# White paper on solutions to mitigate climate change and assessment of Danish Strongholds

Innovation Fund Denmark's Climate Solutions Panel

Innovation Fund Denmark

Copenhagen Institute for **Futures** Studies
Instituttet for Fremtidsforskning

# Welcome

This white paper is a product of the Innovation Fund Denmark's Climate Solutions Panel, which met during the summer of 2019. The work, carried out in partnership with the Copenhagen Institute for Future Studies, aimed at exploring and selecting plausible solutions to mitigate climate change. In addition, it identified Danish Strongholds relevant to these solutions, assessing their relevance, utility and potential for widespread adoption in the face of the climate crisis. The Panel's discussions centred on consideration of those initiatives it would be most appropriate for Denmark to pursue.

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Last edited 13.11.19

# 01 Introduction

# Introduction

The science is clear, the debate is picking up pace and the political ambition has increased. Climate change is now part of our daily conversation, even featuring in the annual reports of the world's largest companies. Yet, knowledge and intentions alone will not solve the problem. In order to curb, or even prevent, the changes and effects foreseen by scientists, we need to act on every level: as citizens, as organisations and as nations. In short, we need to rethink how we organise our society.

Research and innovation is at the forefront of finding new solutions to a problem we have created and exacerbated over many decades. However, as suggested by the Danish political agreement on 2020 research investments in green transformation, this work has to be combined with raising awareness and behavioural change, enabled and supported by robust policy and commitment at the highest level. Actors across all sectors and industries need to collaborate, working to mitigate the effects of climate change across all their activities, both locally and globally.

Innovation Fund Denmark creates a framework for entrepreneurs, researchers and businesses so that they can develop innovative and viable solutions to society's challenges. The climate crisis presents one of the most urgent and compelling of these challenges.

In assembling the Climate Solutions Panel, we aimed to create and facilitate a dialogue across academia, business, NGOs and policymakers. The ultimate objective was to identify solutions that draw on Danish strengths and innovation. While Denmark's own $CO_2$ emissions are proportionately low, accounting for 0.1% of the global total, we are of the view that any solutions we implement should have the potential to positively contribute on a global scale.

The Danish parliament has decided to entrust the Innovation Fund Denmark with almost 800 million DKK in 2020 to finance research and innovation projects with the potential to combat climate change and enable a more sustainable society. Together with the political mandate, the conclusions from the Climate Solutions Panel will serve to guide the Fund and its many collaborators as they seek to identify the most effective solutions.

When humankind first stepped on the moon, hope and inspiration fuelled the innovation that led to this remarkable feat. The following pages present the key findings of the Panel's work and are intended to serve as inspiration for Innovation Fund Denmark's future investments on climate change mitigation. They illuminate the way to realising the government's ambitious targets for 2030 and beyond.

*Daria Krivonos and Tore Duvold*



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# A call for action

Concern about climate change has been voiced by scientists for decades and has now gained widespread acceptance and political priority. The debates regarding the risk to climate stability and humankind's responsibility for it have subsided. They have given way to discussions about actions to take, how, when and by whom they should be taken.

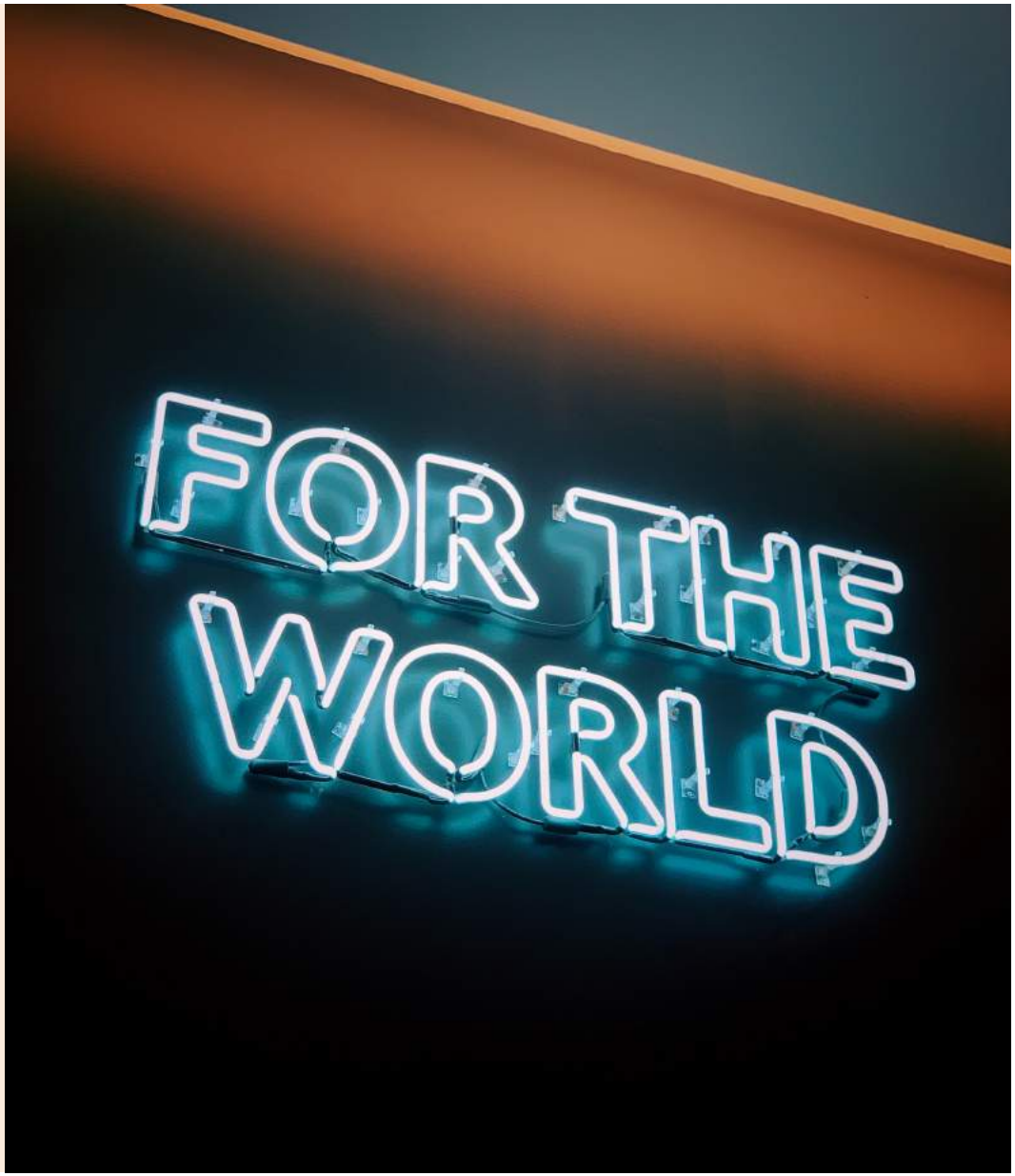
There is a strong global focus on how quickly climate change mitigation can be implemented in order to meet the goals of the Paris Agreement. This includes keeping the global temperature rise below 2 degrees above pre-industrial levels during the present century, with an aspiration to lower the target further to 1.5 degrees. The Danish government's aim to reduce emissions by 70% by 2030 bears witness to this development.

Globalisation, economic growth and demographic development have all contributed towards human progress while simultaneously taking a toll on our ecosystem. No single country, sector or consumer group alone can solve the climate change challenge. The interconnectedness of the global economy, our need for energy to fuel growth and the right of all people to seek to improve their livelihood and meet their needs, all contribute to the complexity of both the climate crisis itself and the steps that can be taken to mitigate it.

Stabilising global climate change in accordance with the Paris Agreement is a systemic, global and intergenerational challenge that requires cross-border, cross-sector, multidisciplinary solutions at an unprecedented scale. The urgency to find solutions will require collaboration between business, science, energy, agriculture, transportation, industry, and infrastructure, requiring alignment with a broad range of economic, societal, and environmental sustainable development goals. This will entail the adoption of low carbon technologies and production processes, as well as universal behavioural changes.

Danish climate change innovation and solutions are at the forefront of the development towards a low carbon society. Future technological innovation, in addition to the design and implementation of policies and regulations, will further accelerate Denmark's transition to a low carbon society that can serve as a beacon for others to follow. This move will serve as the basis for green Danish exports, enabling Danish innovation to play a role in the global climate change mitigation efforts.





01 Introduction

# The Innovation Fund Denmark Climate Solutions Panel

The Climate Solutions Panel was comprised of a multidisciplinary team representing academia, industry, businesses, regulatory bodies and others with a vested interest in the climate agenda. A full list of participants is provided in Appendix X4.

The Panel's overarching objective was to identify research and innovation initiatives and cross-sector, collaborative partnerships that will enable Denmark to undergo a transition to a low carbon society, taking an international lead in climate change mitigation. Ultimately, the Panel's findings will help guide Innovation Fund Denmark's annual investments in excess of 1 billion DKK.

The Panel explored the following questions relating to **plausible solutions, initiatives, and current strongholds**:[1]

What areas of technology and innovation could prove to have the biggest impact while overcoming existing barriers?[2]

What business models, collaborations, and regulatory frameworks could support these innovations in achieving their potential and enabling Denmark to spearhead and champion efforts to mitigate global climate change?

Where is Denmark already well positioned to shape and guide progress towards and beyond 2030 global climate change objectives?

It is important to note that while the Panel highlighted a broad range of current and future technologies, systems and regulatory frameworks, the very nature of innovation leaves room for new discoveries and progress not yet identified. It is with these nascent initiatives, that Innovation Fund Denmark can play a significant role, through timely detection, investments, and support.

*1. For a full overview of the process of the panel's work during summer 2019, please see appendix X3.*
*2. For a full overview of the 62 Plausible Solutions see appendix X1. For detailed descriptions, see Plausible Solutions Catalogue at https://innovationsfonden.dk/sites/default/files/2019-11/innovations-fund-denmark-climate-solutions-panel-updated-plausible-solutions.pdf*



# Danish position and potential

Areas where Denmark is a global leader were identified and assessed in relation to strengths in:

- technology and knowhow
- commercial maturity,
- regulatory framework.

The excellence of Danish expertise and innovation can be put in service of the global climate efforts, as well as generating additional economic and social benefits for Denmark.

The Panel assessed solutions with the potential to have achieved widespread implementation by 2030 and beyond.[3] The solutions and the Danish Strongholds that were identified were grouped into three categories.

**Explore, support and grow.** Solutions where Denmark has strong technology and knowhow. However, these are early stage solutions, so commercialisation and exporting remain a challenge. These solutions can be developed by further investments and research, and through improvements to the regulatory framework that can drive growth.

**Nurture and defend.** Solid technological solutions that have attained a degree of commercial maturity and exportability, and should be maintained and defended on the international market. Further development requires regulatory support, enabling businesses that develop these technologies to remain competitive on a global scale.

**Follow and adopt.** Solutions (such as electric vehicles) with substantial potential for future success in mitigating climate change. Denmark has limited or no competitive position on either technological knowhow or existing businesses. These solutions may well be part of the mix in Denmark's own pursuit of decoupling the economy from emissions, but the market for deployed solutions is likely to be dominated by other countries.



*3.The full mapping of the panel assessment can be found in appendix X2.*

| | *Explore, support & grow* | *Nurture & defend* | *Follow & adopt* |
|---|---|---|---|
| **Industry Energy & Materials efficiency** | - Alternative Cement<br>- Circular Economy<br>- Data, AI, IoT | - Industrial Energy Efficiency<br>- Heat Pumps<br>- Water Distribution<br>- District Heating | - Waste & Recycling<br>- Refrigerant Recycling<br>- Bioplastic<br>- CCU |
| **Energy & Storage** | - Power2X<br>- Grid Flexibility | - Wind (offshore)<br>- Wind (onshore)<br>- Sustainable Biomass<br>- District Heating<br>- Methane Digesters<br>- Cogeneration | - Storage<br>- Solar Farms |
| **Alternative Fuels & Transportation** | - Power2X*<br>- Pyrolysis to Jetfuel<br>- Biofuels (2nd generation)* | - Maritime & Propulsion Technologies<br>- Bike Infrastructure | - Mass Transit<br>- Autonomous Vehicles<br>- Electric Vehicles<br>- Ridesharing |
| **Smart Buildings & Cities** | - Data, AI, IoT* | - Smart Buildings<br>- Smart Windows<br>- Insulation<br>- Water Saving<br>- Smart Thermostats<br>- Heat Pumps* | - LED Lighting<br>- Autonomous Vehicles*<br>- Electric Vehicles* |
| **Sustainable Agriculture & Food value chains** | -Protein Upgrade<br>-Biofuels (2nd generation)<br>-Livestock Feed<br>-Biochar<br>-Microbial Farming<br>-Lab Grown Meat | - Reduced Food Waste<br>- Crop Optimisation<br>- Efficient Agriculture<br>- Precision Farming | - Plant-Rich Diet<br>- Forestation<br>- Ocean Farming<br>- Vertical Farming |

* Some solutions are central to success across several areas, even though they were mainly discussed within a specific initiative.

Please note that overall solutions have multiple sub-solutions and technologies that were not assessed directly. Some Danish initiatives may form an important part of a solution value chain, while not driving the overall progress within that solution.

# Executive summary: cross-sector initiatives

In order to leverage synergies, solutions need to be connected systemically across sectors and players. If the challenge resides within the complex global ecosystem, then the solution design has to mirror this complexity. In order to address this, key initiatives were identified, encompassing a number of relevant supporting solutions. The following reflects five distinct initiatives, which could pave the way towards greater collaboration and have high impact:

**Industry energy & materials efficiency.** Industrial processes form the backbone of many goods and services. However, they are also a large source of GHG emissions and materials use. Transitioning from fossil fuels, increasing process efficiency, improving waste management and limiting materials use (or extending their life cycle) are all potential climate preserving solutions within industrial processes.

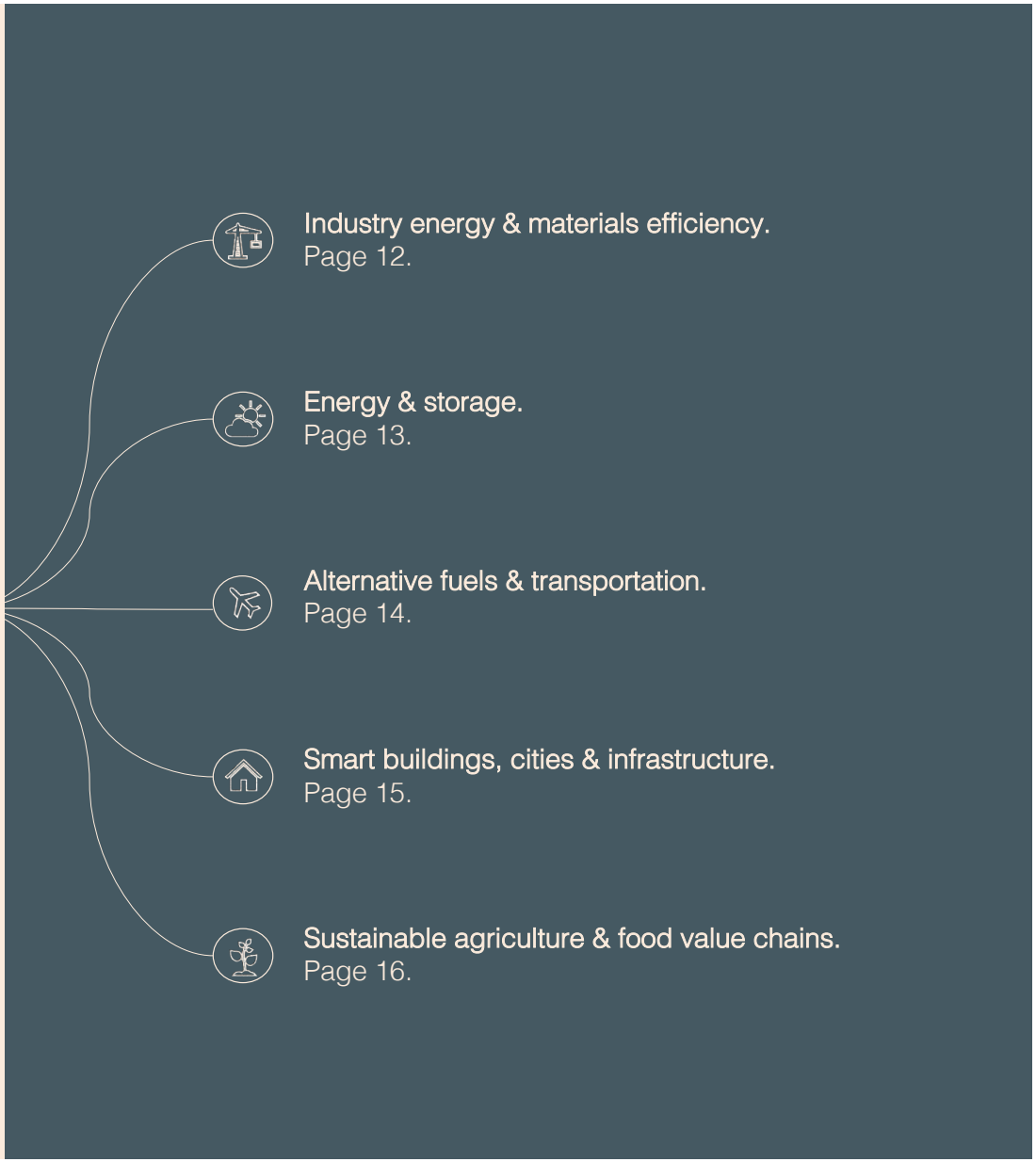
**Energy & storage.** While renewable energy sources are now a significant factor in the supply of global energy, their reliability remains a challenge. It is crucial that infrastructure is improved and better solutions are found for the storage of renewable energy.

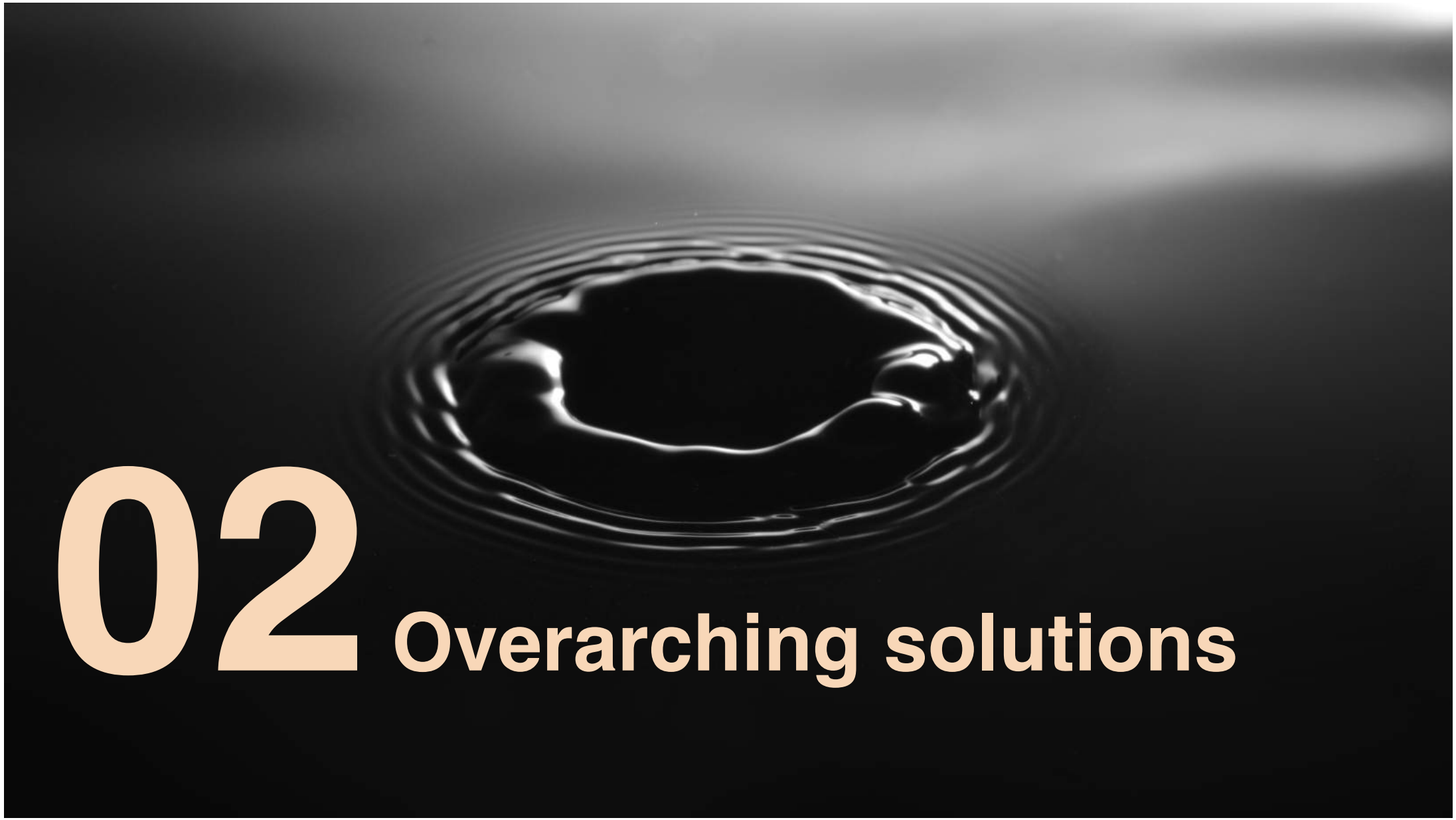
**Alternative fuels & transportation**. Travel and the movement of goods around the globe are a significant source of GHG emissions. Efforts to limit emissions are hampered by the continuing growth in passenger and freight activity. To alleviate this pressure, the use of low-emission fuels is necessary, as is redesign of transport methods themselves.

**Smart buildings, cities & infrastructure.** Demographic projections strongly indicate continued urbanisation and increase in urban density. Traditional city-dwelling is not compatible with solving the climate challenge. Innovation must lead to more energy- and materials-efficient construction and retrofitting of new and existing buildings and infrastructure.

**Sustainable agriculture & food value chains.** The combination of population growth, dietary changes and food loss in transit from field to table, exacerbate the environmental impact of feeding the global population. The value chains must be reconsidered from origin to consumption. Innovation can play a vital role in their optimisation.







# 02 Overarching solutions

02 Overarching solutions

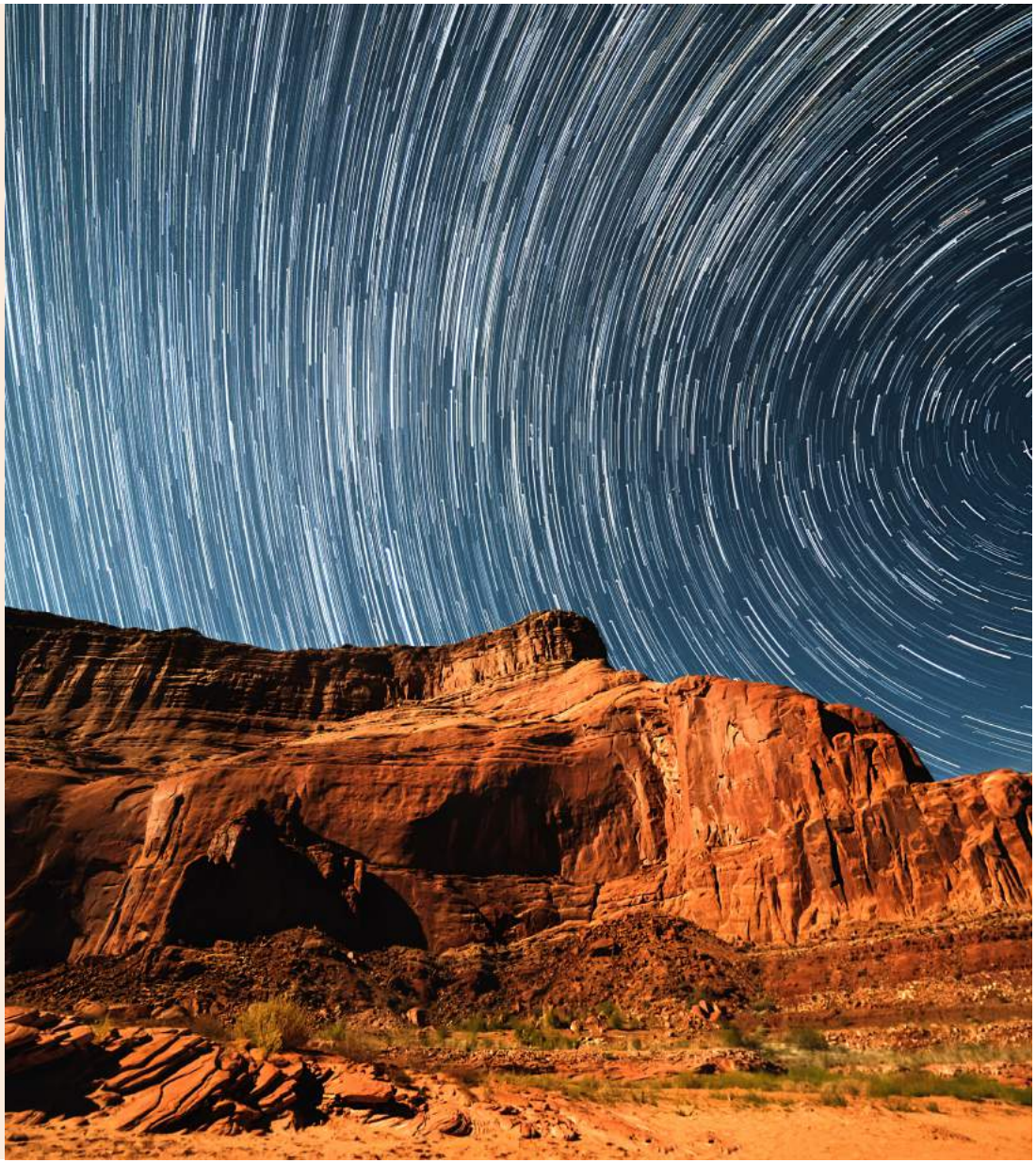
# Circular Economy

Only 9% of the existing global economy is considered circular. In other words, only 9% of more than 90 billion tons of materials are reused. This number has tripled over the last 50 years, and will double again by mid-century, unless we act to slow this trend. Around 66% of all global emissions are released when raw materials are converted, processed and manufactured into goods for consumption. Despite its vast potential, circular economy barely features in the policies of governments trying to comply with the Paris Agreement. In order to address the challenge of climate change, it is crucial to recognise the disconnect between efforts to combat global warming and the continued extraction, production, consumption and discarding of natural resources and manufactured products. Technology and innovative practices can extend the lifespan of materials through scrappage, recycling and reutilisation. This can affect heavy polluters such as the textile industry and construction, which currently accounts for nearly 20% of all emissions and almost 50% of global materials use. Climate solutions need to follow the value chains and circular economy is a big part of the solution.

# Data, AI, IoT

Advanced computing, artificial intelligence, distributed ledger technologies, big data and the internet-of-things will lead to new connected ecosystems, enabling the decentralisation of energy supply and demand. AI can significantly improve the current climate change models, resulting in improved predictions of extreme weather. With access to satellite footage, AI can monitor emissions from powerplants and help enforce regulation. In electricity systems, new technologies can support efficient power distribution and reduce energy losses in transit by applying predictive maintenance on existing installations and infrastructure. Additionally, they can play a significant role in optimising the transport sector, through shared mobility, capacity planning or energy efficiency in freight solutions and routing. Advanced technologies can help curb industry emissions by streamlining supply chains, improving production quality, anticipating and scheduling machine maintenance, optimising heating and cooling processes, and utilising renewable energy rather than hydrocarbons. Smart buildings and cities will rely on the widespread technological advances in AI and IoT. In agriculture, satellite images and analytics can help to identify the optimal crop and management practices to ensure high yield with minimum environmental impact. It is important, however, to remember the energy consumption of such technologies, when moving towards their wider application.





# 03 Key Initiatives

# Industry energy & materials efficiency

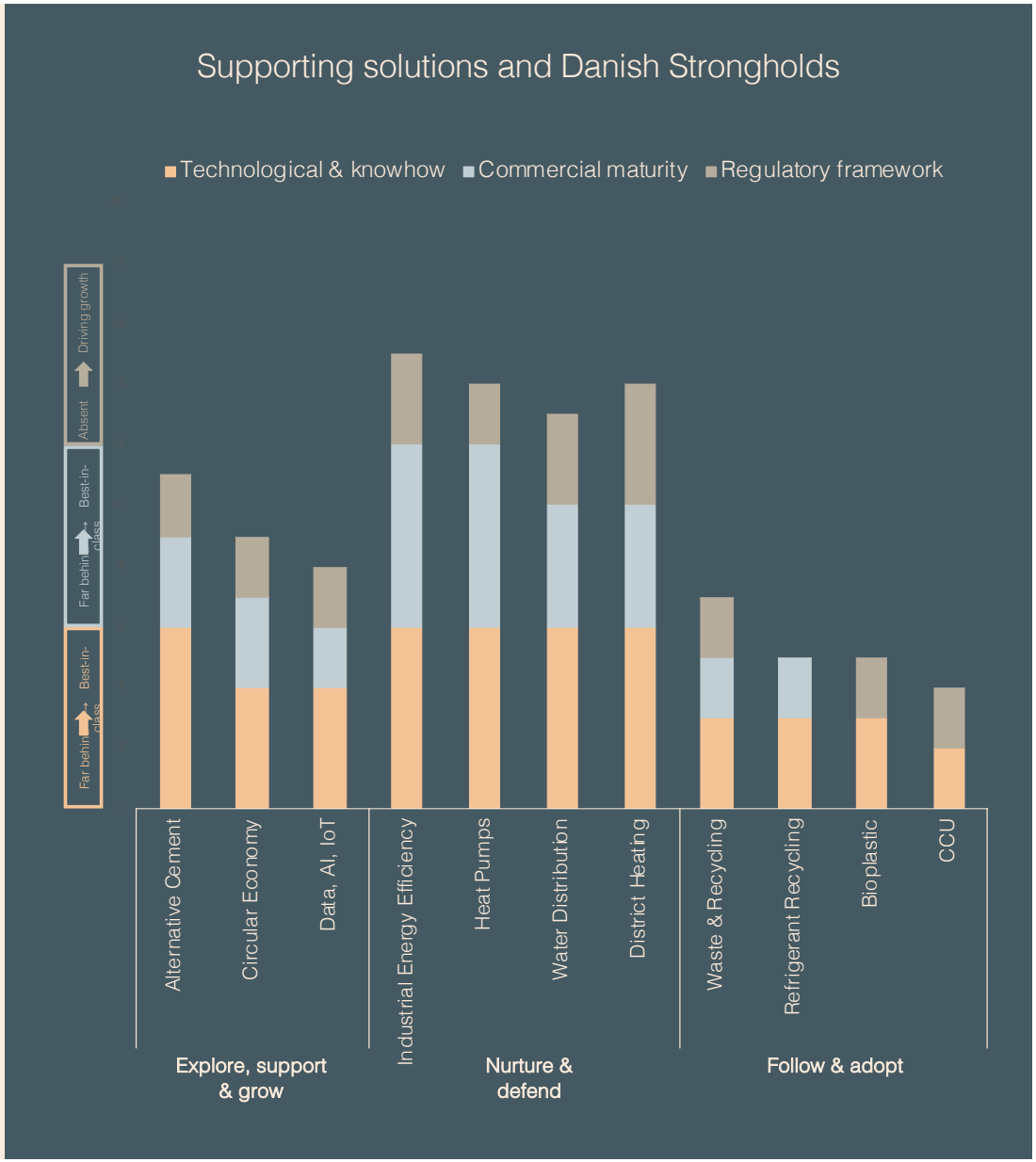
Innovation could lead to significant energy efficiency gains equating to up to 20% reductions across some global industries. Optimisation of steam and process heating systems can be part of the solution. Meanwhile, emission intensity can be improved by switching from oil to gas and renewable sources, and by employing efficient use of energy in industrial combined heat and power systems. The use of waste and biomass for powering industrial processes can also decarbonise the industrial sector. GHG emissions from industrial production can be reduced via recycling, bioprocesses and use of alternative materials. Electronic control systems, as well as AI, improved data collection, sharing and utilisation can all help to optimise industrial production. Systemic thinking, industrial symbiosis and supportive regulatory frameworks, will play an important role, building on interdependencies and synergies in process across sectors.

## Recommendation

A circular approach to construction, industrial processes and energy use across sectors will improve Danish attempts to achieve industrial efficiency and emission reductions. Material lifecycles should last longer. Materials should be recyclable and suitable for re-use in another value chain. Danish maritime technology, for example, has high potential for being re-used and re-purposed. Advanced technologies such as AI, IoT and Blockchain can go a long way to enable efficiency gains across energy and materials use. Similarly, alternative materials and the potential use of oxy-combustion fuel, Carbon Capture and Utilization (CCU) technology, could prove a future commercial and export opportunity, although the latter is not yet commercially mature. Meanwhile, a number of research projects and initiatives have propelled Denmark to the forefront of innovation and expertise within alternative cement. The technology is not yet sufficiently commercialised and would benefit from a supportive regulatory framework.

Heat pumps, district heating and water distribution are all innovative technologies with a substantial commercial presence. These are current Danish Strongholds that need to be maintained on global markets.





# Energy & storage

The majority of GHG emissions are related to the burning of fossil fuels for energy use. Today, electricity generation is the biggest producer of $CO_2$. Denmark is renowned globally for its green technologies, such as the wind turbine. Renewable energy technologies, like wind turbines, are now cost competitive in many parts of the world. However, large variations in energy production remain a barrier. For a transition away from fossil fuels to take place, and for renewables to provide a larger share of electricity, an effective energy distribution and storage system is required.

## Recommendation

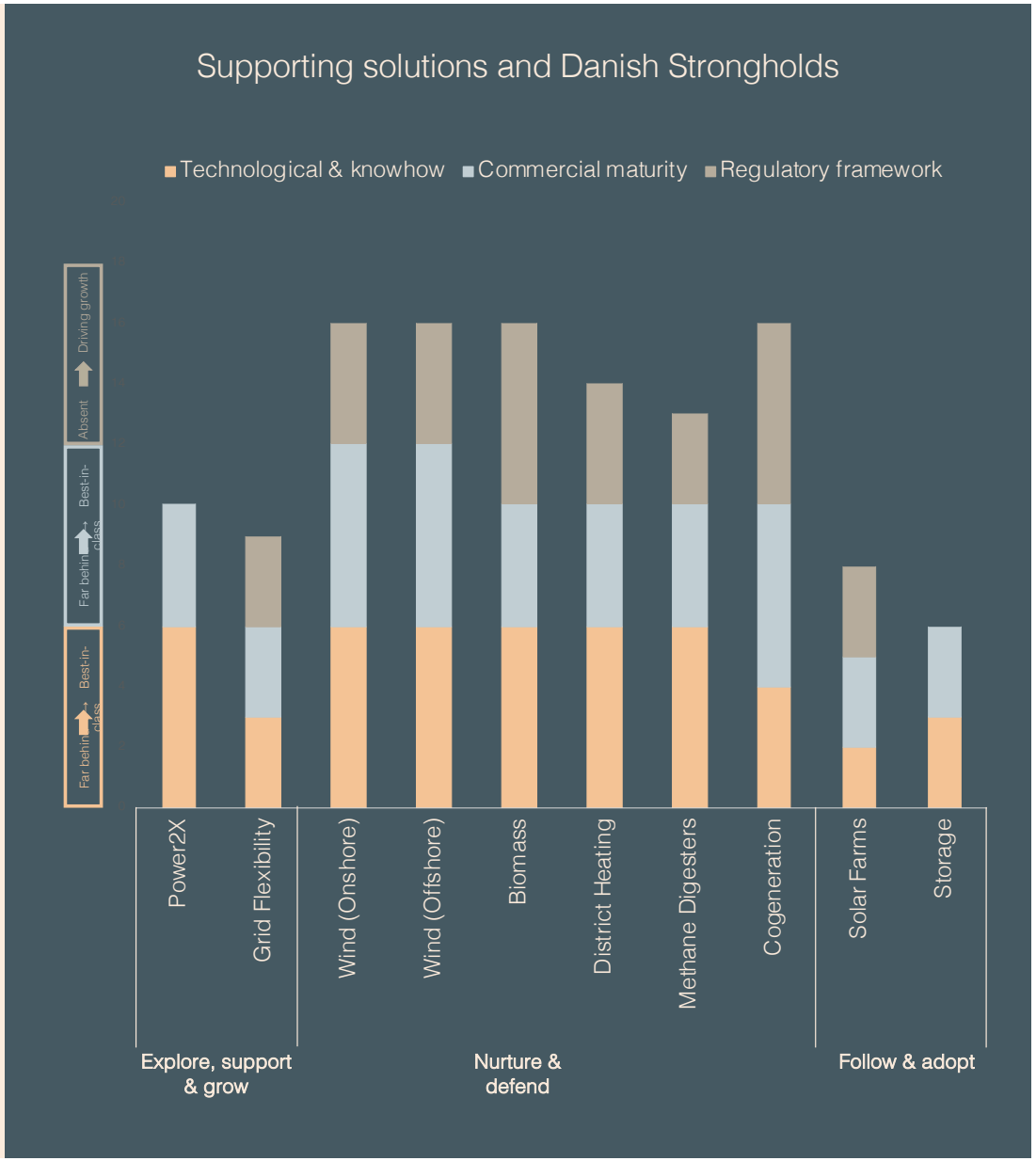
Renewable energy technologies stand out as a particular Danish strength. In terms of future investment and attractiveness, Power2X (or green hydrogen) could be significant for Danish businesses owing to its versatility. Power2X is produced by using electricity to split water into hydrogen and oxygen by means of electrolysis. It can be used for storage and grid buffering, for decarbonised high-heat for industrial processes, where electrification is ill-suited, and as feed stock in industrial processes or the fertiliser industry. Power2X can also be applied in heavy transport like trucks and ships. It is a solution that has the potential to connect and create synergies across agriculture, energy, industry and transport.

Power2X is a relatively mature technology and Denmark has strong competencies in the field. For Power2X to become a viable solution in the future, markets need to be created to scale up production and drive down prices. This can be achieved through strong policy support, with the mandated adoption of Power2X, as has been the case for biofuels.

Flexible grid and storage capabilities are prerequisites for a shift to renewables. Denmark does not necessarily have strong export opportunities in these fields, but they are vital for creating an energy system that can handle the shift to renewables. It is essential that they receive greater attention.

Regulatory systems could be developed and tested in order to promote smart energy system designs and management. This could include digital information exchange in conjunction with economic instruments, applied to facilitate efficiency and flexibility across all parts of the supply, storage and consumptions system.





03 Key Initiatives

# Alternative fuels & transportation

The transport sector, which is still dependent on the combustion engine and fossil fuels, accounts for 25% of global GHG emissions. Growth in passenger and freight activity will inhibit ambitions for the sector to reduce emission levels. Development of viable alternative fuels, transport technologies and infrastructure is necessary as part of an alternative energy strategy for transport. Replacement of fuel-inefficient road, sea and air vehicles will take time. Such an approach requires large capital investment. As such, retrofitting may be an attractive option in the short-term. Structural redesign is likely to follow the commercial availability of alternative fuels, for personal, passenger and freight transport.

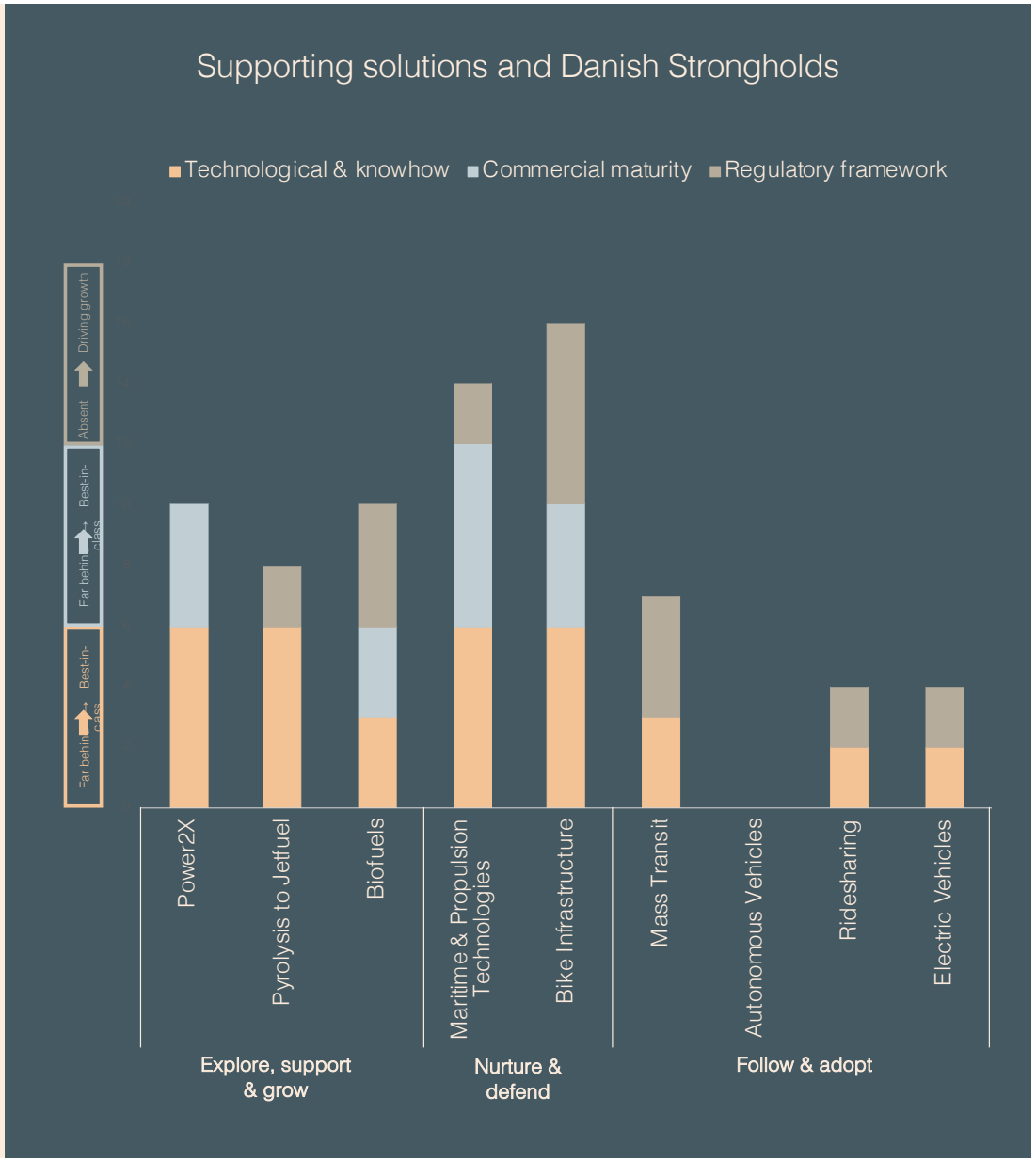
## Recommendation

Denmark is a significant player in global maritime goods transport, a sector capturing 90% of global goods trade. Denmark could become home to world leading businesses focused on low-emission alternative fuel technologies. Power2X can become a key solution for powering future transport, while Pyrolysis to Jetfuel and biofuels are fields in which Denmark can establish a leading global position. Such technologies can serve to mitigate the effects of climate change and have business and export potential as we move towards 2050.

Danish companies and the scientific research community are highly interested in Power2X due to the extensive production of wind energy, which soon covers 50% of Danish electricity consumption. Depending on the availability of affordable electricity, grid access and further cost reductions in the electrolysis process, the technologies can mature and be commercially viable earlier than anticipated. Coupled with innovative propulsion technology and ship design, the potential is great in transitioning from fossil to alternative fuels. Danish innovation and research in freight provides us with an opportunity to set future global standards.

Denmark is also a frontrunner in the use of digital solutions in mass transit. By connecting the ticketing system with the journey planner and personal digital IDs, all public transport modes and services are combined in one mobility platform. The political decision to merge the main journey planning platforms and open up the infrastructure for private initiatives has enabled further development of the seamless mobility solutions. Ongoing research in transport planning and the opportunities presented by public-private partnerships will enable mass transit to be improved even further. While electric and autonomous vehicles will form part of Danish transport solutions going forward, we recognise that this field should not be considered a Danish strength as there are many other nations already leading the way.





03 Key Initiatives

# Smart buildings, cities & infrastructure

Population growth and urbanisation highlight the need to prioritise low energy consumption, low emissions and reduced materials use in new construction. Renovation and retrofitting of existing structures can generate environmental and climate benefits. Smart buildings and urban infrastructure equipped with intelligent user interfaces, AI, IoT and full integration with the energy and utility grids, hold great potential for further emission reduction. It is necessary to adopt full life cycle and circular principles, such as designing for cost-efficient disassembly and material recycling.

## Recommendation

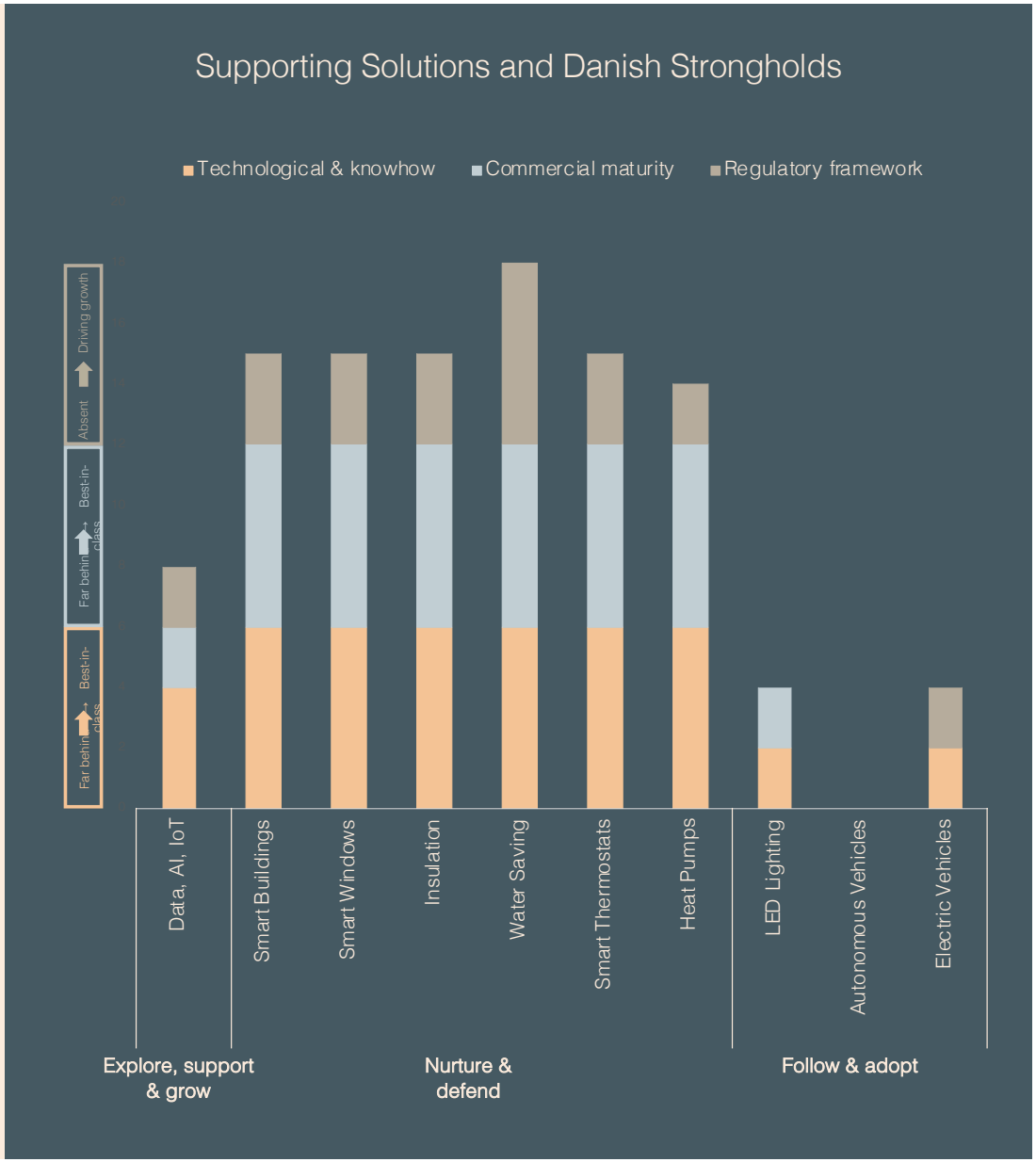
It is important to maintain and further invest in Danish Strongholds relating to materials, technologies and systems used in the construction of smart buildings and in the development of smart urban infrastructure. Years of research and development, as well as successful commercialisation, have established Danish universities and companies as world leaders in these fields. Investing in AI, IoT and data will further support and propel innovation capabilities in smart buildings, cities and infrastructure.

Denmark already has substantial presence in supporting technologies such as smart thermostats, insulation materials, low-emission technologies for building material production and use, energy saving glass and heat pumps. Alternative renewable materials may also play important roles. On the urban mobility side, advanced Danish bicycle infrastructure is world leading. World leading green financing schemes, energy and emission certifications and other regulatory frameworks are key enablers to realize this vision.

While certain key technologies, such as building integrated energy generation and advanced light solutions, are crucial for smart buildings, Denmark's current position is not among world leaders, making it a less attractive area to pursue.

The success of smart cities cannot be measured by emission savings and environmental standards alone. Human wellbeing and behaviour in relation to emission savings are equally important. It is important, therefore, that sociologists and anthropologists work closely with architects, planners and designers, encouraging and enabling these practices. Denmark is home to prominent architecture and design firms and can enhance this position further.





03 Key Initiatives

# Sustainable agriculture & food value chains

Reaching net zero emissions from agriculture poses a significant challenge, requiring new practices and investment across a wide range of technologies. Currently, there are limited business incentives to develop solutions that minimise GHGs emissions from peatlands, which in Denmark alone are vulnerable to a loss of 160 mill. $CO_2$ tons, equivalent to about 3 years of total Danish emissions.

## Recommendation

Increasing productivity while reducing GHG emissions will require investing in new solutions that target management practices, genetic improvements and further processing. It is necessary to reduce methane emissions from dairy production through improved livestock feed composition and additives. Minimising nitrous oxide emissions and increasing carbon storage may be achieved through manure management technologies, optimised fertilisers, biochar, nitrification inhibitors, digitisation and precision farming, plant residue management methods and regenerative efficient agricultural practices.

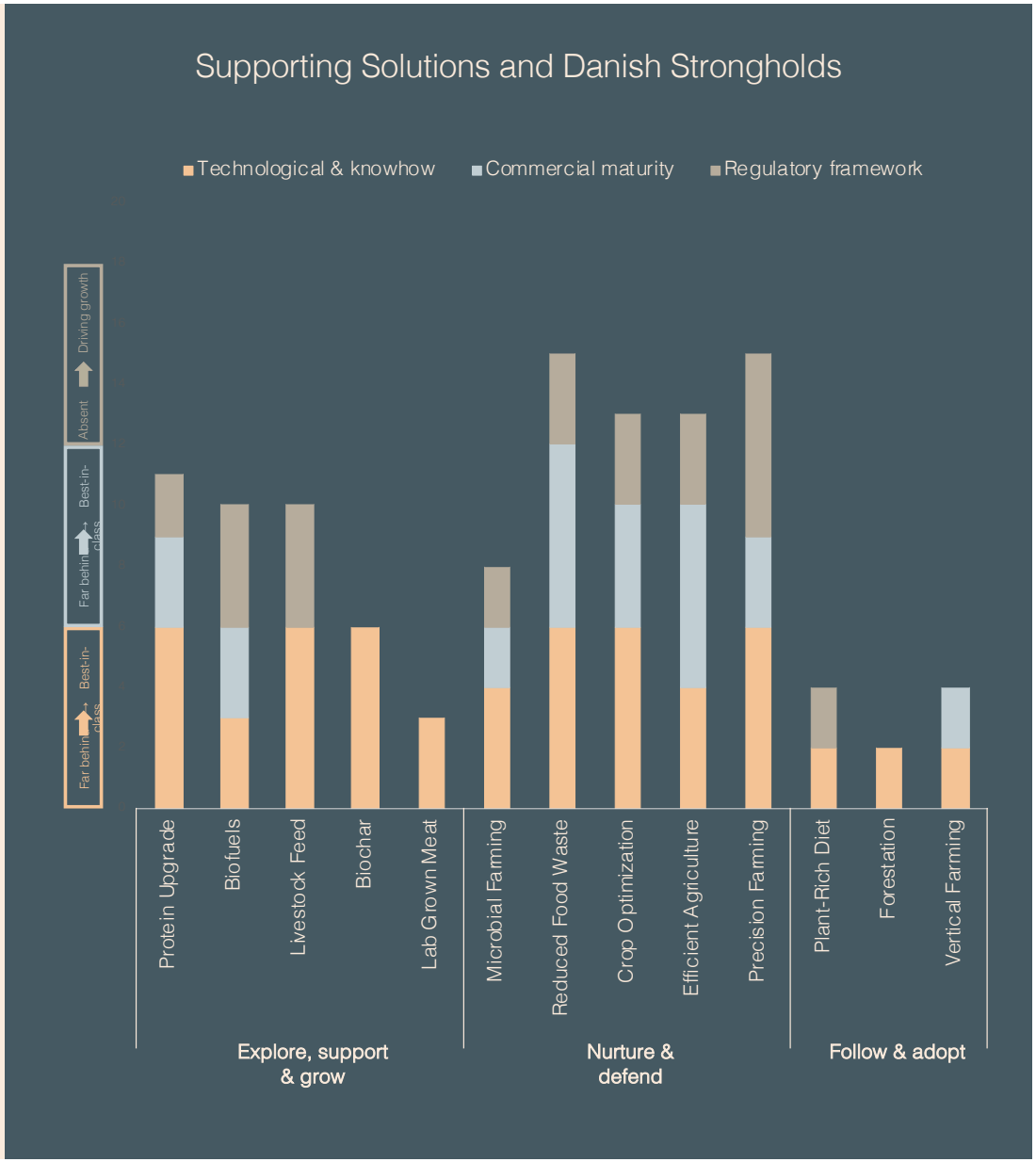
Protein upgrade provides an opportunity to increase primary agricultural production, for example, through the cultivation of grass for biorefining. There is a need for further development of the technology, so the protein quality is suitable for pig and cattle feed and, ultimately, for human food. This technology has potential to reduce GHG emissions, but documentation of grassland's climate profile is required. We need to better understand how genetics may reduce GHG emissions in order to optimise crop and livestock breeding programmes.

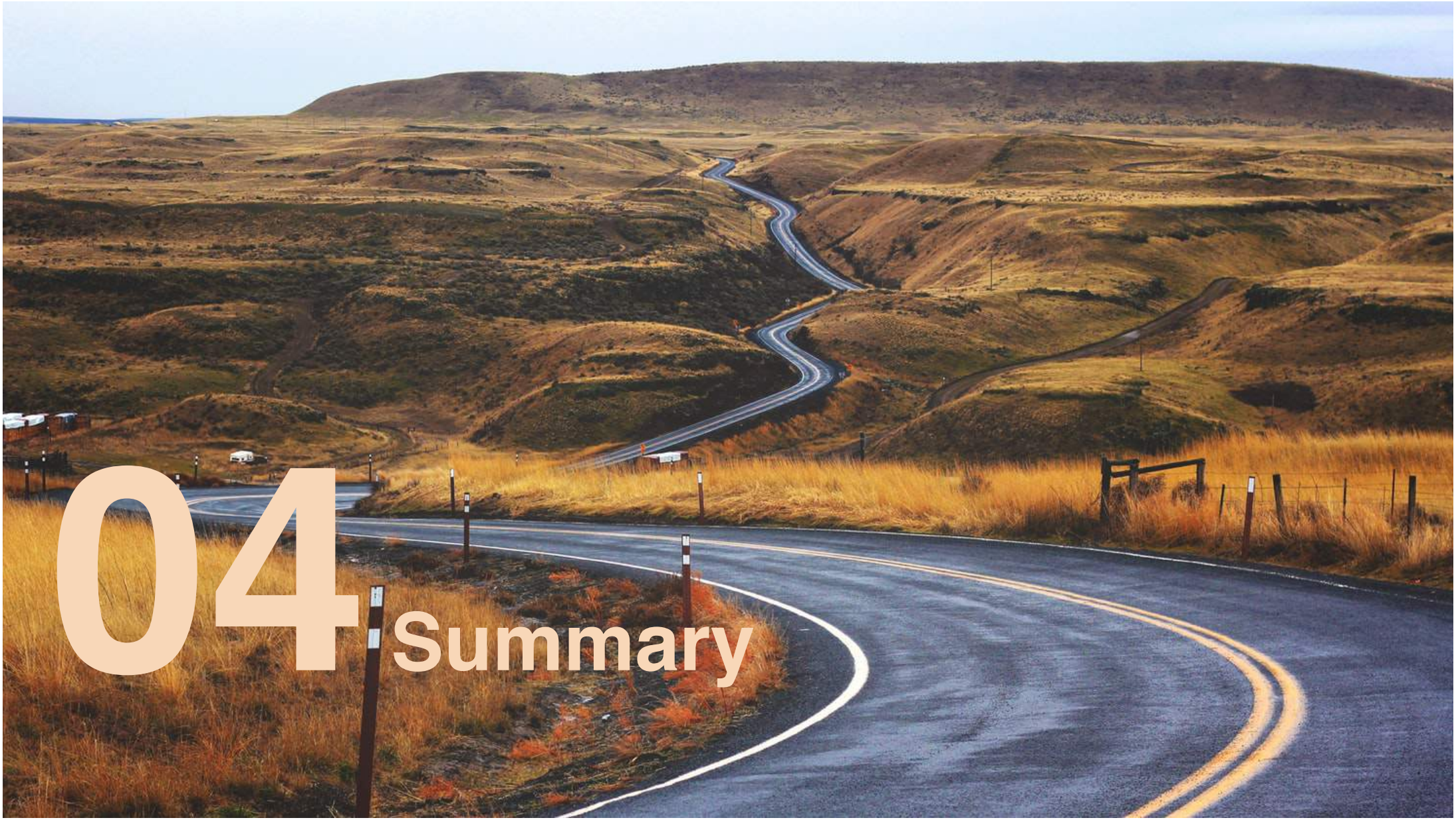
Reducing food waste in the supply chain is a current Danish strength. However, there remains a significant emission reduction potential, which largely rests on changing practices and behaviour. Plant-based meat and dairy replacements are already available and improving in quality. In the future, lab-grown meat and dairy products could significantly affect agriculture, but large uncertainties surround the lab-grown solutions and reliable estimates of the climate impact are lacking. However, as this could have significant consequences for Danish agriculture, we should consider establishing competencies in the field, bearing in mind that we will have some catching up to do.

Second-generation biofuels and biogas represent a bridge solution that may provide significant cross-sector benefits through the production of vital renewable fuels for aviation and greening shipping, but one that is not viable in the long term.

*4. Regenerative agricultural is a conservation and rehabilitation approach to food and farming systems that is not a well-defined. It includes a range of agro-ecological practices, see p. 9 in Catalogue of Plausible Solutions for Workshop 2.*







# 04 Summary

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This report is a product of the Innovation Fund Denmark's Climate Solutions Panel. It focuses on areas where it is thought Danish effort would have the most effect on reduction of $CO_2$-equivalents. This is based on Danish strengths within academia, business and regulation. Hopefully, the report will be challenged and discussed, further enhancing the recommendations.

Innovation Fund Denmark will develop the findings and recommendations into an overall strategy to guide future investments in developing climate solutions. Further, it is our hope that Danish society, academia, business and regulators, will use the findings as inspiration for an even stronger Danish climate effort.



## Summary of Recommendations

*Industry energy & materials efficiency*

- Increase circular approach to industrial processes, materials lifecycles and energy use, including recycling, across sectors
- Increase efficiency through advanced technologies, such as AI, IOT, data collection and harmonisation
- Increase innovation support to alternative materials, such as alternative cement, and the potential use of oxy-combustion fuel, Carbon Capture and Utilisation (CCU) technology
- Create a supportive regulatory framework for alternative cement
- Preserve existing commercial strongholds in heat pumps, district heating and water distribution
- Support development of adequate, transparent and reliable life cycle analyses and labelling, to guide policy makers and consumers.

*Energy & storage*

- Continue the focus on renewable technologies as a particular Danish stronghold
- Establish viable markets, implement supportive policy (with mandatory requirements) and scale up production of Power2X (or green hydrogen)

*Alternative fuels & transportation*

- Maintain and develop further strongholds in Power2X, Pyrolysis to Jetfuel and biofuels
- Maintain Danish strongholds in maritime and propulsion technologies and a collaborative approach to innovative technology for the future of transportation and fuels

*Smart buildings, cities & infrastructure*

- Maintain and further invest in existing strongholds within materials, technologies and systems used in the construction of smart buildings and in the development of smart urban infrastructures
- Invest in world-class research infrastructure with regards to the future-oriented digital technologies that are required to create smart cities and buildings
- Prioritise cooperation between sociologists, anthropologists, architects, urban planners and designers in city and infrastructure planning, to encompass behavioural aspects

*Sustainable agriculture & food value chains*

- Support and further develop protein upgrade solutions to increase primary agricultural production, increase the protein quality of pig and cattle feed and, eventually, of human food
- Minimise methane and nitrous oxide emissions and increase carbon storage through the optimisation of fodder, manure management technologies, fertiliser types, nitrification inhibitors, biochar, plant residue management methods, digitisation and precision farming
- Maintain and improve Danish strengths and efforts relating to the reduction of food waste
- Consider opportunities for lab-grown meat and other alternatives to traditional meat, while maintaining the nutrition focus

# Appendix

- Full list of the 62 plausible solutions and their impact
- Overview of Danish Solutions Strongholds (DSS)
- Overview of solutions and their potential
- Process overview of panel work

# X1 Plausible Solutions

| Level of Impact (Potential gigatons $CO_2e$ reduced or avoided towards 2050) | Agriculture & Food (16 plausible solutions) | Buildings (10 plausible solutions) | Energy (13 plausible solutions) | Industry (12 plausible solutions) | Transportation (11 plausible solutions) |
|---|---|---|---|---|---|
| **Very High ($9 - 102$ $GTCO_2e$)** | Afforestation, Deforestation and Restoration<br>Reduced Food Waste<br>Plant-Rich Diet<br>Regenerative Agriculture<br>Managed Grazing | Rooftop Solar<br>LED Lighting | Wind (Onshore)<br>Solar Farms<br>Wind (Offshore)<br>Concentrated Solar | Refrigerant Recycling | Electric Vehicles |
| **High (4 - 9 GTCO2e)** | | Insulation<br>Solar Water Heating and Cooling<br>Smart Buildings | District Heating<br>Methane Digesters<br>Biomass | Alternative Cement<br>Waste Recycling<br>Heat Pumps | Maritime and Propulsion Technologies<br>Mass Transit<br>Truck Design<br>Airplane Design |
| **Significant ($0.3 - 4$ $GTCO_2e$)** | Irrigation<br>Biochar | Water Saving - Residential<br>Smart Thermostats<br>Smart Glass<br>Green Roofs | Cogeneration<br>Waste-to-Energy | Bioplastic<br>Telepresence<br>Water Distribution | Bike Infrastructure<br>High-Speed Rail<br>Electric bikes<br>Ridesharing |
| **Impact varies across sources due to different assumption** | Biofuels ($2^{nd}$ generation)<br>Protein Upgrade<br>Ocean Farming<br>Microbial Farming<br>Lab Grown Meat<br>Precision Farming<br>Crop Optimisation<br>Livestock Feed<br>Vertical Farming | Building with Wood | Bioenergy with CCS<br>Green Hydrogen (Power2X)<br>Grid Flexibility<br>Storage | AI, Blockchain & Data<br>Carbon Capture Storage<br>Carbon Capture Utilisation<br>Circular Economy<br>Industrial Energy Efficiency | Pyrolysis to Jetfuel<br>Autonomous Vehicles |

*Solutions are ranked based on estimated potential impact in reducing GHG emissions*

*For a full and more detailed description of the individual solutions, please refer to the catalogue serving as pre-read for WS2.*

Source: UNEP, Drawdown.org

# Overview of solutions and their potential

Central to the Panel's work was the identification of the technological solutions that could form the backbone for the success of initiatives. The Panel identified solutions that could be widespread in future endeavours to fight climate change. This means solutions that would have a positive impact on the net reduction of $CO_2$ emissions, but also be interesting from an innovation and export perspective.

The figure to the right highlights the 'future potential' of the solutions. The closer to the centre a solution is located, the greater its potential. Solutions are grouped according to the initiative they were most closely associated with.

*Power2X*, in the central position, is thought to be the solution most likely to have 'future success'. It is also a solution that spans multiple initiatives. *Alternative Cement, Smart Buildings, and renewable energy (Wind Power), Reduced Food Waste, Pyrolysis to Jetfuel and Energy Storage* also were all noted for their future potential.

Some solutions – *Heat Pumps, District Heating, Electric Vehicles and Biofuels* – play a vital role for several initiatives and are therefore depicted on the borders between them.

Peripheral solutions are those deemed less likely to be widespread by 2030, such as *Methane Digesters*, *Bioplastics*, *Ocean Farming* or *Smart Thermostats*.

Two solutions were recognised for how they supplemented and emphasised the potential of all the other initiatives. The notion of planetary boundaries and the need to think of our resources in a circular lifecycle manner puts *Circular Economy* at the forefront of any future approach to climate change and environmental preservation. Similarly, technologies such as *AI and IoT*, which rely on *data* collection, harmonisation and sharing, are crucial enablers of synergies and efficiency gains in all other sectors.


**Legend:** The closer to the center (darker area) a solution is, the higher its future potential was rated by the Panel.
The solution is placed in the quintile of the initiative it is most closely associated with. Some solutions play an important role in several initiatives, thus placed in the 'border' between quintiles. Overarching solutions impact almost all solutions. They are positioned, therefore, in the outer ring of the solution space.

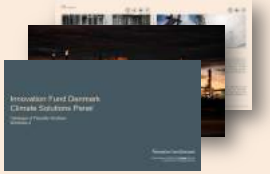
# X3 Process overview

## Workshop I
(26 May 2019)

Prior to Workshop I: Reading materials were produced to provide a foundation for discussion topics covered in the workshop.

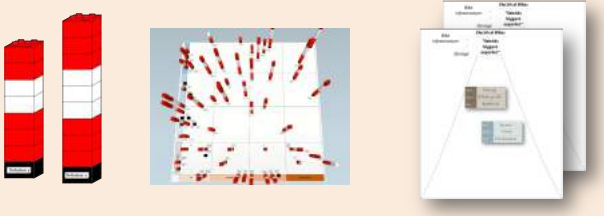
At Workshop I:

- As part of an explorative exercise, the panel mapped and validated **240 possible** climate solutions across the following 5 sectors: Industry, Food & Agriculture, Buildings, Energy and Transport.
- Subsequently, through a voting exercise, the panel identified **80+ plausible** climate solutions across the 5 sectors.
- Finally, the Panel worked on the identification of cross-sector solutions.



## Workshop output – solutions catalogue

The consolidated WS1 outcome, additional research and expert input was summarised in a catalogue of **62 plausible** and viable climate solutions across the 5 sectors.



## Workshop II
(6 September 2019)

Prior to Workshop II: The plausible solutions catalogue was shared with the Panel.

At Workshop II:

- Initially, the Panel discussed and identified key **Danish Solution Strongholds (DSS)** in sector-specific groups, based on technology & knowhow, business & export and regulatory environment.
- Subsequently, the Panel was asked to assess all plausible solutions based on future potential, which resulted in **46 potential 'future successes'.**
- The assessment of DSS, potential 'future successes' and potential impact on emissions towards 2050 was translated into a Lego 'city'.
- Finally, the Panel focused on a roadmap for **5-10** key initiatives. This is a system of solutions based on considerations of emission impact, DSS positions and future success potential.


## Final white paper

The consolidated outcome of the entire process, supplemented by additional input from a broader stakeholder group, has been compiled in a white paper that highlights initiatives and solutions that enables Denmark to spearhead and champion the climate innovation efforts.

Solution space # 240 → 80+ → 62 → 46

# X4 Climate Solutions Panel participants

| | | |
|---|---|---|
| Andrew McMullen | Director of Zero Environmental Impact | LEGO |
| Bjarne Foldager | Senior VP, Head of Two Stroke Business | MAN Energy Solutions |
| Bo Foged | CEO | ATP |
| Bo Øksnebjerg | Secretary General | WWF |
| Brian Vad Mathiassen | Professor | Aalborg University |
| Claus Krogh Ekmann | Director | Danish Ecological Council |
| Claus Møller | CEO | Siemens |
| Connie Hedegaard | Chair | Concito |
| Daria Krivonos | CEO | Copenhagen Institute for Futures Studies |
| Emily Farnworth | Head of Climate Change | World Economic Forum |
| Flemming Besenbacher | Vice Chair / Chair | IFD / Carlsberg Foundation |
| Hanne Søndergaard | EVP, Marketing & Innovation | Arla |
| Henrik Stiesdal | CEO | Stiesdal Technology |
| Ib Enevoldsen | CEO | Rambøll |
| Ingrid Reumert | Vice President | Velux |
| Jacob Krog Søbygaard | Head of Secretariat | Danish Council on Climate Change |
| Jakob Askou Bøss | Senior Vice President | Ørsted |
| Jens Kehlet Nørskov | Professor | Technical University Denmark |
| Jens la Cour | Senior Advisor EU (Environmental policy) | Danish Society for Nature Conservation |
| Jesper Nygaard | CEO | RealDania |
| Jesper Sølver Schou | Head of Section | The Economic Council |
| Johannes Lüneborg | Partner | McKinsey |
| John Kornerup Bang | Head, Sustainability Strategy | Mærsk |
| Jørgen Olesen | Professor | Aarhus University iClimate |
| Kasper Roed Jensen | Vice President | Vestas |
| Katherine Richardson | Professor, Board member of Danish Council on Climate Change | Copenhagen University |
| Kim Grøn Knudsen | EVP, Sustainables Business Unit | Haldor Topsøe |
| Kirsten Halsnæs | Professor | Technical University Denmark |
| Laila Mortensen | CEO | Industriens Pension |
| Lars Schrøder | CEO | Aarhus Water |
| Lars W. Andersen | Director | SAS |
| Lars Aagard | CEO | Danish Energy |
| Michael H. Nielsen | Director | The Danish Construction Association |
| Michael Zöllner | Managing Director | The Danish Green Investment Fund |
| Monika Skadborg | Chair | Ungeklimarådet |
| Nick Johnstone | Head of Division | IEA |
| Niels Peter Nørring | Climate Director | Danish Agriculture & Food Council |
| Peter Birch Sørensen | Professor | Copenhagen University |
| Peter Høngaard | Former CEO | Innovation Fund Denmark |
| Sofus Rex | Head of Department | Danish Ministry of Environment and Food |
| Thomas Mathiasen | Scientific Officer | Innovation Fund Denmark |
| Thomas Uhd | Sustainability Director | Aalborg Portland |
| Thomas Woldbye | Managing Director | CPH Airport |
| Tore Duvold | CEO | Innovation Fund Denmark |
| Ulrich Bang | Head of Climate & Energy policy | The Danish Chamber of Commerce |

## Other contributors:

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# Thank you.

Innovation Fund Denmark

Innovation Fund Denmark invests in the development of new knowledge and technology creating growth and employment in Denmark. The Fund focuses on societal challenges, strengthens research and increases innovation commitment within private companies.

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