Green solutions of the future

Strategy for investments in green research, technology, and innovation

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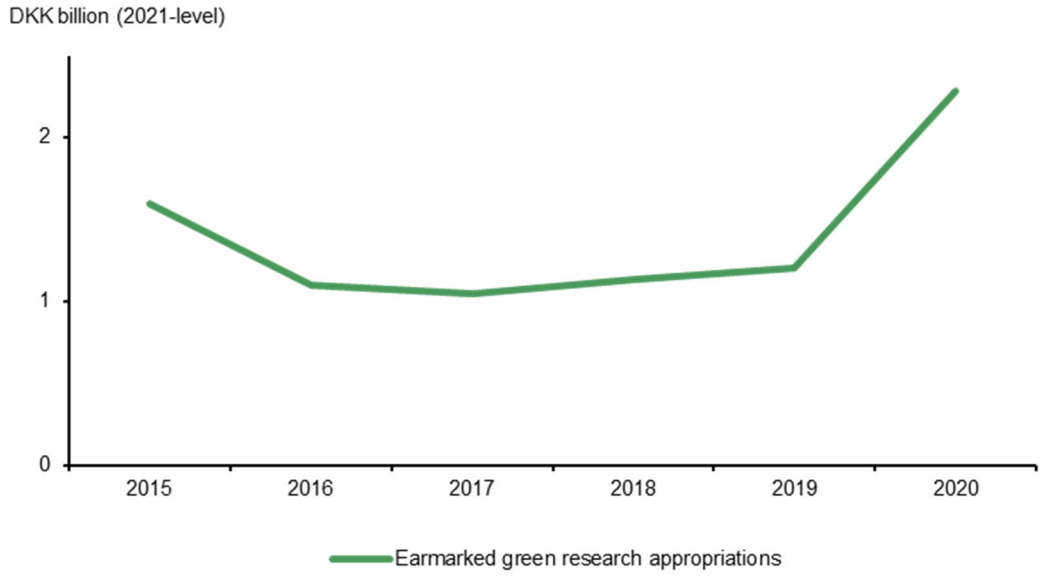
Summary

Research and innovation play a crucial role in attaining the ambitious climate targets of Denmark and safeguarding our nature and environment. With a new comprehensive national strategy, the government sets a long-term direction for green research, innovation, development, and demonstration accelerating the development of new green solutions and technology leaps. In a longer-term perspective, this is to reduce the costs associated with the transition and enable concrete reductions by 2030 and 2050. New solutions and technologies play a decisive role in reaching the target of the green transition in Denmark and the rest of the world. Along with this, we will expand the green frontrunner position of Danish industries to the benefit of exports and green jobs in Denmark.

The government has substantially lifted the level of green research funds with the aim to boost activities. These funds are to be invested in areas where impacts are the largest. In the coming years, there is a need for continued ambitious research and innovation efforts in the green field if we are to realise the green transition and attain the climate targets of 2030 and 2050. The government will therefore maintain the level of the green research funds at least at the 2020 level, corresponding to DKK 2.3 billion in the coming years. In addition, in connection with the 2021 Finance Bill and as part of the restart of the economy the government has proposed to increase the funds earmarked for green research in 2021 to a level exceeding the historic high level of 2020.

Figure 1
Earmarked green research appropriations 2015-2020



Source: Ministry of Higher Education and Science

We will focus efforts on those challenges - *missions* - where answers are most important in order to meet Denmark's climate objectives and to strengthen nature and the environment; missions where, thanks to our research and industry strongholds, we are in a good position to develop new technologies and create new industries, export opportunities, and green jobs in Denmark.

With a mission-driven effort, the government will accelerate developments of cutting-edge green solutions through strategic and coherent green research ranging all the way from basic research to commercialisation. Knowledge-institutions and the business community must cooperate closely, so we gear the public research investments with private funds in order that efforts become as powerful as possible. The interplay and coordination between universities, companies, authorities, and other relevant players must be enhanced to accelerate the development of green solutions and technologies.

In 2021, the government plans to prioritise DKK 750 million for four missions focused on challenges with a special need for cutting-edge solutions in order for Denmark to meet the 2030 targets of the Climate Act and to set the direction towards carbon neutrality by 2050, create new jobs and exports of green solutions contributing to a reduction in greenhouse gas emissions globally.

Therefore, the government proposes to prioritise four green missions in 2021:

1. **Carbon capture and storage or utilisation**
2. **Green fuels for transportation and industry (Power-to-X etc.)**
3. **Climate and environment-friendly agriculture and food production**
4. **Recycling and reduction of plastic waste**

The missions are to support the overall climate efforts of the government. In the *Climate Agreement for Energy and Industry,* it was agreed to focus on the green technologies of the future, including energy storage and conversion (Power-to-X) and carbon capture, utilisation, and storage - CCUS. In addition to the plans for energy and industry and the waste management sector, the climate action plan of 2020 will contain strategies for key sectors such as agriculture and transportation.

The strategy also presents the most essential research needs and potentials in the green field under a number of topics. These topics may serve as the basis for thematic calls for green research funding in public funds and programmes - in addition to the funds prioritised under the four missions.

The strategy also launches a number of concrete initiatives that contribute to the realisation of the strategy and support research and innovation, so we can make a difference in the green transition and promote a competitive green business community. The initiatives are to contribute to building up Denmark's research and innovation capacity in the green field to the benefit of the Danish business community and Danish jobs.

The implementation of the government's green research strategy will be discussed annually with the climate partnerships under the Green Business Forum, including progress in research and innovation efforts and possible future prioritisation.

Therefore, the government presents a number of concrete initiatives:

New initiatives

- An ambitious green research and innovation effort
- Green research and innovation partnerships
- Enhanced green focus for Innovation Fund Denmark
- Better coordination of green research
- Better framework for cooperation between knowledge institutions and the business community
- Strong Danish participation in international cooperation
- Monitoring and impact assessment of green research
- National Centre of Climate Research
- Green study programmes

Initiatives launched

- Denmark's Green Future Fund
- New technologies for a greener Danish business community
- New cluster organisations
- Roadmap for research-based public sector consultancy
- Green perspectives in space
- National robotics strategy
- Roadmap for research infrastructure 2020
- ESS Strategy 2.0

Introduction

The world along with Denmark is facing massive climate challenges. Recent years have been the warmest on record, Arctic sea ice is melting, and water levels in the oceans are rising at a record pace. We are also facing challenges for our environment, nature, and biodiversity.

We only have one Earth, but globally we consume more resources than it can sustain. We cannot continue along this path. The world community has overcome major challenges in the past, and we can do it again. However, we must move fast if we are to succeed in mitigating global warming. We must set out a green direction and create a more sustainable world.

Denmark must be a frontrunner in the fight for climate, environment, and nature protection, and we must take the lead in the green transition. The government and a solid majority of the Danish Parliament agreed in the Climate Act from December 2019 to set a target of 70 percent reduction of greenhouse gas emissions in 2030 compared with 1990 levels and carbon neutrality no later than 2050. This is a very ambitious target. And we need research and innovation to get there.

Up to 2030 and 2050, research must provide the basis for developing green technologies and solutions that are not known today, but are needed to transition to a sustainable future in which we attain the climate targets, protect our environment and nature, and create a green business adventure in Denmark. We have a strong starting point in Denmark with research of high international standing and a number of industry strongholds within green technologies.

In the green field we have a long tradition for close interplay between strong research environments and companies that have contributed to developments, e.g. in the energy field, of a leading wind turbine industry. We can stand on the shoulders of this tradition and develop further. By developing green solutions that can be used in other countries, we can set a footprint that is far bigger than what can be expected considering the size of Denmark and emissions within our borders. This has already been demonstrated with the development and export of, for instance, energy technologies. We will also strengthen efforts for Denmark bringing back knowledge in fields where other countries are frontrunners.

New solutions and exports of green technology can also benefit our economy and green jobs in Denmark. There are many good production jobs in the green industries in Denmark, in particular in rural areas. If we do it right, the higher focus on development of green technologies can therefore also contribute to a more coherent Denmark. We need that - not least in the light of the corona crisis. A clear green direction for the research and innovation effort, thereby, can contribute to supporting sustainable growth and new green jobs all over Denmark.

Backed by a united Parliament in the agreement on the allocation of research reserves for 2020 the government has given a boost to public appropriations for green research.

In the coming years, we must give priority to green research to support a long-term effort bringing us all the way to the targets of 2030 and 2050.

It is important to invest many funds in promising research fields. But it is also decisive that funds are invested in a way that they give the highest possible return on investment in view of attaining the political targets for our climate, environment, and nature at the national, European, and global levels; Investments should also promote the development of a sustainable society, a strong business community, and new green jobs as much as possible.

Therefore, the government will launch a mission-driven research effort making Denmark a frontrunner within the development of new green break-through technologies contributing to a reduction of emissions in Denmark and globally. With the wind turbine technology Denmark has shown that we are able to develop new solutions and create efficient markets that have driven costs down to a level where green energy is competitive with fossil energy.

Strong business community decisive for green transition

A strong business community supported by the right research and technology development along with a good framework for innovation is decisive to succeed with the green transition and attain the ambitious climate targets of Denmark. Companies play a vital role, partly through direct reductions of own emissions from production processes etc., and more importantly through the reductions that are attained through the development of greener products, technologies, services, and business models supporting the green transition in society at large - and in the rest of the world.

The Danish business community plays a vital role in promoting Denmark's global leadership within the climate agenda. Danish global green leaders can pull the world in a better direction by showing leadership and taking the lead in a more sustainable development of their industry and society at large.

The world market for green transition is on a steady increase these days. According to the International Energy Agency, there is a need for investments corresponding to at least DKK 90,000 billion up to 2030 just for meeting the national climate contributions of the parties to the Paris agreement. This is a unique opportunity for the Danish business community. To embrace it, we must establish a close interplay between knowledge institutions and companies - and whenever relevant, also the public sector. Denmark's Green Future Fund, which was established with a total capacity of DKK 25 billion, will give the entire market for green venture capital a massive boost and contribute to the development and dissemination of green solutions and technologies of the future, in Denmark and globally.

The government has entered a close cooperation with the business community in the form of thirteen climate partnerships and a Green Business Forum to focus on how the business community and the government can contribute jointly to solving the climate challenges in a way that supports Danish competitiveness, export, jobs, welfare and prosperity, and that does not lead to higher inequality.

In March 2020, the climate partnerships presented their recommendations with input to the government's climate action plan about which efforts can contribute to attaining

the target of reducing Denmark's carbon emissions by 70 percent in 2030 and making Denmark a frontrunner country in the world. The climate partnerships gave a number of recommendations regarding research and development needs, including recommendations for enhancing public-private cooperation in the form of, for instance, partnerships on research, innovation, development, and demonstration.

The climate partnerships recommended, among other things, to launch research, development, and demonstration efforts within Power-to-X, green fuels, carbon capture, storage or utilisation, energy efficiency, transportation and logistics, agriculture, etc. With this strategy key elements of these recommendations will be addressed.

Research as an important element in the government's climate action plan

During 2020 the government will prepare the first climate action plan. This work is ongoing. The government, backed by a broad majority of the Danish Parliament (the Liberal Party, the Danish People's Party, the Danish Social Liberal Party, the Socialist People's Party, the Red-Green Alliance, the Conservative People's Party, the Alternative, the Liberal Alliance and the Independent Greens) entered *Climate Agreement for Energy and Industry etc.* on 22 June this year. This climate agreement in combination with *Climate Plan for a Green Waste Sector and Circular Economy* of 16 June (the Liberal Party, the Danish Social Liberal Party, the Socialist People's Party, the Red-Green Alliance, the Conservative People's Party, the Alternative, and the Liberal Alliance) - make up the first part of the government's comprehensive climate action plan. With these agreements, it was decided to establish two energy islands with marine wind turbines, increase energy efficiency, ensure green heating for Danes, transition industry, and create a green waste sector. With the climate agreement, the government also reserves DKK 202 million for test turbines in 2022-2024 in order to enhance testing and development activities within renewable energy.

With the *Climate Agreement for Energy and Industry,* it was also agreed to focus on the green technologies of the future, including energy storage and conversion (Power-to-X) and carbon capture, utilisation, and storage - CCUS.

In addition to the plans for energy and industry and the waste management sector, the climate action plan of 2020 will contain strategies for key sectors such as agriculture and transportation.

Meeting Denmark's climate targets for 2030 and 2050 and the global effort for keeping global temperature rises within the objectives of the Paris agreement call for new solutions. Through research and development, we can improve and reduce costs associated with existing green technologies. But we must also develop new solutions making it possible to transition sectors in which it is still difficult and costly to reduce emissions.

International assessments call for strategic direction

In general, the Danish research and innovation system works well, however, international assessments have pointed at a number of challenges.

In its recommendations from November 2019 an international expert panel, which made a review of the Danish innovation system, indicated that Denmark needs a strategic di-

rection for our research and innovation efforts. The panel identified a need for a comprehensive national strategy and general targets for Danish research and innovation. The panel concluded that we are excellent at research in Denmark, but we can greatly improve our conversion of this research knowledge into innovation and concrete solutions. This is seen, among other things, in the fact that Denmark has not improved its innovation capacity significantly in recent years, whereas comparative countries have progressed.

In this connection, the panel also pointed out that there is a potential for enhancing the strategic implementation of funds in the Danish research and innovation system and that Denmark should develop new strategic instruments in the field of innovation. The panel indicated that the Danish system today primarily supports opportunities for financing of stand-alone projects at the expense of large, coherent, and long-term efforts with a focus on solving essential societal challenges. Against this background the panel recommended that we build on previous Danish experience with the development of new strategic instruments in the form of, for instance, platforms and partnerships that have a long-term perspective, cover more projects, and that can mobilise public and private players alike.

Another key recommendation of the international assessment of Innovation Fund Denmark from March 2019 is to turn strategic research into research that creates foundations, has a long-term perspective, is coherent, and builds capacity.

In order to realise our green ambitions it is important that the research and innovation system is designed in a way that is geared to create the largest possible impact - for the green transition and for future growth and jobs all over Denmark.

Strong Danish commitment in international cooperation on green research

With the Paris agreement and the UN Global Goals from 2015 a global agreement was entered on the need for changing direction and taking a greener path. All over the world people emphasise the need for innovative ideas and cutting-edge solutions contributing to meeting the global green ambitions. This creates new opportunities for a small open economy like the Danish one, where we compete, among others, on green knowledge.

In the EU, the green transition up to 2050 is a key focal point. The EU green growth strategy - the 'European Green Deal' - aims to transition the EU into a just and prosperous society with a modern, resource-efficient and competitive economy having by 2050 no longer net emissions of greenhouse gases and having attained a decoupling of economic growth from resource use.

Research and innovation - new technologies and sustainable solutions – become decisive in meeting the ambitions of the EU Green Deal. In the coming EU Research and Innovation Investment Programme Horizon Europe at least 35 percent of the budget is earmarked for climate-relevant activities. Under Horizon Europe a number of concrete research and innovation missions will be identified to outline a clear strategic direction for the future research and innovation effort, among other things within Smart Cities and Adaptation to Climate Change including Societal Transformation. EU programmes such as InvestEU, LIFE, and Innovation Fund are also relevant in the realisation of the Green Deal.

Moreover, Denmark should be a particularly attractive collaborator for countries outside the EU in the development and implementation of green solutions. Bilateral agreements in the research and innovation field, together with Danish innovation centres, can be door openers for cooperation with the most excellent and innovative environments in the world, facilitating access and visibility of Danish researchers and technology-based companies.

It is decisive that Danish researchers, companies, and authorities participate in the best and most promising international cooperations in the green field to achieve new knowledge, attract funding, and develop and commercialise green innovative solutions and technologies. This applies to the EU cooperation and the bilateral and multilateral global cooperation alike. When Danish authorities strive to accelerate the green transition in our partner countries, this cooperation should support research and development in the partner country and brand Denmark as a green entrepreneurial country with strong knowledge institutions.

Comprehensive national strategy for green research and innovation

With our ambitious targets for climate, environment, and nature the government has set a clear direction under which one of the key targets of Danish research and innovation efforts in the coming years will be to contribute to the green transition and, through this transition, support the green frontrunner position of the Danish business community to the highest possible benefit to exports and green jobs in Denmark.

With a new comprehensive national strategy, the government sets a long-term direction for green research, innovation, development, and demonstration in order that efforts support in the best possible way the green transition in Denmark and globally. It should also contribute to realising those targets for climate, environment, and nature set out by the government and the international commitments to be complied with in Denmark.

The strategy stands on two legs:

1. Designation of concrete missions for where it is most important that research and innovation efforts develop solutions in order to obtain the political targets for climate, environment, and nature
2. Launch of specific initiatives making a difference for research and innovation in the green transition

Thus, the purpose of the strategy is, firstly, to set out clear political prioritisations of the future efforts within research, innovation, development, and demonstration by pointing out those challenges and potentials that are most promising and where efforts need boosting. The strategy must contribute to the further developing of promising, existing green technologies and solutions, but also to the development of radically new solutions.

The strategy points out concrete green *missions* that will focus research and innovation efforts so we can accelerate developments of concrete solutions within fields such as

energy, industry, food production, agriculture, transportation, and environment. These missions will form the basis for knowledge institutions, businesses, authorities, and innovation players joining forces for ambitious and focused research and innovation efforts all while enhancing the frontrunner position of the Danish business community in the green field. The strategy also presents a number of topics describing the most essential research needs and potentials in the green field. These topics in a broad perspective may serve as the basis for thematic calls for green research funding in public programmes and funds - in addition to the funds prioritised for the four mission-driven partnerships. The topics may also form the basis for potentially identifying further missions in the coming years.

Secondly, the strategy has a number of concrete initiatives supporting that research and innovation make a difference in the green transition, strengthening the Danish business community, and creating more green jobs. The initiatives will contribute to building Denmark's research and innovation capacity in the green field, including strengthening of interdisciplinary climate research and international research cooperation and promotion of an efficient implementation of research and innovation financing from public programmes and funds, including strengthening of the knowledge base regarding impacts.

Overall, the strategy will promote coherent green research efforts ranging all the way from basic research to commercialisation of new solutions across public and private research-financed funds and programmes as well as education and research institutions, taking the research and innovation needs of the business community into consideration. The strategy will contribute to strengthening the interplay between knowledge institutions, companies, innovation players, and public authorities, so that research results are converted to new green solutions creating jobs in Denmark and being of the largest possible benefit to society.

1. Green missions

The ambition of the government is that Danish research will contribute to the solution of those challenges that are decisive for reaching the green transition goal.

Therefore, research must take its starting point in the most essential challenges to be solved within fields such as energy, industry, food production, transportation, environment, etc., while focusing on the political objectives. This is a recognition that is also reflected in research and innovation policies in the EU and in a number of other countries around the world.

We must concentrate on areas where Denmark can make a real difference. There is a need for focusing efforts, making them even more challenge-driven and mission-oriented than today.

1.1 Climate and environmental challenges

The government wants Denmark with renewed energy to take responsibility for developing the climate solutions of the future and to protect environment and nature. We cannot solve all challenges on our own. Therefore, we must choose those challenges where answers are most important in meeting Denmark's and the world's climate ambitions and protecting environment and nature. We must choose those challenges where we are in a particularly good position thanks to our research and industry strongholds to develop new technologies and create new industries, export opportunities, and green jobs.

Danish greenhouse gas emissions generally come from the energy sector, industry, transportation, and agriculture. To attain the target of a 70 percent greenhouse gas reduction by 2030 compared to 1990 levels and carbon neutrality no later than by 2050 we need a transition of all these sectors. After agreements on energy, industry, and waste, and an agreement on reductions with the cement manufacturer Aalborg Portland Danish greenhouse gas emissions must be reduced by a further 16.1 million tonnes CO_2e (CO2 equivalents) to attain the target of 2030.

Energy, industry

Greenhouse gas emissions from the energy sector in Denmark have decreased by 65 percent from 1990 to 2018; this is one of the main reasons for the historic drop in Danish greenhouse gas emissions. The remaining emissions in the energy and industrial sectors are expected in 2030 to be around 11 million tonnes of CO_2e, deriving primarily from private heat production and, most importantly, processes in industry. With the Agreement for Energy and Industry emissions from these sectors are further reduced by

2.7 million tonnes of CO_2e. In general, technical solutions for transitioning heat production are well known, whereas there are technological barriers for ensuring substantial reductions of greenhouse gas emissions in industry. In industry, some of the emissions can be reduced through energy efficiency measures, while another major share can be reduced through carbon capture technologies. Finally, the energy sector has the potential to support transition in other sectors, such as transportation, through technologies like Power-to-X in which green electricity is converted into green fuels.

Waste

Greenhouse gas emissions from waste management are expected to amount to around 2.3 million tonnes of CO2e in 2030; the largest share derives from waste incineration. With the sector strategy for waste the sector's emissions are reduced by a further 0.7 million tonnes of CO_2e. However, there is a need for researching how to design products causing a smaller plastic share in the waste as well as a maturing of technologies for carbon capture from waste incineration plants.

Transportation

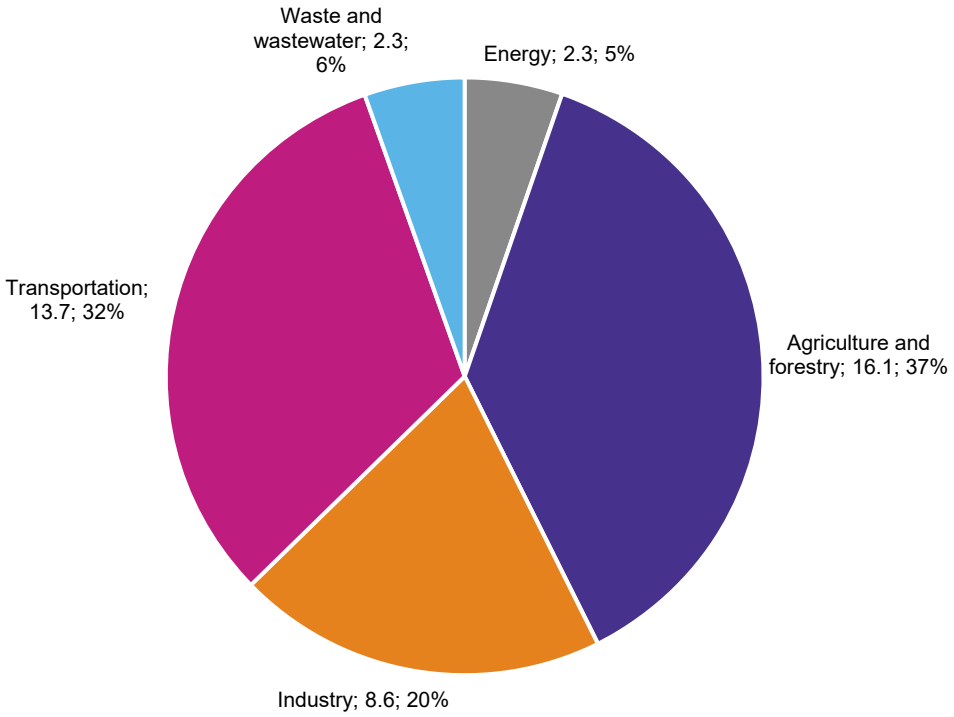
In 2030, the transport sector is expected to account for around 14 million tonnes of CO_2e of which road transport accounts for 92 percent of total domestic emissions; international maritime and air transport is not included in the Danish inventory. According to the most recent basic projection, we only expect a minor reduction in emissions from transportation up to 2030. It is characteristic for the transport sector that technological solutions for transitioning the sector are widely known, but that electric vehicles and renewable fuels are in general more expensive than fossil alternatives. To reach the target of this green transition of the transport sector there is a need for developing green fuels through Power-to-X.

Agriculture and forestry

Greenhouse gas emissions from agriculture and forestry are expected to remain largely unchanged in 2030 compared with today: around 16 million tonnes of CO_2e. Emissions derive from the cultivation of land, management of slurry, decomposition of fertiliser in the fields, and methane from ruminants. The sector is in general characterised by a lack of development of technologies for a substantial reduction of emissions from this sector. Technologies may comprise methods to reduce the methane production by ruminants or alternative products not based on livestock farming. For some of the emissions from this sector technologies are known, but a documentation of the effect of the measures is needed before implementation.

Figure 1.1 shows the projected distribution of emissions in 2030 before the impact from the agreement on sector strategies for energy and industry and waste that will lead to a total further reduction of Danish emissions by 3.4 million tonnes of CO_2e.

Figure 1.1
Total projected emissions in 2030, broken down on sectors, in million tonnes of CO_2e



Note: *The projected 2030 emissions include the most recent climate agreement from June 2020.
Source: Basic projection 2020 and Ministry of Climate, Energy and Utilities

Basic projection

The basic projection is a projection to 2030 of expected developments of emissions under the assumption that no new political measures are launched.[1] The most recent projection (BF20) includes policies adopted up to and including 1 May 2020.

Global pollution of, among other things, air, soil, and water, increasing exploitation of the resources of the Earth, and global climate change are challenging nature, environment, and public health. Also, Denmark and the world are in the midst of a biodiversity crisis caused by man-made pollution and exploitation of natural resources and habitats, global spreading of invasive species, and climate change. The intensive exploitation of the open land, forests, coastal zones, and marine areas has caused nature to be fragmented and continuously exposed to a number of stress factors, which means that biodiversity is on a constant decline.

[1] Primary drivers of emissions in the basic projection are demographic developments, economic growth, world market prices of fuels, and technological developments further to existing regulation and taxes.

1.2 Mission-driven efforts for development of green solutions

There is a need for a general prioritisation of green research to reach the goal of the green transition. However, there are other areas with a special need for a strategic approach to accelerate the development of green solutions to concrete challenges, and where Denmark is in a particularly good position to be a frontrunner and harvest the benefits on a growing global market for green transition.

During the spring of 2020, the Ministry of Higher Education and Science has mapped substantial green research needs and potentials along with business and research strongholds and potentials within seven topics. The mapping was conducted in a number of consultations involving ministries, higher educational institutions, government-approved research and technology organisations (GTS institutes), innovation networks and clusters, public and private funds, business and interest organisations, NGOs, and professional organisations, and the recommendations of the climate partnerships.[2]

Based on this mapping the government has identified a number of topics and four concrete green missions. The four missions will be the impetus for focusing and accelerating the research and innovation efforts and will constitute the framework for a multiannual effort in order that Danish researchers and companies are at the forefront when it comes to the development of new solutions and technologies driving the green transition (see initiative 2.1.2).

Green missions will constitute the framework for a coherent strategic effort covering the entire value chain from long-term basic research to capacity building over development, testing, and demonstration to commercialisation of green solutions closer to the market.

The concrete missions are to be accomplished by green partnerships in which all relevant knowledge institutions, businesses, public authorities, and private players etc. join forces in a joint research and innovation effort over several years.

The designation of the concrete missions has taken its starting point in the following criteria.

[2] The extensive knowledge basis can be found on www.ufm.dk/groenforskning (only available in Danish) .It gives a picture of the green research landscape in Denmark and its potential for contributing to the green transition.

Criteria for green missions

Green potential:
Focus on concrete challenges within sectors where the need for new solutions and the potential for meeting the green objectives are the largest in Denmark as well as on the global scale.

Business strengths and potentials:
Focus on challenges where the Danish business community has a strong position for developing green solutions along with a clear competitive advantage. A growing world market for green solutions, products, and services presents an opportunity for Danish researchers, companies, and entrepreneurs to turn challenges into new business opportunities and to expand their green solutions all over the world.

Research strength:
Focus on challenges where Danish researchers have strongholds and preconditions for entering cooperation and partnerships with researchers and knowledge institutions all over the world, bringing back knowledge and attracting research funding, in particular from the EU research programmes.

Partnership potential:
The missions must be suitable for being the starting point for green research and innovation partnerships with the opportunity for cooperation between universities, companies, government-approved research and technology organisations, authorities, etc. They must make the research and innovation efforts concrete and target-oriented, so it is possible to accelerate the realisation and scaling of the concrete results in relation to the green transition.

Every year the government will assess the need for launching new missions as well as the progress of the existing missions.

1.2.1 Government proposal for 2021 missions

The government proposes to prioritise four missions with DKK 750 million in 2021. This decision is based on a total assessment of the largest need for new solutions and potentials for reducing greenhouse gas emissions and creating improvements for environment and nature in Denmark and globally; this is combined with Danish research and business strengths and potentials as well as the potential for these missions to form the basis for green research and innovation partnerships.

These are also areas where the potentials for research and innovation supporting the government's overall climate efforts are the largest and where it can contribute to meeting the objectives of the Climate Act of a 70 percent reduction of greenhouse gas emissions in 2030 compared with the 1990 level as well as carbon neutrality no later than by 2050. In addition, these are areas where the climate partnerships of the government and the business community have recommended to act with research, development, and demonstration efforts.

Therefore, the government proposes to prioritise four green missions in 2021:

1. **Carbon capture and storage or utilisation**
   Development of cost-effective solutions for carbon capture and storage that can be used to reduce carbon emissions and create negative emissions from large industrial emitters, waste incineration plants, biogas plants, and biomass based combined power and heating plants. Together with hydrogen from renewable energy the captured carbon can supply carbon for new climate neutral solutions.

2. **Green fuels for transportation and industry (Power-to-X etc.)**
   Development of solutions to convert electricity from renewable energy to products that can be used to reduce emissions from parts of the transport and energy sectors where there are no existing cost-effective alternatives to fossil energy.

3. **Climate and environment-friendly agriculture and food production**
   Development of technologies and solutions significantly reducing climate and environmental impacts from conventional as well as organic food production and agriculture, including emissions from livestock, fertilisation, and land reducing derived effects on nature. This may be through technologies and more circular and sustainable solutions regarding carbon sequestration in soil and forests, bio-refining including pyrolysis, new food and feed products with smaller carbon footprints, plant breeding, and support of knowledge needs in relation to efficient regulation, including documentation of emissions.

4. **Recycling and reduction of plastic waste**
   Development of new technologies and manufacturing methods making way for waste reduction and better sorting and recycling of plastic waste into new plastics products. Development of plastic-containing products designed for reuse or recycling, with regard to chemical composition of feedstock and additives and the composition of materials in each product.

1. Carbon capture and storage or utilisation (CCUS)

To meet Denmark's climate targets and the global objectives of the Paris agreement we need to reduce carbon emissions from industrial processes such as cement and steel and to make it possible to store carbon from renewable sources, thereby removing carbon from the atmosphere or using it in new climate-neutral fuels or materials.

Therefore, there is a need for developing cost-effective solutions for carbon capture from large industrial emitters, waste incineration plants, biogas plants, and biomass based combined power and heating plants, or directly from the atmosphere. We also need solutions to store carbon safely and permanently and to use carbon from renewable sources in new climate-neutral solutions.

It is assessed that in 2030-2040 there will be a potential for capture and storage or utilisation in the magnitude of 4-9 million tonnes[3] from Danish carbon emitters (there is an overlap with the potential for Power-to-X, since carbon can be both stored and utilised, for instance in Power-to-X products). The potential for storage in the Danish underground is assessed at 22 billion tonnes of CO_2; there is thereby an opportunity to store CO_2 from other countries. Research and development efforts must contribute to making carbon capture cheaper; this is a precondition for storage and utilisation. And it must contribute to the development of a cost-effective, safe, and environmentally acceptable infrastructure for the transportation and storage of CO_2.

Well-established Danish research environments on CCUS exist at several research institutions. There are few, but essential Danish business strengths and good preconditions for storing carbon from other countries. A growing global market is expected on which Danish companies can prevail. Potential partners for the development of a Danish CCUS industry are the present oil industry, the transport sector, the cement industry, the refineries, waste incineration plants, and other energy-intensive companies.

2. Green fuels for transportation and industry (Power-to-X etc.)

Without a focused effort, especially within heavy land, maritime and air transport, and some parts of industry, it is not assessed to be possible to base Denmark's energy system in 2050 100 percent on renewable energy.

Solutions must be developed for producing new green fuels. This may be done, for instance, by converting electricity from renewable energy to products that can be used to reduce emissions from parts of the transport and energy sectors where there are no existing cost-effective alternatives to fossil energy. The potential for carbon reductions from Power-to-X is large. Theoretically, it can replace all fossil fuels provided that enough renewable electricity, and maybe also carbon, is accessible. It is assessed that we have a long-term technical reduction potential of 1.5-7.5 million tonnes, of which 1-4 million tonnes in international maritime and air transport (that does not count in the Danish inventory of greenhouse gas emissions). Up to 2030, the technical domestic potential is assessed at 0.5-3.5 million tonnes of CO_2 (there is an overlap with the potential for CCUS, since carbon can be both stored and utilised, for instance in Power-to-X products, cf. above).[4]

The demand for green hydrogen and other Power-to-X products is not sufficient for having a market-driven expansion, neither in Denmark nor abroad. This may be due to the fact that large costs are associated with the production, so the price of the green hydrogen and other hydrogen-based products will be relatively high compared with fossil alternatives. There is a need for focused research, development, and demonstration efforts to bring these sub-technologies to a level of technological maturity allowing for

[3] The reduction potentials are general, uncertain assessments of the technical options for reducing greenhouse gas emissions with the stipulated technologies. Costs of technologies have not been considered in the assessment of these technical potentials, only what is in theory technically possible and theoretically feasible by 2030. This potential is associated with high uncertainty when it comes to effect, documentation, and potential for dissemination. Therefore, reservations are made as to the realisation of this potential. The estimates cannot be summed up due to several possible overlaps. Launching the research missions does not necessary mean realising the reduction potentials, cf. Appendix 1 (only available in Danish).

[4] This potential is associated with high uncertainty when it comes to effect, documentation, and potential for dissemination. Therefore, significant reservations are made as to the realisation of this potential. The estimates cannot be summed up due to several possible overlaps. Launching the research missions does not necessary mean realising the reduction potentials, cf. Appendix 1 (only available in Danish).

commercial use, just as there is a need for demonstrating how Power-to-X systems can be integrated in the overall energy system, for instance in the heating sector.

Denmark can build on a strong research tradition within hydrogen and electrolysis, as we have research environments at several universities. There is a major potential for a Danish business stronghold within Power-to-X. Business strengths within green energy technology, maritime industries, transportation and logistics, chemicals, etc. allow for building partnerships covering the entire Power-to-X value chain.

3. Climate and environment-friendly agriculture and food production

Greenhouse gas emissions from agriculture and food production make up a significant and growing share of Denmark's and the world's climate impacts that is not expected to change much with the agreed policies up to 2030. Agriculture and forestry, without new measures, are expected to account for some 37 percent of Denmark's total greenhouse gas emissions in 2030. At present there are a number of known instruments here that can produce an effect, but today no known instruments can reduce the greenhouse gas emissions significantly without major consequences for production and income. In addition, there is a challenge regarding the environmental and nature impacts from agriculture, including a further reduction of nitrogen and ammonia emissions and the associated impacts.

Hence, in the field of agriculture and food there is an urgent need for new cost-effective technologies and instruments to reduce emissions of greenhouse gases and increase sequestration of CO2, for larger focus on circular and sustainable solutions, and more precise knowledge about the correlation between existing agricultural activities and the level of emissions. The latter is a decisive precondition for a true and fair inventory of the sector's emissions, and also for a true and fair basis for a cost-effective regulation of the sector that takes a cross-cutting approach to climate and environment challenges.

A number of new technologies and solutions are being developed; some of the research projects within feed additives, slurry additives, and bio-refining have shown some potential. For instance, one of the most promising feed additives has demonstrated the potential for reducing methane emissions from dairy cattle by some 35-40 percent. Research is also ongoing in an additive for slurry that will potentially reduce emissions of methane from stables and stores by up to 50 percent. Finally, within bio-refining there is a major reduction potential, including from the pyrolysis process that converts biomass into bio-coal, oil, and gas. The Technical University of Denmark assesses, with considerable uncertainty, that the carbon sequestration from bio-coal has a technical reduction potential of up to 6 million tonnes.

When you burn one litre of petrol, you know how much CO_2 is released. However, the loss of methane and nitrous oxide from agriculture depends on the feed, management, choice of crop, stable systems, slurry management etc. Here we do not have the research basis to make a differentiation. For cost-effective measures to be designed, we need research in emission factors. It should be noted that the mentioned technical reduction potentials at the present time are subject to large uncertainty regarding effect, documentation, and potential for dissemination.

There are competences within agriculture and food research of very high quality at several universities, but the capacity is limited; it is decisive to uphold and strengthen the capacity, so the research needs in the climate and environment fields of the coming years can be met.

Denmark has an internationally competitive agriculture and food sector with focus on sustainability and climate efficiency. In the sector it is recognised that in the coming years there must be more focus on research and innovation as well as use of new technologies that can reduce carbon emissions and promote the development of new sustainable food, production methods, feed types, and ingredients. The sector has itself set a target of climate neutrality in 2050.

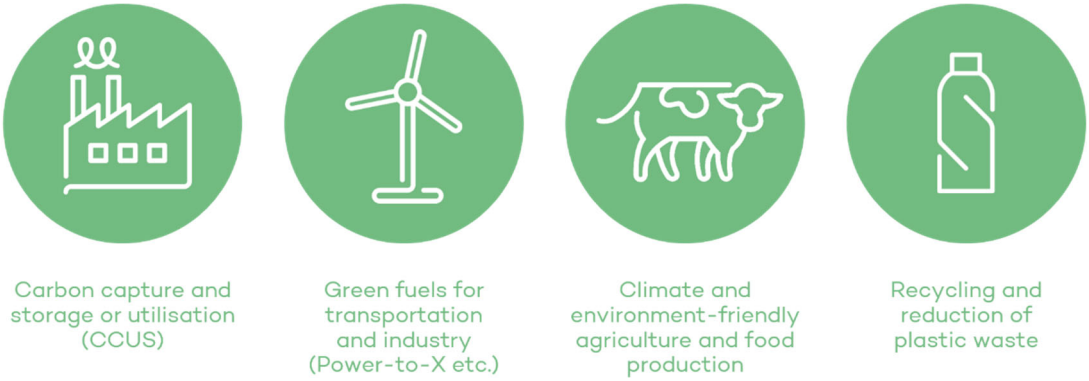
4. Recycling and reduction of plastic waste

More plastic must be reused and recycled, the amount of plastic waste must be reduced and environmental and climate impacts must be curbed. There is a special need for solutions ensuring tracing, sorting, and recycling of plastics as well as a reduction of plastic waste. Technologies and solutions giving a high quality recycling and a small loss of materials along with sorting, reprocessing, and recycling of plastic-containing textiles are assessed to potentially reduce amounts of plastic and fossil textile waste by around 53,000 tonnes on top of the reduction following from the *Agreement on a Green Waste Sector and Circular Economy*. If this further quantity is removed from waste incineration, Denmark will attain the objective of diverting 80 percent of plastic waste from incineration in 2030; this will cause a reduction of CO_2e from waste incineration by approx. 0.15 million tonnes of CO_2e in 2030. [5]

At the Danish universities, we have today many competences within life cycle assessments, environmental considerations in product development, consumer behaviour, waste and recycling, etc. Research within plastics takes place at several research institutions. The present research capacity must be strengthened to match the challenge to be faced in Denmark when it comes to plastics. Among Danish companies, the first steps towards introducing circular solutions are being taken, and there is already a large sector within traditional linear design, production, and sale of products of plastic and textile with a major potential for circular business models. Thereby, there is a potential for creating a new business strength, but today there is no well-established industry within the recycling of plastic waste.

[5]This potential is associated with high uncertainty when it comes to effect, documentation, and potential for dissemination. Therefore, significant reservations are made as to the realisation of this potential. The estimates cannot be summed up due to several possible overlaps. Launching the research missions does not necessary mean realising the reduction potentials, cf. Appendix 1 (only available in Danish).

Figure 1.2
The government proposes to prioritise four green mission in 2021



1.2.2 Topics for green research efforts

Based on the mapping of green research needs and potentials seven topics for the green research efforts have been identified. These topics may serve as the basis for the political prioritisation of funds in connection with agreements on the allocation of research reserves, and they can serve as a basis for thematic calls for green funding in public programmes and funds in addition to the funds prioritised for the mission-driven partnership appropriations, cf. Table 1.1. The topics may also form the basis for potentially identifying further missions in the coming years. The topics of the strategy are described in detail in Appendix 1 (only available in Danish).

Table 1.1
Outline of topics and missions

Topics	Examples of research needs	Missions
Energy production etc.	Carbon capture from point sources or the atmosphere	Carbon capture and storage or utilisation
	Carbon utilisation for climate-neutral products	Green fuels for transportation and industry (Power-to-X etc.)
	Carbon storage	
	Hydrogen production	
	Green fuels and materials for transportation and industry	
	Intelligent solutions for integration of renewable energy	
	Cost-effective renewable energy technologies for energy production	
Energy efficiency	Optimisation of production processes and systems	
	Energy efficient building and renovation	

Topics	Examples of research needs	Missions
Agriculture and food production	Sustainable animal production Climate, environment, and nature friendly cultivation systems Sustainable proteins	**Climate and environment-friendly agriculture and food production**
Transportation	Climate friendly transportation and logistics Optimisation of transport capacity and infrastructure Transition of heavy transport, international shipping, and air transport	**Green fuels for transportation and industry (Power-to-X etc.), cf. mission under Energy**
Environment and circular economy	Sustainable water resources and technologies Clean maritime environment Air pollution Sorting, recycling, and reduction of waste Recycling of textiles Circular economy	**Recycling and reduction of plastic waste**
Nature and biodiversity	Effects of instruments for preservation, restoration, and management of nature and biodiversity Ecosystem dynamics Climate change and adaptation, including in the Arctics	
Sustainable behaviour and societal consequences	Sustainable behaviour Societal consequences of green transition	

2. Initiatives

The Danish research and innovation efforts must support the green transition as much as possible and promote a sustainable green business community. For this to happen we must strengthen Denmark's research and innovation in the green field.

Therefore, the government presents a number of concrete initiatives:

New initiatives

- An ambitious green research and innovation effort
- Green research and innovation partnerships
- Enhanced green focus for Innovation Fund Denmark
- Better coordination of green research
- Better framework for cooperation between knowledge institutions and the business community
- Strong Danish participation in international cooperation
- Monitoring and impact assessments of green research
- National Centre of Climate Research
- Green study programmes

Initiatives launched

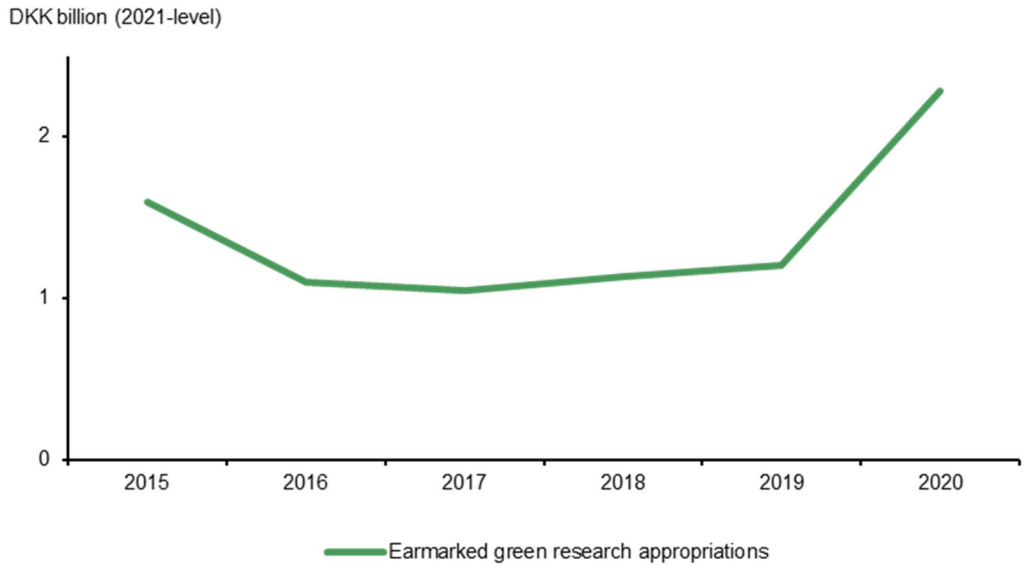
- Denmark's Green Future Fund
- New technologies for a greener Danish business community
- New cluster organisations
- Roadmap for research-based public sector consultancy
- Green perspectives in space
- National robotics strategy
- Roadmap for research infrastructure 2020
- ESS Strategy 2.0

2.1 New initiatives

2.1.1 An ambitious green research and innovation effort

Together with a united Parliament, the government decided in the agreement on the allocation of research reserves for 2020 to give a boost to public appropriations for green research.

Figure 2.1
Earmarked green research appropriations 2015-2020



Source: Ministry of Higher Education and Science

In the coming years, there is a need for continued ambitious research and innovation efforts in the green field, if we are to realise the green transition and attain the 2030 and 2050 climate targets. Therefore, the government intends to maintain the level of green research funds at least at the 2020 level corresponding to DKK 2.3 billion in the coming years. In addition, in connection with the 2021 Finance Bill and as part of the restart of the economy the government has proposed to increase the funds earmarked for green research in 2021 to a level exceeding the historic high level of 2020.

2.1.2 Green research and innovation partnerships

Green partnerships are a new instrument in the research and innovation policy. The objective of partnerships is to gather all relevant stakeholders from research, the business community, and authorities to undertake a long-term and strategic multiannual research and innovation effort contributing to bringing Danish researchers and companies at the forefront when it comes to the development of new solutions. The aim is to focus research and innovation efforts all the way from basic research to commercialisation in order to accelerate the pace of development of new solutions within areas

with particularly promising perspectives for Denmark. The goal of the green partnerships is to accomplish the *missions* set out in the green research strategy. Results and concrete solutions are to promote the green transition and contribute to the competitiveness of companies and the development of new green jobs in Denmark. Innovation Fund Denmark, in coordination and dialogue with other relevant stakeholders, including Denmark's Green Future Fund, will be in charge of the implementation of the appropriations for the mission-driven partnerships that are distributed in open calls.

2.1.3 Enhanced green focus for Innovation Fund Denmark

Innovation Fund Denmark plays a key role as the implementing fund for public strategic research and innovation funds open to competition. When turning the challenges we are facing as a society - the climate challenge in particular - into new solutions and business opportunities it is decisive that Innovation Fund Denmark has the best possible framework for assuming this role. Therefore, the government proposes to adjust the legal basis for Innovation Fund Denmark, so that the Fund has a clear green mandate as the key player that is to realise the political priorities in the implementation of funds for research and innovation contributing to the green transition.

2.1.4 Better coordination of green research

The implementation of the government's green research strategy will be discussed annually with the Green Business Forum, including progress in research and innovation efforts and possible future prioritisation. The government will work to strengthen dialogue and cooperation between the players in the green field, including the research-financed funds, education and research institutions, and the business community. The aim will be to create a common direction and a more coherent green effort across the value chain from basic research to commercialisation of new solutions.

2.1.5 Better framework for cooperation between knowledge institutions and the business community

The Ministry of Higher Education and Science and the Ministry of Industry, Business and Financial Affairs will jointly launch an initiative concerning the framework for cooperation between knowledge institutions and companies in the field of innovation. The aim is to even more turn Denmark's strong knowledge and research position into innovation, growth in companies, attractive investment options, and more high-productive jobs all over the country. This work will build on the recommendations from the international panel that evaluated the Danish innovation system in 2019. It will, among other things, look at the framework for commercialisation of research results and the strengthening of an entrepreneurial culture among researchers and students. The work will support the government's climate action plan and green research strategy by supporting the conversion of green research into new green solutions that are brought into real life.

2.1.6 Strong Danish participation in international cooperation

The green transition calls for strong international research and innovation cooperation. International cooperation enhances the quality of Danish research; it gives access to cutting-edge knowledge, financing, and talents outside the borders of Denmark. Moreover, the Danish research strongholds and Danish solutions and technologies capable of coming into play in the global green transition are made visible.

To strengthen Danish participation in international research cooperation contributing to the realisation of the political targets for climate, environment, and nature the government plans the following measures: 1) Preparation of an action plan supporting a quick kick-off in Denmark when the next seven-year programme period in the EU (Horizon Europe) starts in 2021, 2) Support to a more strategic and coordinated approach to Danish commitment in global and European research and innovation partnerships that often presuppose national co-financing, and 3) Enhancement of the cooperation of Danish stakeholders with global players in the hotspots where environments are strongest within Danish green research and innovation priorities, among others through the Danish innovation centres.

2.1.7 Monitoring and impact assessments of green research

A solid data and analysis basis is needed to monitor and assess the impact of the green research effort and to enhance the decision-making basis for the political choices to be made. Therefore, the government will strengthen the work of building knowledge and analytical capacity to support the research effort, so that it contributes to the best possible extent to attaining the political targets in the field of climate, environment, and nature. The Ministry of Higher Education and Science will coordinate this work with involvement of experts from the universities.

2.1.8 National Centre of Climate Research

The government will continue and strengthen the National Centre of Climate Research (NCKF) in view of supporting an efficient green transition and climate adaptation effort in all of the Kingdom of Denmark and making Denmark an international frontrunner within climate research. In the future, NCKF must strengthen the climate science foundation by researching in the most critical research fields, gathering knowledge, and pooling climate research in the Kingdom of Denmark through research cooperation across universities, knowledge institutions, public agencies, and decision makers. NCKF will help making the latest climate research easily accessible for decision makers and citizens so the civil society can address climate change in the best possible and economically most advantageous way.

2.1.9 Green study programmes

Higher education plays a vital role in the green transition. Through solid education, we create a strong foundation for having competent researchers and other staff members at our research and knowledge institutions, in the companies and the public sector etc. They are all to create new knowledge and convert this knowledge into concrete green results that make a difference and pave the way for a greener and more climate-friendly society. The government finds it important that the food chain from university graduates to researchers and staff members in companies and the public sector interplays optimally with the green transition. Therefore, the government will focus on how to support and strengthen the coherence between our study programmes and the green transition.

2.2 Initiatives launched

In addition to the new initiatives presented in the strategy, the government has recently launched a number of initiatives also supporting green research and innovation.

2.2.1 Denmark's Green Future Fund

The establishment of Denmark's Green Future Fund was decided in the Finance Act for 2020; the Fund is to contribute to a national and global green transition, including development and dissemination of new technologies, conversion of the energy systems to renewable energy, storage and efficient use of energy, etc., and it will promote a global export of green technology. The Fund will also contribute to solving the challenges caused by climate change and a growing world population in the form of food and water shortage. The Fund will give the entire market for green venture capital a massive boost and contribute to the development and dissemination of green solutions of the future, in Denmark and globally. This applies from development over commercialisation (primarily Vaekstfonden - the Danish state's investment fund), to scaling of production (Vaekstfonden and the Danish Green Investment Fund) and global dissemination (Denmark's Export Credit Agency and the Investment Fund for Developing Countries). Denmark's Green Future Fund will be established with a total capacity of DKK 25 billion that is to be invested on market terms with a view to delivering a positive long-term yield return.

2.2.2 New technologies for a greener Danish business community

The seven government-approved technological service organisations (GTS) deliver technological services to around 16,000 Danish companies and 1,000 public customers a year. The GTS have for many years helped companies implementing new knowledge and technologies in their products and services. In the coming years, the GTS are to have special focus on the development of services contributing to a green transition of Danish companies. The Ministry of Higher Education and Science will therefore in payment by performance contracts with the GTS for the period 2021-2024 have special focus on the GTS's role in strengthening the green transition and innovation in Danish companies.

2.2.3 New cluster organisations

As from 2021, the Ministry of Higher Education and Science together with the Danish Board of Business Development will distribute funds to twelve new national cluster organisations and a number of emerging cluster organisations. The core task of the new cluster organisations will be to contribute to innovation in an interplay between research and knowledge environments, companies, and other relevant stakeholders. It is a stand-alone ambition for the cluster organisations that they contribute to a green and climate-friendly transition of companies and society.

2.2.4 Roadmap for research-based public sector consultancy

The Ministry of Environment and Food launched in November 2019 together with the universities of Aarhus and Copenhagen and the Technical University of Denmark the preparation of a roadmap of research work to support core tasks in the field of environment and food, in particular within climate transition at the national and international

levels in the period 2020-2030. The purpose was to create a stronger strategic focus on long-term essential priorities in the working fields of the Ministry of Environment and Food.

The purpose of preparing a roadmap for research-based public sector consultancy is to bring about a common understanding of the following issues:

- Professional objectives for the next ten years in the fields of environment and food
- The most important priorities for research efforts for the next ten years
- Potential funding options in the fields of environment and food, so the Ministry in cooperation with the universities become better at attracting relevant funding

This roadmap is a supplement to the green research strategy; it clarifies the research efforts that are to support the missions and topics of the strategy in the fields of environment and food.

2.2.5 Green perspectives in space

Space infrastructure is a significant element of the green transition, for instance when it comes to monitoring of reduction targets, earth observation and satellite navigation data, or development of solutions for transition of heavily emitting sectors such as agriculture and transportation. The Interministerial Space Committee has started an update of the objectives of the national spatial strategy so they contribute better to solving the challenges associated with climate, nature, biodiversity, and environment and enhance the use of European spatial infrastructure to support the green transition in Denmark and at global level.

2.2.6 National robotics strategy supporting a sustainable Denmark

In February 2020, the government launched a national robotics strategy with the aim to support Denmark in realising fully the potentials associated with the development and use of robots, including how robotics technology can support the development of a more sustainable Denmark.

2.2.7 Roadmap for research infrastructure 2020

In 2020, the Ministry of Higher Education and Science will prepare a new roadmap for research infrastructure presenting a catalogue of proposals for national research infrastructures within all subject areas. This catalogue will form the basis of the Ministry's investments from its Fund for Research infrastructure in the period 2020-2023. The roadmap will make way for a research infrastructure that can support a green transition of society.

2.2.8 ESS Strategy 2.0

The European research facility European Spallation Source (ESS), which is being established in Lund in Sweden and in Copenhagen, will be the world's largest and most sophisticated neutron scattering facility. ESS is a large and very sophisticated microscope that makes it possible to study the inner structure and dynamics of materials and to produce new opportunities for scientific discoveries. The Danish ESS strategy

2.0 describes how Denmark can harvest the full benefit of being an ESS co-host. It is a key target that ESS and the other materials research facilities established in the vicinity of Denmark can contribute to the development of new materials to be used in climate-friendly technologies.