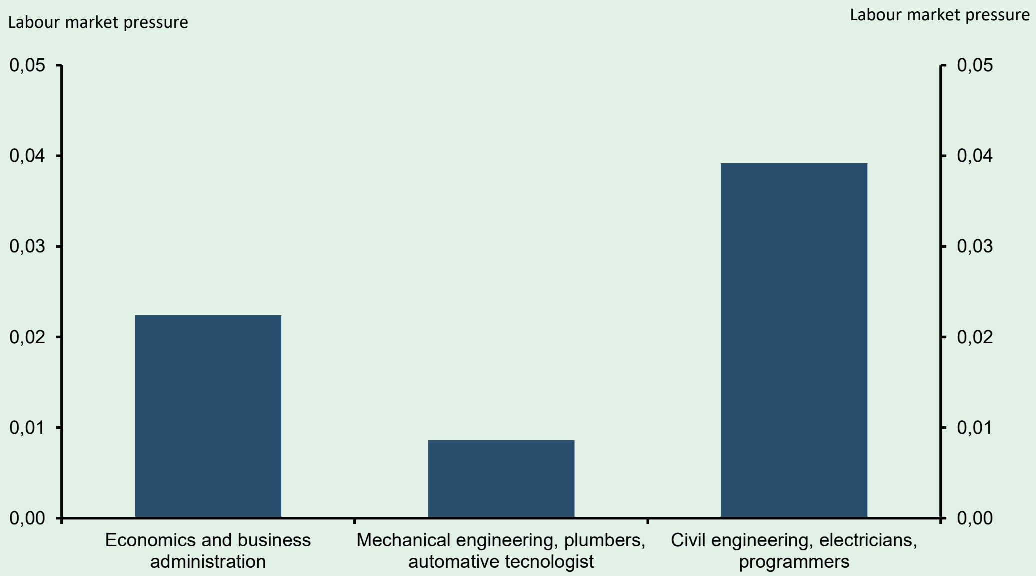
The short-term pressure on each segment is calculated based on 2011, which HBS considers a relatively normal year in terms of economic trends. Projecting employment based on workforce trends across different segments, including levels of both employment and unemployment, establishes a baseline for 2021 assuming that employment had developed in line with the workforce. Part of the short-term labour market pressure can be attributed to 2021 being an atypical year, with employment rates still affected by recent crisis conditions. In an alternative measure of labour market pressure, cyclical effects are removed by performing the same calculation across the 15 specialist areas and subsequently distributing across individual segments. The model contains the two following measures of pressure. Short-term pressure and cyclically adjusted labour market pressure.

Short-term labour market pressure is most relevant for labour market segments that are not sensitive to economic trends. However, for cyclically sensitive segments, it is more informative to look at labour market pressure adjusted to account for economic trends.  Length of education is often a good indicator of cyclical sensitivity, with longer education programmes being less sensitive. Similarly, the degree of employment in the private sector can also be used as an indicator, given that private sector employment tends to be more sensitive to the economic cycle. The figure below shows an example of results from the model. The figure indicates that within 'Energy production', there is a demand for education programmes within the themes 'Engineering, technology and industrial production',

[54] The expert group has previously shown that PhD graduates who, during their PhD studies, conducted research within the seven research themes related to the green transition, also work within the same themes in private-sector businesses.
[55] Danish Agency for Higher Education and Science (2022), *Kortlægning af grønt læringsudbytte i uddannelserne*, https://ufm.dk/uddannelse/videregaende-uddannelse/temaer/gron-omstilling-i-uddannelser/kortlaegning-af-gron-laeringsudbytte-i-uddannelserne

'Business economics' and 'Mechanics and metallurgy'. However, demand is highest in 'Engineering, technology and industrial production'.

**Figure 6.16**
Example of labour market pressure for themes within the 'Energy production, etc.' area, 2022-2026




*Source: Expert group on the significance of research for the green transition's own calculations using data from HBS Economics*

The ordinary educational system represents just one of many paths towards the skills needed for green initiatives. Technological development and the green transition will cause some jobs to disappear, while new ones will emerge. Upskilling the workforce, especially among the unemployed, can help meet specific labour market pressure. Continuing education provides new skills or certifications that are required by authorities or industries. For example, unskilled workers can be certified to perform cable pulling, a task usually performed by electricians, freeing up electricians for other important tasks. Continuing education may also reduce resistance to the green transition by reducing unemployment and preventing skill erosion, both of which typically lead to negative attitudes toward the green transition (see governance parameters below). However, the complex nature of continuing education could complicate identification of barriers to specific initiatives. Instead, assessing the flexibility of the continuing education system could be a relevant indicator of the adaptability of the system to increased or new demands for skills.

There are several advantages to using education when assessing the capacity required by an initiative. First, the workforce can be assessed based on educational attainment, making it possible to assess labour market pressure. This assessment also includes a breakdown of the educational level of the unemployed. Second, the Danish Agency for Higher Education and Science has mapped the extent the green transition has been integrated into higher education through institutional reporting of learning outcomes within the seven themes in the research strategy. Third, a high level of education is key in the context of research and innovation initiatives, as such initiatives require highly specialised knowledge that is typically obtained through education. Fourth, education is a political priority and thus a barrier that can potentially be addressed through political decisions. A drawback of basing the assessment on education is that the formal education of people with extensive professional experience may not necessarily reflect their current skills. Furthermore, learning outcomes have only been examined for higher education programmes, and not for vocational education and training or unskilled workers, and data for these groups cannot be distributed across the seven themes. The limitation of only having seven themes poses an additional challenge. Finally, the relatively short time horizon for the green transition means that opportunities to address barriers through education policy are primarily limited to short-term programmes and continuing education.

#### 6.6.1.2 Job functions

Another approach to assessing potential capacity constraints is to inventory the specific job functions needed for a given initiative across the value chain. Implementing and scaling the results of initiatives often requires skilled technical labour, for example for establishing and operating biogas plants. Some roles may require specialised green skills, particularly knowledge of sustainability and the circular economy. While some positions demand specific qualifications and certifications, the relationship between job functions and educational background is often less clearly defined. While education has previously been assessed based on seven themes, the options for assessing job functions are more flexible. Internationally, substantial efforts have been made to measure green skills and job functions. For example, ESCO (European Skills, Competences, Qualifications and Occupations), a European classification of skills, competences and occupations, identifies 571 green skills and knowledge concepts to describe green jobs. Specific job functions are associated with these skills and knowledge areas. However, there is no standard for the area, so for each initiative, an assessment must be made as to which classification is most appropriate.

An approach focusing on job functions enables use of the labour market balance model developed by the Danish Ministry of Employment[56]. This model inventories job opportunities for around 850 job functions in eight regions for the period 2014-2024. In addition, the Danish Agency for Labour Market and Recruitment (STAR) has developed a skills tool that can be used to estimate the number of job postings with green skills content or specific job functions. The advantage of using job functions is that all individuals in employment, regardless of their work experience, can be assigned to a job function, and this job function can be assigned to a range of green skills, such as the 571 skills defined by ESCO. This applies to all individuals in employment, including skilled and unskilled workers, who will also be needed in the green transition. The downside is that it is more challenging to assess labour market pressure as unemployed individuals cannot be categorised by job function. This challenge is addressed by the labour market balance model that uses education as a proxy measure, enabling the assessment of labour market pressure based on the workforce's educational qualifications. The scope for policy intervention to address barriers is further limited by the vague connection between many job functions and formal educational requirements. To assess how human capital influences an initiative's potential to reduce emissions and to identify related barriers and challenges, a framework of indicators and variables has been developed, see table 6.20.

[56] Styrelsen for Arbejdsmarked og Rekruttering (2024), *Arbejdsmarkedsbalancen*, https://arbejdsmarkedsbalancen.dk/

**Table 6.20**

Indicators and variables for assessing human capital

| Indicator | Variable | Description | Source |
|---|---|---|---|
| Education | Projection of labour market pressure | The pressure on different educational programmes related to the initiative. | Statistics Denmark<br>HBS Economics |
| | PhD graduates with green interests | The number of PhD graduates with green interests within specific research areas is used. Going forward, this will be possible for the seven green research themes, as the PhD survey has included questions about this in recent years. | Statistics Denmark |
| | Flexible continuing education system | Is there a continuing education system in place to address a potential need for continuing education? | Ministry of Higher Education and Science |
| Job functions | Labour market pressure in relation to various green job functions | Model of the regional labour market by job functions (labour market balance) | Statistics Denmark<br>Ministry of Employment |
| | Job postings | STAR has developed a skills tool that can determine which skills are typically found in job postings for various job functions, which in turn can be cross-referenced with ESCO's description of green skills/job functions. | STAR<br>ESCO |

**Example of assessment of human capital**

This example uses a circular economy initiative, which includes development of solutions to reduce waste in order to reduce greenhouse gas emissions.

This initiative requires technical expertise from long-cycle higher education programmes within circular economy that reflect the 'Environment and circular economy' theme. This theme also encompasses environmental aspects, covering soil contamination, air and noise pollution, etc. The model includes long-cycle technical degree programmes where this theme appears both in the programme description and in at least one mandatory course. The MSc in Engineering is the predominant degree programme, with the three largest specialisations being 'Mathematical modelling and computing', 'Sustainable energy' and 'Industrial technology and technology management'.

The model shows that in 2021, approximately 4,035 individuals holding advanced technical degrees with expertise in environmental issues and circular economy were in employment. A projection of employment from 2011 to 2021, based on workforce trends within these same degree programmes, indicates that employment will reach 4,031 individuals in employment in 2021. The resulting short-term labour market pressure is therefore only 4 individuals or 0%, reflecting that, in a normal year, unemployment is very low for this group. Consequently, businesses will find it difficult to recruit employees with these qualifications without offering more attractive positions or recruiting through international networks.

An alternative to the seven themes is to focus on labour market pressure for degree programmes used in sectors working with the circular economy, such as 'Collection, treatment and disposal of waste and recycling'. On the one hand, this approach does not capture work to reduce waste in other industries. On the other hand, it does not include air, water and noise pollution. If developing waste reduction methods is sector-specific and thus something primarily learned through work experience, it may be relevant to look at job functions.

### 6.6.2 Infrastructure

Infrastructure represents another type of capacity where barriers may arise. There are several different types of infrastructure where capacity demands may potentially arise. These are discussed below.

#### 6.6.2.1 Research infrastructure

Research infrastructure can encompass various aspects, including capital-intensive facilities such as quantum computers, which cannot be funded solely by basic funding or research funds. It can also include permits for conducting research under special conditions. While this is a relatively broad area, access to relevant research infrastructure is often necessary to advance research in a particular field. It should be noted that robust research infrastructure can attract international researchers, especially if such infrastructure does not exist in other countries, and this may reduce barriers to human capital. Conversely, Danish researchers will also be attracted to research opportunities available through research infrastructure in other countries.

#### 6.6.2.2 Test and demonstration facilities

Infrastructure in the form of test and demonstration facilities may be necessary to promote the further development of technologies and solutions for the green transition. Access to such facilities is crucial, especially when unproven technologies, such as pyrolysis, need to be tested on a scale similar to real-life production facilities. This creates an investment need that cannot always be met through market financing. While less capital-intensive projects with high risk may receive support from venture capital funds, highly capital-intensive projects may struggle to attract sufficient private funding. For this reason, there is an overlap with the parameter concerning funding of the initiative, as the need for publicly funded test and demonstration facilities can constitute a barrier to development.

#### 6.6.2.3 Complementary assets

Another type of infrastructure that should be considered when assessing an initiative is complementary assets. Development within a given field often requires complementary innovations, primarily because early-stage innovations tend to be both inefficient and costly. Complementary assets can increase the value of an initiative and make it more profitable, thereby driving it forward in the market. Launching complementary assets at the same time as an initiative can accelerate market adoption. For instance, the hydrogen market cannot develop at scale without stable transportation infrastructure. Likewise, the installation of offshore wind turbines may require special port facilities. As with other infrastructure, such large-scale projects may require separate public funding, and this parameter therefore overlaps with the funding parameter.

Infrastructure projects are often large and complex, requiring thorough qualitative assessment of their necessity. Data sources can include specific lists of existing infrastructures. A set of indicators, questions and possible data sources are presented in the table below to help in the assessment of infrastructure as a condition for an initiative and to identify potential challenges in accessing the necessary infrastructure. The questions can be applied to each initiative, and inventories of existing infrastructure can be used to assess the need for additional infrastructure.

**Table 6.21**
Indicators and questions for assessing infrastructure

| Indicator | Question | Source |
|---|---|---|
| Research infrastructure | Does the initiative require research infrastructure such as laboratories, data environments etc.?<br>- Does the initiative already have access to the necessary infrastructure?<br>- If no, is the initiative expected to gain access to the necessary infrastructure? | The Finance Act<br>Danish Test Facilities included in the Danish Company Guide (Virksomhedsguiden) |
| Test and demonstration facilities | Does the initiative require test and demonstration facilities?<br>- Does the initiative already have access to the necessary infrastructure?<br>- If no, is the initiative expected to gain access to the necessary infrastructure? | Danish Test Facilities included in the Danish Company Guide (Virksomhedsguiden) |
| Complementary assets | Does the initiative require facilities for implementation and scaling of electricity and gas grids, water supply, heating supply or similar?<br>- Does the initiative already have access to the necessary facilities?<br>- If no, is the initiative expected to gain access to the necessary facilities? | |

**Example of infrastructure**

The following example is based an initiative for the production of green fuels using electrolysis technology.

An electrolysis plant will produce hydrogen, which can be used either as fuel or be further processed into other chemical products. Ensuring that the hydrogen is completely green requires a significant amount of electricity, preferably cheap and green electricity from renewable energy sources. This requires a well-developed energy system based on renewable energy. Since market prices for electricity, especially from solar and wind energy, fluctuate from hour to hour, the electrolysis plant must be able to produce hydrogen during the hours when electricity is cheapest. The hydrogen consumers will likely demand a continuous supply. To scale hydrogen production to a larger scale, a hydrogen infrastructure that enables storage and transportation of the hydrogen is needed. Developing this infrastructure in parallel with developing the electrolysis plant could accelerate the implementation of electrolysis as an efficient green energy source.

Besides, when the energy system is based on renewable energy sources like wind and the sun, electrolysis can also help stabilise the energy system by buying excess energy when the system is overloaded. This creates a mutual benefit where electrolysis not only capitalises on the electricity produced, but also supports the energy system by balancing supply and demand.

## 6.6.3 Other input factors

In addition to human capital and infrastructure, an initiative might require other types of capacity, for example, to scale its results. There may be scarcity of this capacity or significant uncertainty surrounding its supply chain. Scarcity is the result of insufficient production of the input in relation to demand. This is the case for many modern technologies used in a broad array of products globally and for areas with significant investment, such as the green transition in many countries. Furthermore, certain raw materials are produced in very few countries, making their supply chains subject to significant geopolitical uncertainty. A particular challenge in accounting for various inputs is that they may not necessarily serve as direct inputs in production, but rather may be intermediate input in semi-finished products used in production. Understanding the supply chain is thus crucial in assessing this parameter. As was the case with infrastructure, other inputs include specific, critical components which may be scarce. Generally, there may be shortages of inputs at a given price; however, this aspect should not be assessed here, as the market can be expected to resolve common resource scarcities resulting from the green transition. To assess whether other input factors are needed, an approach is presented here that enables assessment of requirements for the individual initiatives, as illustrated in the following table. Some examples of other input factors are given, but it is important to note that the list is not exhaustive.

**Table 6.22**
Indicators and questions for assessing other input factors

| Indicator | Question | Source |
|---|---|---|
| Other input factors | Does the initiative require other input factors such as biomass, land, critical raw materials, etc.?<br>- Does the initiative already have access to the necessary input factors?<br>- If no, is the initiative expected to gain access to the necessary input factors? | Statistics Denmark (land)<br>Eurostat (critical raw materials)<br>United Nations System of Environmental-Economic Accounting (SEEA) |

**Example of assessment of other input factors**

The following example is based on an initiative to reduce emissions from agriculture through pyrolysis technology, for example.

Pyrolysis technology can reduce agricultural emissions by transforming biomass such as straw and slurry into biochar, which can be stored as carbon in the soil. This requires sufficient access to land that can be used for multiple activities. First and foremost, land is required for biomass production. Additionally, pyrolysis facilities must be established, which also requires space, and finally, the converted biochar must be distributed and integrated into agricultural soil, which also requires access to land.

A challenge may arise in achieving sufficient quantities of biochar and land, as land is currently in demand and expected to be required for other purposes in the green transition. This may include land for renewable energy production, such as the establishment of solar farms, as well as land to be used for other carbon storage purposes, for example, afforestation or setting aside of organogenic soils. Thus, potential challenges may arise in securing the necessary input for pyrolysis, and this will affect the probability of the initiative's success.

## 6.7 Governance

This section presents an approach to assessing governance, because structural and systemic conditions must be of a nature that facilitates the research and innovation initiative, so that it can deliver greenhouse gas emission reductions. It is particularly relevant to examine policy instruments, as they can be decisive for the initiative and its ability to realise its reduction potential. This involves assessing instruments such as legislation, taxes, regulation, subsidies, standards, etc. in terms of whether they support or impede the initiative. Furthermore, it should be assessed whether there is likely to be backing for the initiative. Backing can be assessed at various levels, from local backing to international backing, and for various activities in the initiative. This is particularly relevant, as lack of backing can constitute a significant barrier to implementation. Following this, it can also be relevant to assess whether society is genuinely willing and able to transform, particularly through behavioural changes. This goes beyond looking at whether there is backing in society to looking at whether society is truly prepared adapt and to accept any burdens and trade-offs associated with new solutions.

A qualitative approach is used to assess the structural and systemic conditions that affect research and innovation initiatives. This assessment is operationalised through a worksheet designed to facilitate a structured assessment of the specific initiative, see table 6.23 The purpose of the worksheet is to identify relevant and significant governance factors that will influence both the initiative and the implementation of the solutions it aims to deliver. The primary purpose, however, is to identify potential significant barriers to the initiative. The worksheet is designed as a dynamic tool that can be revisited multiple times to reassess the same initiative and can be adapted to specific situations. As this involves a qualitative examination of structural conditions, the assessment naturally carries a degree of uncertainty, and assessments should therefore be interpreted with caution. Furthermore, it is important to note that because such assessments are highly subjective, the worksheet can be used to structure the process. The operationalisation of policy instruments is based in part on the European Environment Agency's (EEA) classification of policy instruments for green transition. The purpose is to assess whether significant policy instruments exist that support the initiative, whether key instruments are missing, or whether existing instruments act as substantial barriers to the initiative. The work sheet identifies the two following types of policy instruments considered particularly relevant for the green transition: Regulatory and market-based. These instruments can be both national and international. Operationalisation of backing and the adaptability of society follows the same logic as for policy instruments. This includes describing and assessing whether backing or resistance to the initiative and associated activities can be identified.

**Table 6.23**

Governance assessment worksheet

Description of policy instruments and backing for [initiative]

*The purpose of this worksheet is to describe any barriers related to policy instruments and lack of backing for a research and innovation initiative. Examples of such barriers are policy instruments such as taxes, bans and similar that are expected to impact the initiative. Other barriers could be resistance from, for example, interest groups, businesses or citizens to such an extent that it becomes a barrier to implementation.*

**Policy instruments**

*Describe policy instruments (legislation, taxes, subsidies, etc.) that are expected to have a significant impact on the initiative, either by facilitating or limiting its chances of success. Write a maximum of 10-15 lines for each. If no significant impact on the initiative is anticipated, write: Not relevant.*

**Regulatory**

*Are there any barriers in the current legislation that are expected to have a significant impact on the initiative? Please describe the expected impact on the initiative.*

**Market-based**

*Are there any significant taxes, subsidies or environmental levies that are expected to impact the initiative? Please describe the expected impact on the initiative.*

On a scale of 1-10, to what extent are the policy instruments expected to impact the initiative?

| Barrier | | | | No barrier | | | | | Facilitates |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

**Backing and adaptability**

*Describe whether there may be backing/resistance among relevant actors that can be expected to impact the initiative's probability of success. Also, describe if there is expected to be a real ability to change behaviour. Write a maximum of 10-15 lines for each. If no significant impact on the initiative is anticipated, write: Not relevant.*

**The population**

*Add an assessment of the public's attitude towards the initiative – is there expected to be resistance of such a nature that it would be a barrier to the initiative? An example of resistance is resistance toward establishing test facilities. It should also be assessed whether the public is expected to be able to adapt to the initiative, for example, through behavioural changes.*

**Stakeholder organisations**

*Is the initiative expected to face significant resistance from relevant stakeholder organisations? Examples of interest organisations are the Danish Chamber of Commerce, the Danish Society for Nature Conservation or FDM.*

**The business sector**

*Are there businesses that are expected to have a strong interest in the initiative and whose resistance may impede the initiative? Is there expected to be demand among businesses and in the business community?*

**Internationally**

*Is the initiative expected to face significant resistance from international organisations such as the UN, EU, IEA or similar?*

On a scale of 1-10, to what extent are backing or resistance expected to impact the initiative?

| Barrier | | | | No barrier | | | | | Facilitates |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

## 6.8 Step 3: Important considerations

In the expert group's assessment, several other important considerations could be included in the overall assessment of research and innovation initiatives to ensure a holistic assessment. As there can be many and currently unknown considerations to take into account, step 3 has been designed to be flexible. As mentioned above, these considerations fall into two categories: political and strategic considerations. Political considerations include other political prioritisation or bottom lines beyond emissions reductions. For example, this could be a political wish to support biodiversity. Strategic considerations extend beyond the individual initiative and look at each initiative within the broader context of other research and innovation initiatives in the field. For example, this covers looking at whether the initiative complements the existing portfolio of initiatives, and whether the initiative contributes to diversification and risk spreading within the portfolio of initiatives. Assessment of whether there are other important considerations should be conducted individually for each initiative. See the table below with questions to guide this process. Furthermore, assessment of political and strategic considerations can be linked to the initial description of the initiative, the purpose of which was to identify any relevant areas of attention.

**Table 6.24**

Questions for assessing important considerations

| Considerations | Question |
|---|---|
| Political | Will the initiative have a positive or negative impact on other important political considerations? If yes, these can be included as a consideration in the overall assessment.<br>- For example, distribution policy, biodiversity, etc. |
| Strategic | How does the initiative fit with the other initiatives in the area?<br>- For example, in terms of risk diversification, time horizon, complexity |

**Example of assessment of important considerations**

To illustrate how relevant political and strategic considerations can be included in the assessment of a research and innovation initiative, a number of examples are provided here.

**Political considerations**

A political consideration could be biodiversity. Wind technology is an example of an initiative with potential negative biodiversity impacts, as the deployment of full-scale wind energy production requires the construction of wind farms. Large wind farms, especially onshore, can disrupt local ecosystems. They can affect bird populations, as birds risk colliding with the turbines, and they can also disturb habitats for animals such as bats or other small mammals. Another policy consideration related to the environment could be noise pollution. Major energy projects often involve construction of new roads, transmission lines and other infrastructure components. The construction process and increased traffic associated with these projects can cause noise nuisance for the local community.

**Strategic considerations**

A strategic consideration may be to support sufficient risk diversification within an area. Take for example technologies or solutions currently favoured because of their potential for emission reductions in specific sectors. Although these technologies demonstrate promising potential, they risk being overvalued if not properly developed or implemented, or if they reveal unforeseen limitations. Examples include an over-reliance on pyrolysis in agriculture, or depending solely on CCS technology to achieve zero emissions in energy and manufacturing industries. Another strategic consideration involves supporting coherence with other initiatives, particularly regarding resource utilisation. For example, an initiative focused on biofuel development, where land is a critical input resource. In such cases, it is essential to assess whether other initiatives, such as solar farms, are competing for the same land resources. Similarly, land is an input for purposes beyond research and innovation initiatives, such as afforestation, food production, setting aside organogenic land, etc.

# 7. Annexes

## 7.1 Annex 1: The expert group's task

The expert group was established in June 2022 by the government then in office, with the aim of strengthening the knowledge base about the effect of research and innovation. In early 2023, the new government decided that the expert group's work should continue. The expert group's main purpose is to establish an analytical framework to estimate the effect of investment in research and innovation to reduce greenhouse gas emissions. The group consists of three members with expertise in economics, environmental economics, and innovation and green transition. The members were chosen for their expertise and experience in their respective fields. The expert group has been supported by a small secretariat consisting of staff from the Ministry of Higher Education and Science, and monitored by a cross-ministerial advisory group, consisting of members from the Ministry of Finance, the Ministry of Industry, Business and Financial Affairs, the Ministry of Environment, the Ministry of Food, Agriculture and Fisheries, the Ministry of Transport, the Ministry of Higher Education and Science, and the Ministry of Climate, Energy and Utilities.

The expert group has held regular meetings with the secretariat in a variety of formats. A total of seven in-person meetings of 3-4 hours duration were held, along with a two-day residential seminar, 11 online working meetings and regular status meetings with the chair. In parallel, the expert group held a total of 12 meetings with external stakeholders and experts to gather input from various types of actors, e.g. universities, foundations, businesses, organisations etc., and across different areas such as agriculture, manufacturing industries, energy etc. Contributions from these meetings have been implemented in the expert group's work and its development of the analytical framework. During the expert group's final period, meetings were held on an almost weekly basis, focusing on operationalisation of the analytical framework. The expert group also obtained feedback on the final report from a range of different actors, including peers from Scandinavia, the Danish Council on Climate Change, and Innovation Fund Denmark.

Every six months in connection with the Climate Programme and the research reserve, the expert group has provided status updates on its work. The expert group regularly published its findings on its website. The expert group published a report in August 2023, followed by three technical analysis reports in 2024, as well as the present concluding report. These reports are publicly available and aim to inform policymakers and the general public.

The expert group has completed its work and submitted its results. The expert group hopes that the Ministry of Higher Education and Science will now continue its efforts as well as the analytical framework. As the analytical framework is not a static tool, regular maintenance as well as updates and adjustments to the structure, data and input of the tool will be required.

## 7.2 Annex 2: Stakeholder engagement

Stakeholder involvement is set out as a prerequisite in the expert group's terms of reference. This has been a major focus for the expert group, which throughout 2023 and 2024 therefore involved a wide range of actors, experts and other interested parties in its work. The expert group reached out to several different stakeholders and also held meetings at the specific request of external actors. Below is a summary of meetings held. The stakeholders involved have generally been welcoming of the expert group's work and in agreement with its assessments. Furthermore, the stakeholders have supplemented the expert group's work by contributing elements they believe should be included in the assessment and policy-making basis for public research and innovation. All of the above has been considered in the development of the assessment tool.

**Table 7.25**

Meetings held with external stakeholders

| |
|---|
| **Experts and researchers** |
| Peter Møllgaard, chair of the Climate Council and rector at CBS<br>Ole-Kenneth Nielsen, emission inventories expert at DCE - Danish Centre for Environment and Energy<br>Lars Gårn Hansen, national environmental economic advisor and professor at the Department of Food and Resource Economics<br>Maria-Theresa Norn, senior researcher, Danish Centre for Studies in Research and Research Policy, Aarhus University<br>Lars J. Nilsson, Professor of Environmental and Energy Systems, Department of Technology and Society, Lund University<br>Markus Steen, senior researcher, SINTEF<br>Lars Coenen, Professor, Western Norway University of Applied Sciences<br>Håkon Endresen Normann, researcher, NIFU Nordic Institute for Studies in Innovation, Research and Education<br>Katarina Elofsson, professor at the Department of Environmental Science - Social and Geographical Environmental Research, Aarhus University |
| **Universities** |
| Aarhus University (including Faculty of Technical Sciences), Aalborg University, University of Copenhagen, Copenhagen Business School, University of Southern Denmark, Roskilde University, Technical University of Denmark and IT University of Copenhagen |
| **Public funds and foundations** |
| Innovation Fund Denmark, Independent Research Fund Denmark, Danish National Research Foundation and Danish Export and Investment Fund |
| **Private funds and foundations** |
| Novo Nordisk Foundation, Danish Industry Foundation, Villumfonden and Realdania |
| **Private businesses** |
| Aalborg Portland, Blue Water Shipping, Crossbridge Energy Fredericia and Ørsted |
| **Spinoff businesses** |
| 21st.BIO, Blue World, HealthyCrop and PlantCarb |
| **Trade unions** |
| FH - Danish Trade Union Confederation and Danish Society of Engineers, IDA |
| **Actors within food and agriculture** |
| SEGES Innovation, Danish Agriculture & Food Council, Food & Bio Cluster Denmark and Danish Technological Institute |
| **Actors within industry and construction** |
| Confederation of Danish Industry, WeBuild Denmark, Climate Partnership: the building and construction sector, Danish Technological Institute and Danish Institute of Fire and Security Technology |
| **Actors within energy, waste and utilities** |

Green Power Denmark, Energy Cluster Denmark, Confederation of Danish Industry, FORCE Technology and Danish National Metrology Institute

# 7.3 Annex 3: Recap of the tool

**Table 7.26**

Recap of the assessment tool

**Description of the initiative**

Description of the initiative: General description of the initiative that can be communicated across different types of actors.

Reductions: Description of how the initiative is expected to reduce emissions.

Areas of attention: Identification of any areas of attention that are expected to be relevant to the initiative.

| Step | Parameter | Indicators |
|---|---|---|
| ***Step 1: Reduction potential*** | National emissions | - |
| | Climate footprint | - |
| | Projections | - |
| | Global emissions | - |
| | Time horizon | - |
| | Complexity | - |
| | Obsolescence risk | - |
| ***Step 2: Conditions*** | Investments and funding | Investment needs<br>Funding opportunities |
| | Strengths | Research strength<br>Commercial strength |
| | Capacity | Human capital<br>Infrastructure<br>Other input factors |
| | Governance | Policy instruments<br>Support<br>Adaptability of society |
| ***Step 3: Important considerations*** | Political considerations | For example, distribution policy, biodiversity, etc. |
| | Strategic considerations | E.g. risk diversification, time horizon, complexity, etc. |

**Table 7.27**
Summary of relevant data and sources

| Step | Parameter | Indicators | Data | Source |
|---|---|---|---|---|
| ***Step 1: Reduction potential*** | National emissions | - | National Inventory Report<br>DRIVHUS | Danish Centre for Environment and Energy (DCE)<br>Statistics Denmark |
| | Climate footprint | - | AFTRYK1 and AFTRYK2<br>Denmark's Global Climate Impact – Global Impact Reporting | Danish Energy Agency and Statistics Denmark<br>Danish Energy Agency |
| | Projections | - | Denmark's Climate Status and Outlook | Ministry of Climate, Energy and Utilities |
| | Global emissions | - | GHG data | IPCC (Intergovernmental Panel on Climate Change) |
| | Time horizon | - | Qualitative assessment | |
| | Complexity | - | | |
| | Obsolescence risk | - | | |
| ***Step 2: Conditions*** | Investments and funding | Investment needs | Green Project Bank<br>Energy research<br>Project descriptions | Danish Agricultural Agency<br>Danish Energy Agency<br>The International Energy Agency (IEA), European Commission, Department for Business, Energy & Industrial Strategy, The U.S. Department of Energy, $CO_2$ Value Europe |
| | | Funding opportunities | Denmark<br>Internationally | |

| Step | Parameter | Indicators | Data | Source |
|---|---|---|---|---|
| | Strengths | Research | Bibliometric data | Scopus and Web of Science |
| | | | PhD graduates, public research investments and public funds granted | Statistics Denmark |
| | | Industry | Employment, value creation, goods exports, productivity.<br>International ownership, relative strengths, export intensity.<br>RDI active businesses, spinoff businesses, private research investments, patents, international knowledge workers | Statistics Denmark and the OECD |
| | Capacity | Human capital | Projection of labour market pressure | Statistics Denmark and HBS Economics |
| | | | PhD graduates with green interests | Statistics Denmark |
| | | | Flexible continuing education system | Ministry of Higher Education and Science |
| | | | Labour market pressure in relation to various green job functions | Statistics Denmark and the Ministry of Employment |
| | | | Job postings | STAR and ESCO |
| | | Infrastructure | Research infrastructure | The Finance Act |
| | | | Test and demonstration facilities | Danish Test Facilities included in the Danish Company Guide (Virksomhedsguiden) |
| | | | Complementary assets | |

| Step | Parameter | Indicators | Data | Source |
| --- | --- | --- | --- | --- |
| | | Other input factors | - | Statistics Denmark (land)<br>Eurostat (critical raw materials)<br>United Nations System of Environmental-Economic Accounting (SEEA) |
| | Governance | Policy instruments | Assessment using worksheet | |
| | | Backing | | |
| | | Adaptability of society | | |
| ***Step 3: Important considerations*** | Political considerations | For example, distribution policy, biodiversity, etc. | Qualitative assessment | |
| | Strategic considerations | For example, portfolio, risk diversification, time horizon, complexity, etc. | | |

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