Research programmes with a mission

Hessels, Laurens; van Drooge, Leonie; van den Broek, Jos; van Elzakker, Isabelle

2022

Rathenau Instituut

Research programmes with a mission

Lessons for challenge-driven innovation policy

Report

Authors

Laurens Hessels, Jos van den Broek, Isabelle van Elzakker, Leonie van Drooge and Jasper Deuten

Cover photograph
Thisisengineering via Unsplash

Preferred citation:
Rathenau Instituut (2021). *Research programmes with a mission - Lessons for challenge-driven innovation policy*. The Hague.

Foreword

We cannot solve the great challenges of our time through technological innovation alone. For example, the transition to circular agriculture envisaged by the outgoing Dutch government, requires not only new farming techniques, but also a revolution in the way we market, transport and even consume food. To achieve this kind of transition, it helps to develop innovation policies which have a different focus. In a Message to Parliament in 2020, the Rathenau Instituut advocated *challenge-driven innovation policy*, an approach that does not try to promote specific technologies or sectors, but takes a societal challenge as its starting point.

Building on our earlier analysis of European research and innovation policy, the Rathenau Instituut wants to use this report to contribute to the continuing development of this new genre of challenge-driven innovation policy. We focus on *research programmes* that are intended to help address societal challenges. Based on insights from the scientific literature and an analysis of three international examples, we formulate some points of attention for organising this type of research programme.

Whereas the governance and management of scientific research has traditionally left researchers and consortiums considerable leeway, we see that challenge-driven programmes require firmer coordination and management at programme level. At the same time, the programmes have to be sufficiently agile. Given the dynamic environment of challenge-driven programmes, they will need to continually evaluate their focus and approach to ensure that their activities match their stakeholders' knowledge needs and capabilities. The government itself also plays a key part in this, partly because of the politically charged goals set for these types of programmes.

If the government really intends to mobilise research and innovation to tackle societal challenges, such as the transition to circular agriculture, it must also invest in its own capacity to participate as an active partner in the knowledge ecosystems surrounding societal challenges. The aim should be not only to bring in knowledge and expertise from policy, but also to ensure that research is driven by public values.

Jeroen Heres
Chief scientist, Rathenau Instituut

Summary

In recent years, the Dutch government has been trying to focus science and innovation policies more strongly on societal challenges, such as reducing climate change, keeping healthcare affordable or transitioning to a sustainable system of food production and consumption. This is reflected, for example, in the Dutch National Research Agenda (NWA) and in the government's mission-oriented top sectors and innovation policy introduced in 2019. This policy change is part of a broader international trend in which governments are seeking to use research and innovation in a more targeted way to address complex societal challenges. This ambition differs from previous research and innovation policies that focused on economic earning power, technological opportunities or scientific curiosity. The new ambition to help address societal challenges in a targeted way calls for a new, complementary *genre* of research and innovation policy. We call this *challenge-driven research and innovation policy*.

The Rathenau Instituut wants to contribute to the development of this new genre, and does so in various projects. In previous publications we reflected on, among other things, developments within Dutch innovation policy (Rathenau Instituut, 2020c) and the way in which the European Union is fulfilling its ambition to refocus research and innovation on societal challenges (Rathenau Instituut, 2020a, b). In this study, our focus is on research programmes, as there is little experience with these programmes to date. The key research question is: what requirements does a challenge-driven approach impose on the design and management of research programmes?

Based on desk research, a workshop, and an analysis of international examples, this report explores what it takes to design and manage challenge-driven research programmes. Our goal is to provide practical insights for those involved in the funding, design, governance and management of research programmes, such as research funders, programme managers, and policy staff in the various government departments.

The report consists of four parts: In the first part (Sections 1 and 2), we position challenge-driven research programmes within a broader trend in which the government is trying to mobilise research and innovation more specifically towards societal challenges. We describe characteristic differences between *challenge-driven programmes* and *innovation-driven programmes*. In Section 3, we discuss three international examples of programmes with challenge-driven features. In Section 4, we identify practical building blocks which can be used to design and

manage challenge-driven research programmes. Finally, we reflect on questions that this new way of programming raises about the multiple roles of government in mobilising research and innovation in challenge-driven research programmes.

Challenge-driven research programmes

Based on the literature, we argue that challenge-driven research programmes have a different 'theory of change' than traditional research programmes that focus on stimulating new knowledge and new (often technological) solutions. The starting point of challenge-driven programmes is not the promise of new scientific knowledge or an emerging key technology, but a complex societal problem and the socio-technical system change needed to solve it. The nature of the problem and the system change determine what knowledge and solutions are needed. It may be just as necessary to combine knowledge from different sources and disciplines as it is to develop new knowledge or technology. Another typical component of a challenge-driven theory of change therefore involves connecting, reordering and building knowledge ecosystems.

Because challenge-driven research programmes are based on a different theory of change than conventional research programmes, research funders and programme managers will have to develop new ways of working. The question is how.

Three international cases

We look at three international examples to learn lessons on ways of designing and managing challenge-driven research programmes:

1. CGIAR's Climate Change, Agriculture and Food Security (CCAFS) programme. CGIAR is a global alliance of international organisations involved in food security research.
2. The Defense Advanced Research Projects Agency (DARPA), an agency of the US Department of Defense responsible for developing emerging technologies for use by the military.
3. The Utmaningsdriven innovation (UDI, challenge-driven innovation) programme of VINNOVA, the innovation agency of the Swedish government.

We selected these three cases because they all have a specific (societal) challenge as a starting point. CGIAR's CCAFS programme mobilises research to help develop a safe and future-proof food system. DARPA promotes research and technology development to enhance national security. Sweden's UDI programme funds research and innovation to contribute to the United Nations Sustainable Development Goals.

It turned out that the three programmes were not *challenge-driven* in every respect as defined above. Of the three programmes, Sweden's UDI most closely resembles

a conventional innovation-driven programme using calls for proposals which allow researchers and stakeholders ample scope to develop and submit their own project proposals. The CCAFS and DARPA examples provide more avenues for learning about the targeted mobilisation of research and innovation to address societal challenges.

Both in CCAFS and DARPA we observe an active and guiding role for programme management. The design, governance and management of the programmes are based on a well-developed theory of change which takes the societal challenge as its starting point. Unlike conventional innovation-driven programmes, programme management remains closely involved with the projects over the course of the projects. Programme managers make interim adaptations when there is a risk of the projects no longer aligning with the overarching programme. With CCAFS, we also see that the programme explicitly addresses responsible research practices at both project and programme level. At all stages of the programme cycle, participants work with actors who are needed to put the knowledge and solutions developed into practice, such as local communities. They therefore pay close attention to the way research programmes are embedded in the ongoing innovation and transition process.

Building blocks for a challenge-driven approach

From our desk research and international cases, we distil two major characteristics of challenge-driven research programmes that carry over into their design, organisation and control: active programme management and reflexivity.

1. *Active programme management throughout the programme cycle*
   The international cases show that challenge-driven programming of research requires active and decisive programme management to organise and monitor their orientation towards societal challenges. Appropriate activities include developing a shared *theory of change* at the start of the programme, creating and monitoring coherence between projects, adapting specific projects as necessary, organising interactions with stakeholders inside and outside the programme and integrating results.

2. *Learning approach*
   Challenge-driven research programming also requires reflexivity in which programme management and participants regularly reflect on whether the theory of change is still appropriate and whether the projects and goals are still relevant. After all, the societal context in which the results must be applied is dynamic, and interim project results may prompt adjustments to the portfolio, e.g. by organising additional activities, involving new parties or linking up projects.

These two characteristics require investment in time and in skills. These investments can only be justified if the active and targeted mobilisation of research actually ensures a more effective contribution to addressing the challenge concerned. Partly for this reason, proper monitoring and evaluation is important.

From the literature and the analysis of international examples, we have distilled practical action options for adopting a challenge-driven approach in research programming. We describe these options using ten phases of the programme cycle, from programme preparation to completion and evaluation.

Concluding remarks on roles of government
Challenge-driven programmes depend in part on active and variegated involvement and direction from policymakers. Indeed, a typical feature of challenge-driven research programmes is that government itself is also part of the underlying theory of change - often in different ways. To a greater extent than in innovation-driven research programmes, it is important for government to participate in the design of the theory of change. This is necessary to focus the programme on public values and to make explicit what roles the government itself should play.

We identify typical roles that the government can play, e.g. creating the right conditions for developing the programme, investing in and supplying knowledge, participating in projects and promoting knowledge utilisation in policy and/or practice.

Contents

1 Introduction

In this introduction, we begin by explaining the reason for this report, namely the emergence of a different kind of innovation policy that is focused not so much on *more* innovation, but on innovation that helps to resolve societal challenges. Next, we describe the objective of and research question of this study and the approach we adopted in answering these questions.

1.1 Background

The major societal challenges of our times, such as the energy and climate transition, the nitrogen problem, sustainable mobility, social inequality, affordable healthcare and equal opportunities in education, are systemic problems. The current Covid-19 pandemic is a perfect illustration of how complex, multifaceted and uncertain the problems raised by societal challenges can be, and how difficult it is to develop an effective approach that takes account of all the aspects and interests involved.

There is now a growing realisation among policymakers that the structural changes needed require a transition approach. A good example of this is the European Green Deal through which the European Commission aims to provide a roadmap to make the EU economy sustainable. The Green Deal states that this will succeed only if the climate and environmental problems in all policy domains are used as an opportunity to make the transition as fair and inclusive as possible for everyone (Rathenau Instituut, 2020a). A similar initiative in the Netherlands is the Climate Agreement in which industry, civil society organisations and government bodies have jointly set out a package of measures and agreements aimed at roughly halving greenhouse gas emissions in the Netherlands by 2030.

The policy domain covering research and innovation is not immune to the increasing focus on societal challenges and transitions. Until now, innovation policy has been used primarily to stimulate economic growth by strengthening the (mainly technological) innovation capacity of industry. Although some policy instruments are linked to societal challenges, addressing them is usually a secondary objective alongside increasing competitiveness. There is now a growing awareness that this business-oriented approach is not sufficient to ensure that innovation helps to address societal challenges and transitions. More active involvement on the part of government and society is needed for all research and innovation activities to

contribute to a systemic innovation as part of a socially responsible transition process. This new approach is emerging alongside conventional innovation policies that focus on technology development and business competitiveness.

In the Netherlands, we see this shift in emphasis in innovation policy in the Mission-oriented Top Sectors and Innovation Policy introduced by the government in 2019. A number of major societal challenges have been crystallised into 25 specific missions for which knowledge institutions and industry have jointly drawn up *multi-year mission-oriented innovation programmes*. These agendas provide guidance on the substance of research and innovation projects. The Dutch National Research Agenda is another example of the growing ambition among policymakers to connect scientific research to societal challenges and societal partners.

The European Commission is known as a prime mover with its focus on societal challenges as a mainspring for research and innovation. A clear example of EU innovation policy being used to address societal challenges is provided by the *missions* in the new Horizon Europe framework programme. Artificial intelligence policy also focuses not only on technology incentives and high-tech companies, but also on getting society involved in developing and applying this new key technology. In addition to the *ecosystem of excellence*, the Commission also wants to build an *ecosystem of trust.*[1]

Those who put structural societal change centre stage will need to rethink the instruments of innovation policy as existing innovation policy is designed to encourage industry investment in research and innovation and to get industry to work better with knowledge institutions. When societal challenges and transitions are chosen as policy goals, it is no longer sufficient to focus on technology development, business innovation and cooperation between industry and knowledge institutions, as societal challenges are more than a commercial opportunity for industry. And technological solutions can only contribute to tackling societal challenges if they are part of a system innovation.

Social innovation is every bit as important as technological innovation. When societal challenges are chosen as the main objective of innovation policy, a new genre of *challenge-driven* innovation policy is needed, in addition to existing technology- and business-oriented innovation policy (Rathenau Instituut, 2020c).

A typical feature of a challenge-driven innovation policy is that research and innovation are used to serve a societal transition. Challenge-driven innovation policy cannot therefore be viewed in isolation from the social and political debate

1 Rathenau Instituut, 2020a. *De belofte van opgavegericht innovatiebeleid: Een analyse van Europees innovatiebeleid voor de Green Deal en kunstmatige intelligentie*. Rathenau Instituut, The Hague.

around what exactly the problem is and what changes and innovations are necessary and desirable in order to address it. The agenda for research and innovation is determined by what politicians and society deem necessary to give system change more focus and/or greater momentum, leading to specific requirements for knowledge and solutions for each societal challenge.

This change in perspective brings into focus a wider range of actors and aspects that may need to play a part in developing and implementing innovation policy. In addition to the *usual suspects* such as industry and knowledge institutions, we also expect civil-society organisations, public sector professionals, citizens and municipalities to be key players in challenge-driven innovation policy. The change in perspective also allows for a greater understanding of what counts as relevant research and innovation. It does not always or only take ground-breaking scientific research or high-tech development to tackle societal challenges. Sometimes it will actually be essential to build on existing knowledge or to combine knowledge or to join with users to achieve social innovations through co-creation.

This new genre of innovation policy is still in its infancy. There are still many questions to be answered about how this policy can be structured and what measures and policy instruments are appropriate. As part of *Horizon Europe*, the European Commission has defined five missions, including Climate-neutral and smart cities and Soil health and Food. In 2020, a mission board submitted an overall proposal for the activities to be performed by each mission to achieve its objective. It is evident from these proposals that there are still many questions to be answered about the exact way in which the coherence between the projects will be monitored and about the division of tasks between different parties in managing and supervising the projects. In the Netherlands, government, industry and knowledge institutions have jointly formulated multi-year mission-oriented innovation programmes and the first projects under these programmes are currently being developed. Again, this still raises plenty of questions about project management, monitoring and evaluation.

The Rathenau Instituut would like to contribute to the further development of challenge-driven innovation policy. In this report we focus on a specific part of this policy innovation, i.e. on the question of what challenge-driven innovation policy means for the design and management of *research programmes*.

Since the emergence of innovation policy in the 1990s, research funders such as NWO have gained considerable experience in involving industry and other knowledge users in research programmes and projects and their governance. These include the Netherlands Genomics Initiative, the programme for Responsible Innovation, and the National Research Agenda. Public-private partnerships in

research are now an established part of the repertoire of innovation-driven research programming.

However, a *challenge-driven* approach requires further innovation in the way research is funded, programmed and supervised. According to existing practice, research programmes often give considerable leeway to individual researchers or research consortiums to formulate their own projects, whether or not within a thematic focus area. For example, in the case of project proposals aimed at societal breakthroughs NWO does ask applicants to make the intended impact clear in advance, based on a *theory of change*[2] or explicit *impact pathways*, but this only relates to the impact of the individual project. The question is whether this bottom-up approach of soliciting research proposals based on a work programme provides enough coherence and continuity in research. How do you ensure that it is not the interests and concerns of research groups that take precedence, but the question of what society needs to step up transitions? Mobilising scientific research to address a societal challenge seems to require more active involvement from programme management. The question is how.

1.2 Objective

The objective of this report is to contribute to the development of a new genre of *challenge-driven* innovation policy, to complement the existing genre of technology- and business-oriented innovation policy. We do this by formulating lessons on the design and management of challenge-driven research programmes.

This objective is consistent with the Rathenau Instituut's mission to support the political and public debate on the impact of science and technology on society with information and analysis to ensure that science, technology and innovation benefit society. Challenge-driven research programmes are an excellent means of ensuring that scientific knowledge is developed and deployed to achieve social goals.

This project builds on previous research into mobilising and coordinating diverse actors in research and innovation.[3] We have also previously conducted research into the management and programming of multi- and transdisciplinary research that is indispensable for tackling many societal challenges.[4]

2 A theory of change describes the causal relationships assumed between a particular intervention (such as a research project) and its intended impact on society.
3 For example, on living labs (*Living labs in Nederland*, 2017), research coordination (*Coördinatie van onderzoek in publiek-private samenwerkingsverbanden*, 2012) and social embedding of innovation (*Voorbij lokaal enthousiasme*, 2020).
4 For example, the report on knowledge co-creation (*Samen werken aan werkzame kennis*, 2012).

1.3 Our approach

The key question in this study is: what is needed to design and manage research programmes in a challenge-driven way? Our ambition is to provide practical insights for those involved in funding, designing, and managing research programmes, such as research funders, programme managers, and policy staff in the various government departments.

Our approach to answering this question consists of four components: desk research, an online workshop, three international cases and an empirical exploration.

Desk research
We first conducted desk research into recent trends in innovation policy in general and the role of research programmes within it in particular. Based on this research, we characterised challenge-driven research programmes in terms of their typical theory of change. Much has been written about the role of societal challenges and societal missions in innovation policy, but little about the implications for research programming. We found good pointers in the literature on transdisciplinary research because transdisciplinary researchers also need new ways of programming research. In transdisciplinary research, scientists work closely with practitioners such as health care workers or conservationists based on the realisation that input from different disciplines and domains is needed to arrive at integrated (systemic) solutions.[5] The ideas formulated from the transdisciplinary research tradition to programme research differently are also relevant to challenge-driven research programmes.

Online workshop
To complement the desk research, we also held an online workshop involving some 25 experts and policymakers. The aim was to organise a dialogue between policymakers and programme leaders on the one hand and researchers in the field of science policy and transdisciplinary collaboration on the other. This workshop was a digital alternative to a session we had prepared for the cancelled conference of the European Forum for Studies on Policies for Research and Innovation (Eu-SPRI) in Utrecht. The Rathenau Instituut collaborated with Dr Flurina Schneider of the University of Bern, an expert in research programmes for social transformation. We used the experience gained from this to deepen and refine our findings.

5 The OECD recently published a report on the potential of using transdisciplinary research to address societal challenges (OECD, 2020. Addressing socetial challenges using transdisciplinary research. OECD, Paris.)

International cases
Third, we looked at three international cases to learn how programming for mission-oriented research has been designed:

- The Climate Change, Agriculture and Food Security programme (CCAFS) run by CGIAR, an international NGO in the field of research on sustainable agriculture and development cooperation;
- The Defense Advanced Research Projects Agency (DARPA) in the United States;
- The *Utmaningsdriven innovation* (UDI, challenge-driven innovation) programme of VINNOVA, the Swedish innovation agency.

There are currently no longer-running research programmes that are designed and managed in a challenge-driven manner in all respects. We have therefore chosen programmes that have been around for a long time and each of them, in its own way, embodies an interesting aspect of the challenge-driven approach.

The CCAFS programme was chosen because, based on a well-developed theory of change, it seeks to ensure that research and innovation make a targeted contribution to sustainable agriculture in times of climate change. The DARPA case was chosen so that we could learn about the role of programme management throughout the programme cycle. The Swedish programme was selected because it seeks to mobilise consortiums that want to contribute directly to addressing a societal challenge through research and innovation. Because of their different approaches, they constitute extreme cases, each highlighting a particular aspect of a challenge-driven approach.

Empirical exploration
Finally, we also conducted an empirical exploration of current trends in research programming for the food transition in the Netherlands. This exploration is based on desk research, interviews with those directly involved and observations during online and in-person meetings. We held about ten exploratory interviews with various stakeholders, including policy makers in local and national government, researchers and stakeholders from bodies such as the Food Transition Coalition. We will describe this case by way of an interlude to illustrate the pitfalls that stakeholders may encounter when trying to deploy research and innovation to address a (contested) societal challenge.

1.4 Reading guide

In the next section, we first explain the key concepts of this report in more detail. Among other things, we explain what we mean by challenge-driven innovation

policy as a new genre of innovation policy, and how this relates to mission-oriented innovation policy. In addition, we draw on the literature to present an outline of challenge-driven research programmes in terms of their characteristic logic of change.

In Section 3, we discuss the three international examples, i.e. CCAFS, DARPA, and UDI. For each programme, we will discuss the approach at two levels: programme level and project support.

Section 4 formulates lessons for the coordination and management of challenge-driven programmes based on the literature and international examples. We will present these lessons in relation to ten phases in the life cycle of a research programme. The main concerns are active programme management and reflexivity.

Finally, in Section 5 we focus on the political and managerial context of challenge-driven research programmes. Precisely because of the normative orientation of these programmes, government will have to be an active partner. We cannot provide a blueprint for exactly how this role should be filled. If government is serious about challenge-driven innovation policy, this also requires a learning process with regard to its own role. This role will depend in part on the nature of the challenge, the capabilities of other parties and the choices made by politicians.

2 Challenge-driven innovation policy

2.1 A new genre of innovation policy

In recent years we have noticed a development in innovation policy in which the government is targeting its subsidies and other measures so as to tackle societal challenges. The development of innovation policy is often described in terms of three "generations".[6] First-generation innovation policy from the 1950s focused on enticing firms to invest more in research and technology development. Beginning in 1990, this policy was supplemented by encouraging cooperation in innovation systems. Since the mid-2000s, there has been an increasing focus on innovations aimed at effecting transitions needed to tackle societal challenges. Whereas societal transitions initially played a modest part in innovation policy, they are currently featuring more prominently. From 2020 onwards, the policy mix therefore consists of three parts: enticing industry to invest in research and technology development, encouraging public-private partnerships in research and innovation and addressing societal challenges (see box *Three generations of innovation policy*).

We explain the emergence of transitions as an additional motive for innovation policy by touching on two different trends. On the one hand, governments, civil-society organisations and research and innovation funders are gradually realising that a number of persistent problems in the world, such as climate change, declining biodiversity, an ageing population and economic inequality, cannot be solved without transitions. Addressing these challenges can only be effective if we radically change our economy and the way we have organised society. In particular, the United Nations Sustainable Development Goals are a powerful symbol for raising awareness of these issues. In addition, there is a growing belief that government is capable of guiding innovation.

6 See also Schot, J., Steinmueller, W.E., 2018. Three frames for innovation policy: R&D, systems of innovation and transformative change. Research Policy 47, 1554-1567. and the relevant article on the Rathenau website: https://www.rathenau.nl/en/knowledge-ecosystems/mission-driven-innovation-policy-what-how-why

Three generations of innovation policy[7]

From 1950 onwards: enticing industry
Up to and including the 1980s, government innovation policies primarily sought to entice industry to invest more in research and technology development by providing subsidies, tax breaks and intellectual property protection. The legitimacy for this policy was the principle of market failure: companies will be less inclined to invest in research and development (R&D) than is socially desirable because others will benefit from its results.

From 1990 onwards: connecting parties
Starting in the 1990s, the idea of national innovation systems came to predominate, with the government's primary role being to fix system failures. Innovation policy focused more on connecting actors in the innovation system, mainly by encouraging public-private partnerships between knowledge institutions and industry.

From 2020: stepping up societal transitions
In the past few years we have seen the emergence of a challenge-driven innovation policy alongside the existing genres. This policy aims to stimulate targeted and selective innovations that help to step up societal transitions. In this new approach, government has a more substantive and guiding role in helping to find innovative solutions and transition paths for pressing social challenges, such as the transition to a low-carbon economy or a circular economy (Schot & Steinmueller, 2018).

Mariana Mazzucato's work has shown how decisive publicly funded research has been for some of the technological innovations of the twentieth century and for the economic ascendancy of Silicon Valley in particular (Mazzucato, 2015). If government can exert so much influence on innovation in industry, why shouldn't government use it for public interests? Motivated by this initiative, more and more governments are orienting their innovation policies towards transitions, giving innovation policy broader legitimacy. Government interventions in this area no longer serve just to resolve deficiencies in the market and drive interactions in the innovation system that do not emerge spontaneously but also to address *transition failures*. Transition failure refers to the problem that desired social changes seldom

7 Based on https://www.rathenau.nl/en/knowledge-ecosystems/mission-driven-innovation-policy-what-how-why

get off the ground without government direction.[8] The new genre of *challenge-driven innovation policy* is therefore emerging in addition to existing policy.

This report is about organising research programmes as part of third-generation innovation policy. We want to explore how research programmes can be designed to contribute to transitions needed to address societal challenges. We therefore refer to *challenge-driven research programmes*, building on the concept of *challenge-driven innovation policy* that we introduced in an earlier report (Rathenau Instituut, 2020a) and a Message to Parliament (Rathenau Instituut, 2020c).

The public-private partnerships that the government has pushed as part of second-generation innovation policy, with schemes such as the Innovation-Oriented Research Programmes, the Leading Technology Institutes, and the BSIK/FES incentives were primarily established within the context of a technological promise or economic opportunity for industry. This includes the Dutch Polymer Institute (DPI), a leading technological institute which has developed high-level scientific knowledge about polymers and strengthened the links between knowledge institutions and industry. Initiatives such as the DPI have enhanced the competitiveness of Dutch industry and the development of knowledge ecosystems. A number of programmes have also certainly contributed to sustainability or other social goals. However, addressing a societal challenge was rarely their primary goal.[9]

A more coherent and integrated approach is needed to effectively address persistent societal problems. An illustration of this is the OECD's 2015 analysis of the Dutch agricultural research and innovation system (OECD, 2015). The report underscored the fact that although this system is very effectively designed to increase productivity, it is inadequately equipped to make Dutch agriculture climate-smart.

Challenge-driven innovation policy is distinguished from second-generation innovation policy in that its primary goal is stepping up and/or adapting societal transitions. The basic premise of this policy is that more innovation is not always better, but that innovation should be used selectively and in a targeted manner to achieve social objectives. In this genre of innovation policy, government provides new *direction* for innovation policy *(directionality)*.[10]

---

8 Frenken, K., Hekkert, M.P., 2017. Innovatiebeleid in tijden van maatschappelijke uitdagingen, Sturen in een verweven dynamiek. Ministerie van Economische Zaken.

9 A good example of a public-private research programme that did explicitly focus on a societal challenge is TransForum (sustainable agriculture), but this programme did not come about thanks to challenge-driven innovation policies. The challenge-driven approach was the initiative of the consortium partners rather than the grant scheme that funded it (BSIK/FES).

10 See, for example Schot, J., Steinmueller, W.E., 2018. Three frames for innovation policy: R&D, systems of innovation and transformative change. Research Policy 47, 1554-1567.

In this connection, challenge-driven innovation policy is based on a very different theory than previous generations of innovation policy. The societal challenge is not primarily defined as an economic opportunity for industry. Challenge-driven innovation policy considers the societal challenge as a complex and multifaceted problem for which different solutions must be developed *in conjunction*. According to this policy theory, societal transitions are needed to bring about system-level change, i.e. a coherent set of innovations that collectively add up to system change.[11]

With this goal in mind, challenge-driven innovation policy uses a broad definition of innovation. The basic premise is that for an innovation to be a success, it must be socially embedded. This requires research and development in multiple dimensions. Besides technological development, economic, legal and socio-cultural perspectives are particularly important.[12] In many cases, therefore, an interdisciplinary or even transdisciplinary approach is required.

Moreover, challenge-driven innovation policy must anticipate the (sometimes unintended) impact of innovation on society, especially when it comes to radical innovations that can become part of disruptive system changes. To this end, the principles of responsible research and innovation provide guidance.[13]

According to the scientific literature, challenge-driven innovation also requires greater diversity in knowledge networks and partnerships than conventional innovation policy, which focuses on companies, consortiums and knowledge institutions. In addition to the usual focus on researchers and entrepreneurs who explore and exploit new technological options, challenge-driven innovation policy therefore also focuses on the actors who have to embed the innovations in society and ensure that they become part of the envisaged system changes.[14] Depending on the type of challenge, these can be consumers and professional users, network managers, regulatory and supervisory bodies, civil society organisations, interest groups, residents' associations, standardisation organisations, water boards, provinces or municipalities and their departments. For this, the government will have to develop appropriate instruments to organise and monitor cooperation and exchange.

---

11 Ibid.

12 Rathenau Instituut, 2019. Voorbereid op de praktijk: anticiperen op de maatschappelijke inbedding van innovatie bij onderzoeks- & ontwikkelprogramma's. Rathenau Instituut, The Hague.

13 For more information, see:von Schomberg, R., 2013. A vision of responsible innovation, in: Owen, R., Heintz, M., Bessant, J. (Eds.), Responsible Innovation. John Wiley, London.

14 Kuhlmann, S., Rip, A., 2018. Next-generation innovation policy and grand challenges. Science and Public Policy 45, 448-454.

2.2 Missions in challenge-driven innovation policy

The new orientation of innovation policy towards societal challenges is mainly identified in the scientific literature as the emergence of mission-oriented innovation policy.[15] In addition to numerous academic articles, reports by TNO (TNO, 2018), the OECD (Larrue, 2021) and the European Commission (Mazzucato, 2018) have recently been published with pointers for the further development of this type of policy. Utrecht University has set up a special policy lab to analyse mission-oriented innovation policy[16] and TNO is participating in an international observatory for mission-oriented research and innovation.[17] A characteristic of mission-oriented policy is that it formulates specific, ambitious but achievable goals.

The Rathenau Instituut has deliberately chosen the broader term *challenge-driven* to highlight the complexity and multifaceted nature of societal challenges. Formulating missions with specific goals can be a powerful tool for challenge-driven innovation policy, but it will not always be necessary or possible. Missions are especially meaningful when there is agreement on the direction of the solution route. This was the case, for example, when a mission approach was used in the space and defence industries in the past. The most famous example is probably the legendary Apollo project in which NASA went all out to put a man on the moon in the foreseeable future. But also, closer to home, the Delta Works can be seen as a mission-oriented project for which much (mainly technological) research and innovation had to be mobilised with the clear goal of protecting the Netherlands from the sea.

To use missions as part of a challenge-driven approach, they must form a link within a broad and far-reaching change process whose solutions are only partially known. Creating such a mission requires more than just research and technology development. For example, major changes are needed in existing food production and distribution systems in order to step up the transition to circular agriculture. Technological innovation is only one dimension of this transformation process. Innovations in production chains and revenue models, changes in legislation, and changes in the attitudes and routines of farmers, supermarkets and consumers, for example, are at least as important.

The advantage of choosing the term *challenge-driven* instead of mission-oriented is that it emphasises that missions are only one part of the policy mix which

15 For an accessible introduction, see Janssen, M., Hekkert, M., Frenken, K., 2020. Missiegedreven innovatiebeleid: een nieuw perspectief op vernieuwing en vergroening Wetenschappelijk Bureau GroenLinks, Utrecht.

16 https://www.uu.nl/en/research/copernicus-institute-of-sustainable-development/mission-oriented-innovation-policy-observatory

17 https://jiip.eu/mop/wp/

governments can use to tackle major societal challenges such as the climate challenge. By using the term "challenge-driven" we want to take account of the uncertainty, complexity and (often) controversy that characterise transitions.

Transitions cannot be planned. This means that government has to adopt a reflexive attitude, experiment with new instruments and institute a learning process to constantly improve its own approach. Stefan Kuhlmann and colleagues (Kuhlmann et al., 2019) therefore speak of "tentative governance arrangements," a policy approach that takes a tentative position but constantly adapts it as needed. In this case, public and private interventions and actions form part of a continuously evolving process that is adjusted and adapted along the way. This attitude also chimes with the trends of *adaptive governance* in environmental management and *anticipatory governance* of innovation.[18]

It is not immediately obvious how missions based on specific goals and timelines can be fitted into such a flexible and learning strategy. They can only make a powerful contribution to transitions where sufficient learning capacity and reflexivity have been organised at the overarching level of the transition approach. In our project, we will be exploring the possible demands this places on the coordination and governance of research programmes.

2.3 The logic of challenge-driven research programmes

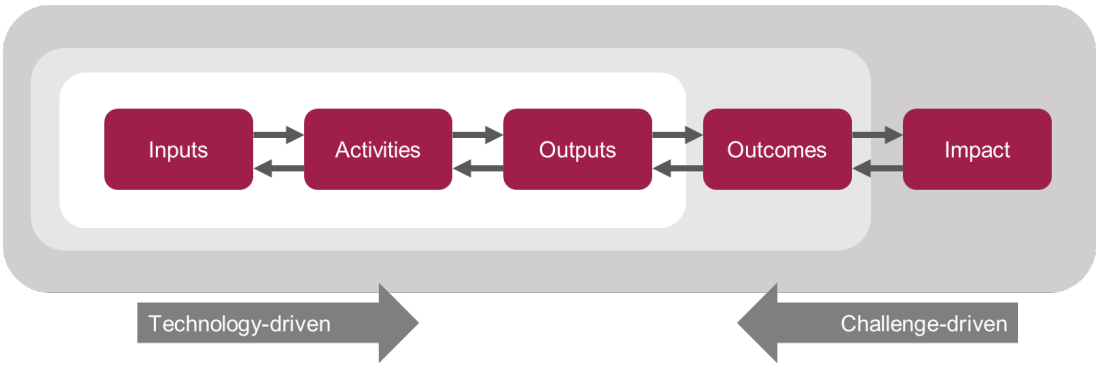
Despite the increasing amount of literature on mission-oriented and challenge-driven innovation policy, relatively little has been written about the organisation and governance of challenge-driven research programmes. In this section, we use the more general literature on the new generation of innovation policy to outline challenge-driven research programmes in terms of their theory of change. This outline serves as a basis for examining the design and management of these types of programmes based on the practice in some international examples (Section 3).

A theory of change describes all the expectations people have about the way activities will lead to a change in practice and in society. It is a cause-and-effect reasoning in which *inputs* (resources, such as time, money, and expertise) are used in a mix of *activities* that will lead to *outputs* (results of the activities). The use of

18 See, for example Folke, C., Hahn, T., Olsson, P., Norberg, J., 2005. Adaptive governance of social-ecological systems. Annu. Rev. Environ. Resour. 30, 441-473.; Guston, D.H., 2014. Understanding 'anticipatory governance'. Social Studies of Science 44, 218-242.

these outputs will lead to *outcomes*, which will then contribute to effects at the level of *impacts* (see Figure 1).

Figure 1 Theory of change as cause-and-effect reasoning



In conventional innovation policy, a theory of change is used (implicitly or explicitly) to show what economic and social impacts are possible thanks to investments in research, development and innovation. This helps to legitimise public investment and, in addition, to take into account at an early stage the possible application of the results in practice, so that attention can be paid to the broader embedding of the innovations in society.

Typically, a challenge-driven theory of change starts with a complex societal change challenge. Impact is formulated in terms of the contribution to be made to addressing a complex societal change challenge. One example would be the energy transition that requires a fundamental socio-technical systems change in the way we produce, distribute and use energy.

The cause-and-effect reasoning starts with a socio-technical system innovation and step by step we work back through outcomes to the kinds of outputs, activities, and inputs that are required for them. This kind of challenge-driven theory of change helps to make choices about what activities are suitable for creating the desired impact paths.

Challenge-driven theories of change take a broad view of what counts as relevant outcomes, outputs and activities. After all, challenge-driven research programmes

are about targeted and coherent innovations that can add up to integrated solutions and changes at system level.[19] [20]

System change not only requires technological innovation, it also needs social innovation. For example, in addition to disciplinary scientific research, there will be room for other knowledge practices, such as bringing together existing knowledge from different disciplines and domains, co-creation with practitioners or individuals and embedding innovations in practice and society. This means that in addition to a holistic view, a forward-looking and anticipatory view is needed to mobilise a wider range of actors and activities.

Another important output of challenge-driven research programmes could be the creation of new knowledge networks that help to strengthen research and innovation ecosystems around a specific societal challenge. Thus, typical *outputs* need not be defined only in terms of research results, but can also be formulated in terms of new combinations of existing knowledge from different domains or of new networks and relationships (in knowledge ecosystems).

By characterising a challenge-driven theory of change as above, we mainly want to show that the perspective on what counts as relevant knowledge, as relevant knowledge activities or as relevant knowledge partners becomes much wider. This is not to say that all challenge-driven programmes always have to utilise this perspective to its full extent or that research must always be multidisciplinary or transdisciplinary. It is even quite conceivable that a programme might decide to focus on basic disciplinary research if the theory of change shows that a lack of fundamental knowledge is a major problem.

19 Kuhlmann, S., Rip, A., 2018. Next-generation innovation policy and grand challenges. Science and Public Policy 45, 448-454.

20 Schot, J., Steinmueller, W.E., 2018. Three frames for innovation policy: R&D, systems of innovation and transformative change. Research Policy 47, 1554-1567.

Interlude - Food transition

Introduction: the food system is stuck

Farmers' protests, potato surpluses and distressing figures on biodiversity loss: our agriculture and food system is squeezed on all sides, as Carola Schouten, the then Dutch Minister of Agriculture, Nature and Food Quality also wrote in her 2018 vision for the future.[21] The need to change the current situation is very urgent. In the Netherlands (and the rest of Europe), the credo "Never hungry again" has led to increasingly efficient food production in recent decades, focused on economies of scale and exporting. It is now clear that our environment is paying the price for this.[22]

Most parties seem to agree on the question of *whether* the current agricultural and food system is in need of a thorough overhaul.[23] But a unanimous answer to the question of *what* this system should look like - and, consequently, what changes will be needed and who will have to bear the burden - seems to be a distant prospect at present. From the report of the first election debate of 2021 by newspaper Trouw: "All parties agree with the statement that farmers can hardly run a profitable business any more, but the solutions vary from 'halving livestock' (D66 and GroenLinks) to 'it's not right to blame farmers' (CDA and PVV)".[24]

Moreover, the discussion about the transition to a sustainable agricultural and food system affects not only the farmer, but also the processing industry, the multinational food corporations, the large supermarket chains and ultimately all of us as individuals and consumers. Farming differently, producing differently, eating differently: the transition to a sustainable agricultural and food system is not so simple.

An additional exploration

In this report, we explore what it takes to develop challenge-driven research programmes. To answer this question, we analyse three cases, each of which has some characteristics of a challenge-driven approach. Indeed, *fully* challenge-driven research and innovation programmes are not yet commonplace in the real world.

---

21 https://www.rijksoverheid.nl/ministeries/ministerie-van-landbouw-natuur-en-voedselkwaliteit/documenten/beleidsnota-s/2018/09/08/visie-landbouw-natuur-en-voedsel-waardevol-en-verbonden
22 https://www.cbs.nl/nl-nl/corporate/2020/06/zicht-op-100-jaar-afname-biodiversiteit-in-agrarisch-gebied
23 https://www.agf.nl/article/9289914/noodzaak-transitie-naar-duurzame-landbouw-erkend-in-verkiezingsdebat/
24 https://www.trouw.nl/politiek/in-het-eerste-lijsttrekkersdebat-komt-wilders-als-sterkste-naar-voren~be2bf7ce/

To gain an insight into the challenges parties face when trying to put a challenge-driven approach into practice, we conducted an additional exploration for which we used the transition to a sustainable agricultural and food system, or food transition for short, as a case study. In this interlude[25] we report on this exploration with regard to the following two questions:

- What issues do parties face when deploying research and innovation to step up the food transition?
- What insights does this provide for challenge-driven programming of research and innovation?

Research and innovation do not equal structural change

Politicians, farmers and businesses all hope that research and innovation will help develop insights and solutions that can speed up the shift to a sustainable food system, e.g. by developing new farming techniques, innovative products and sustainable revenue models for producers.

While our interlocutors endorse the importance of research and innovation, they question the assumption that investing more in research and innovation will naturally lead to innovation and therefore speeding up of the transition. After all, the transition to a sustainable food system requires *system change.* In this regard, research and innovation - and the parties involved, funding structures, partnerships - are not separate from the system but are themselves part of it.

In a recent Letter to Parliament, Minister Schouten stated: "[...] that research and innovation are at the heart of the success of Dutch agriculture, horticulture and fisheries."[26] This quote illustrates the interconnectedness of the current research field with these industries. Take Wageningen University and Research (WUR). WUR has traditionally had a leading position in agricultural research, education and consultancy and from this position has made a significant contribution to the development of current agricultural practices. Or take the evolution of the food supply: consumer preference-inspired product innovations have led to the massive range of products we now find in the supermarket.

Existing research and innovation ecosystems are therefore closely linked to the current agricultural and food system. The analysis of the Dutch agricultural innovation system presented by the OECD in 2015 endorses this observation: research and innovation mainly contribute to increasing productivity and exports, but are insufficiently focused on making the agricultural system more sustainable (OECD, 2015).

---

25 This interlude is based on a number of informal conversations with various parties involved in research and innovation in the agriculture and food domain and on relevant policy documents and articles. In this interlude we give an impression of the practice appropriate to the main questions of this report. In doing so, we cannot do full justice to the complexity of the discussion on the transition to a sustainable food system.

26 https://www.rijksoverheid.nl/documenten/kamerstukken/2021/02/10/kamerbrief-over-inzet-speciaal-gezant-innovatie

Thus, if the goal is to change the current system, this raises questions about the organisation of research and innovation as part of this system. What kind of research and innovation ecosystems do we need? How can or should existing ecosystems change with them? And how can we get that done?

We highlight two practical challenges faced by policymakers seeking to drive a transition in such an environment, i.e. positioning the programme and encouraging innovation.

Positioning the programme within the societal challenge
Researchers and companies who want to contribute to the transition to a sustainable food system through research and innovation find that they become part of the normative discussion surrounding the challenge. The *struggle* over the transition to a sustainable food system is echoed in the discussion of what research is needed, who decides, and then who can participate.

In some cases, even the question *of whether* investing in research and innovation makes sense is up for debate. For example, we heard from innovators in the sector that they sometimes experience investment in research as a strategy of policymakers to avoid or postpone making policy decisions and taking concrete action.

Even when government, knowledge institutions and industry agree on the importance of research and innovation in a general sense, their visions of the necessary direction of innovation can clash. For example, farmers who advocate commitment to further technological development may find themselves diametrically opposed in the public debate to colleagues who advocate commitment to experimenting with nature-inclusive forms of agriculture (known as the technologists versus ecologists debate).[27]

These examples show that the content and form of research within a contested societal challenge can be controversial. What this means for challenge-driven programmes is that they cannot avoid their partly normative nature. A key challenge for this type of programme is therefore to be transparent and reflexive about how the approach within the programme relates to the societal challenge. Discussing the programme's theory of change and making it explicit can help achieve this.

Stimulating innovation
Research and innovation can never provide a complete solution to a complex societal challenge: it also requires political choices and specific changes. For example, the transition to a sustainable food system will require farmers to cultivate their land differently and consumers to change their eating habits.

27 https://www.volkskrant.nl/kijkverder/2018/voedselzaak/artikelen/weg-met-het-hokjesdenken-in-de-landbouw

The lesson is that all parties necessary to bring about specific change must be involved in the design and implementation of the programme. Thus, the design of a challenge-driven research programme is not just a matter for researchers and technology developers. In our interviews, for example, it emerged that "new" parties - such as (innovative) farmers or civil-society organisations - cannot easily join existing programmes because they are not seen as relevant knowledge partners or cannot claim financial support for participation. This is problematic because parties with practical experience should be able to share their thoughts about what innovations are necessary and feasible and how they can then be put into practice.

A similar conclusion was drawn from the debate organised by the Rathenau Instituut in 2019 on how knowledge can contribute to the transition within the agricultural sector: a bridge needs to be built between research, education, practical applications, industry and government policy.[28] Circulation of knowledge is vital in this regard because there is also a lot of knowledge to be gained on the farm. Experiences and questions from the field should therefore be part of joint research programming.

The recent review of the FoodSwitch proposal submitted to the Dutch National Growth Fund shows that this perspective is increasingly shared.[29] In justifying the decision not to fund the proposal, the assessment committee indicated, among other things, that the proposal does not sufficiently involve the demand side and does not provide enough space for new players, despite the fact that they are badly needed for change and innovation.[30]

In conclusion: shared responsibility

As described in the introduction, we see from the agriculture and food domain that there are still many differing views on the route to be taken towards system change. We see a similar diversity in the (current) research and innovation landscape: from scientific programmes that focus on technological innovations[31], to civil-society parties that experiment on a small scale with an area-based approach[32], and multinationals such as Unilever that invest in numerous innovations within their own ranks because they consider it necessary to have a fundamental transformation of the food system.[33]

28 https://www.rathenau.nl/nl/terugblik/maatschappelijke-transitie-alleen-mogelijk-met-circulaire-kennis
29 https://www.rijksoverheid.nl/documenten/publicaties/2021/04/9/rapport-beoordelingsadviescommissie-ngf-eerste-ronde
30 https://www.nationaalgroeifonds.nl/documenten/rapporten/2021/04/09/adviesrapport-eerste-beoordelingsronde-commissie-nationaal-groeifonds
31 https://www.wur.nl/en/Dossiers/file/dossier-precision-agriculture.htm
32 https://www.staatsbosbeheer.nl/Over-Staatsbosbeheer/Dossiers/natuurinclusieve-landbouw
33 https://www.unilever.nl/news/overig-nieuws/2019/unilever-opent-nieuw-foods-innovation-centre-in-wageningen.html

It is a given that a variety of parties, programmes and projects cluster around a particular transition. To avoid fragmentation and a lack of direction, various parties, including the Dutch Food Transition Coalition[34], stress the importance of conducting a clear problem analysis in advance, and of having a shared vision of how the various projects and programmes are interrelated and can build on each other.

Ultimately, it's about political choices: how do we want to change our agricultural and food system? And how do we use research and innovation to contribute to these choices? Precisely because this requires balancing (conflicting) interests and potentially drastic changes, politicians and policymakers will have to be actively involved in this.

Learning along the way about what is a good approach to the challenge is key. However, within the agriculture and food domain, stakeholders point out that as long as politicians and policymakers lack a clear overview and direction, there is a high probability that businesses and researchers will continue to work on different futures for too long.

34 https://transitiecoalitievoedsel.nl/wp-content/uploads/2020/05/Voorstellen-missiegedreven-innovatie-van-TcV.pdf

3 Three international examples

In this section, we provide three examples of how different international organisations are trying to use their programmes to mobilise research and innovation to address a societal challenge. The three examples are:

- CGIAR's Climate Change, Agriculture and Food Security (CCAFS) programme. CGIAR is a global partnership of international organisations engaged in food security research which aims to reduce rural poverty, increase food security, improve health and nutrition and make natural resource management more sustainable.
- The Defense Advanced Research Projects Agency (DARPA), an agency of the US Department of Defense, which is responsible for developing emerging technologies for use by the military.
- The Utmaningsdriven innovation (UDI, challenge-driven innovation) programme of VINNOVA, the innovation agency of the Swedish government. The UDI programme focuses on funding projects that seek to make a specific contribution to addressing a societal challenge within one of the United Nations Sustainable Development Goals.

All three organisations are tasked with helping to address a specific societal challenge. Each organisation tries in its own way to ensure that its programme and projects make a contribution. We see differences and similarities in the way the organisations develop this focus in the design and implementation of specific programmes. The examples therefore serve as an illustration of and inspiration for ways of developing a challenge-driven approach to the design and implementation of research programmes.

For the case descriptions, we consulted various sources to get an impression of how the different programmes work and made a selection of relevant material for each example, based on availability and quality. The description of CGIAR/CCAFS is based on public information provided by CGIAR. For the description of DARPA, we relied primarily on public information and several chapters from the book *The DARPA Model for Transformative Technologies Perspectives on the US*: *Defense Advanced Research Projects Agency* (Bonvillian et al., 2019). Finally, for the description of the UDI programme, Technopolis Group conducted a preliminary study commissioned by the Rathenau Instituut, which has also allowed us to utilise Swedish-language material. For a complete overview and justification of sources used, please refer to Appendix 1 of this report.

The section is structured as follows. First, we introduce the framework we use to analyse the three cases. We then provide a brief description of each case. In the final paragraph of this section, we show the pointers a comparison of the different cases provides for the further development of a challenge-driven approach to research programming.

Lessons learned from transdisciplinary programmes

A key feature of challenge-driven research programmes is that they seek to involve different parties in the production and application of knowledge, including researchers from different disciplines and professionals from the field. Precisely because of the complexity of societal challenges, the programmes must bring together diverse parties to jointly develop knowledge. Experience with this form of collaboration has been gained in recent decades in the school of *transdisciplinary* research.

This framework discusses the relevance of transdisciplinary experience for coordinating and managing challenge-driven research programmes, based on academic literature and a workshop[35] involving policymakers and experts in mission-oriented innovation policy and transdisciplinary research.

In transdisciplinary research, researchers from different disciplines collaborate with practitioners. Like challenge-driven research programmes, transdisciplinary programmes often focus on a societal challenge. The OECD recently emphasised the added value of adopting a transdisciplinary approach to societal challenges (OECD, 2020). The survey also showed the problems that can arise when putting a transdisciplinary approach into practice. This report shows that the way we fund and organise research is often not appropriate for transdisciplinary collaboration.

Transdisciplinary research programmes are not the same as challenge-driven programmes as in a challenge-driven programme not all the research needs to be transdisciplinary. On some issues, a monodisciplinary approach (input from a single scientific discipline) or an interdisciplinary approach (integration of research from different disciplines, without an explicit role for practitioners) will suffice. The type of research needed is determined by the theory of change

35 This online meeting was held on 18 June 2020. For more details, see Section 1.3.

and the specific contribution the programme seeks to make to the pace or direction of societal transition.

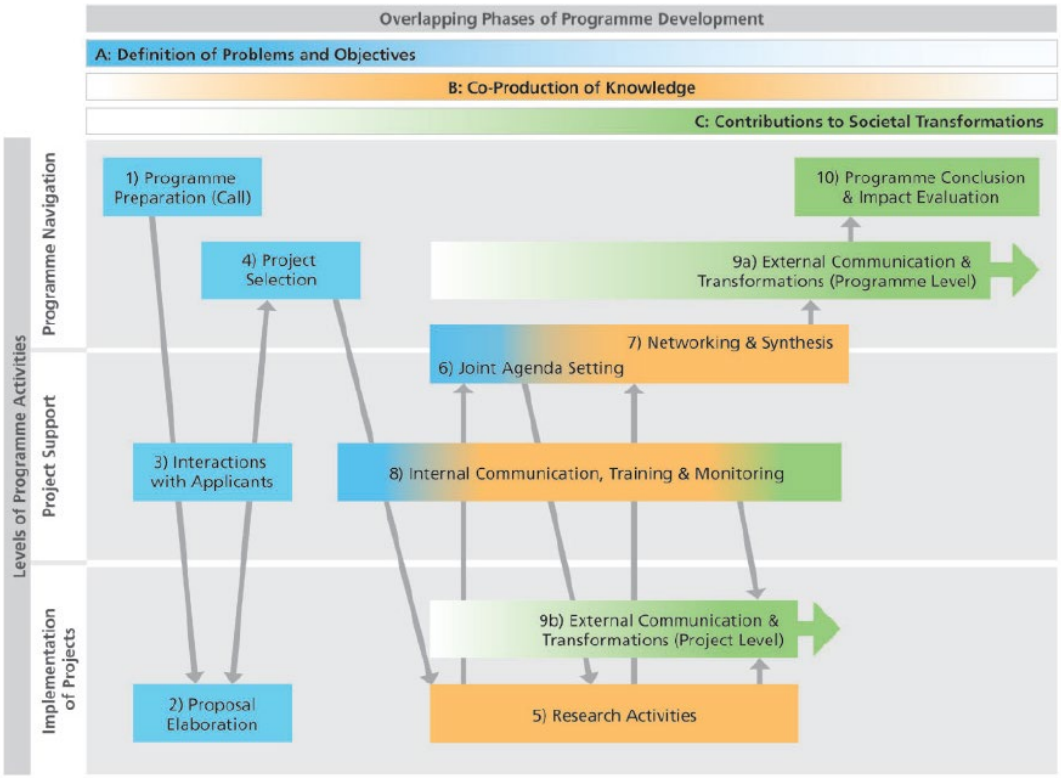
In addition, the aim of challenge-driven programmes, more so than transdisciplinary programmes, is to help address a particular challenge. This direction means that challenge-driven programmes place a greater emphasis on both connecting parties within the programme and coordinating with and following developments outside the programme

Despite these differences, the insights gained from transdisciplinary research offer valuable pointers for the design of challenge-driven programmes. What experience with transdisciplinary research has taught us is that bringing together different parties and integrating different perspectives is quite a challenge. We have also learned that programmes whose ambition is to connect different parties and have them develop knowledge together require a wider interpretation of the role of programme management than is usual. This mainly involves creating synergy between projects, supporting researchers with new ways of working and ensuring that both the various projects and the entire programme are and remain focused.

3.1 Analytical framework

To analyse the cases, we build on a model developed by Flurina Schneider and colleagues based on experience gained from a number of transdisciplinary research programmes (Figure 2) (Schneider et al., 2019). In this model, they distinguish between activities at programme level and at project level. Between them is the project support level: interventions from the programme to assist the projects to optimise their contribution to the programme. During the programme cycle, different types of activities, such as programme preparation and project selection, can be clustered into ten steps spread across these three levels (see Figure 2). In this report, we will use this diagram as a framework for analysis.

Figure 2 Ten stages in the development of research programmes (Schneider et al., 2019).



This model involves three levels of activity: (1) programme, (2) project support and (3) project implementation. We are disregarding Level 3, project implementation, because we are specifically interested in the role of programme management. Our analysis therefore focuses on the programme level and project support.

Programme level

Activities at this level focus on aligning the programme and its portfolio of projects with the societal change challenge. At this level, the issue is how the stakeholders involved develop the programme's theory of change and how they determine what kinds of activities and projects are needed to achieve the intended outcomes and social impact. How do they ensure that developments in the programme's environment are considered during the course of the programme in order to make interim revisions to the theory of change and associated activities and projects, if necessary?

Project support

This level is between the programme and the projects. At this level, the issue is how the programme aligns the goals of individual projects with the programme goals and what the parties involved are doing to monitor this coherence. In what ways does

programme management monitor the progress of specific projects? To what extent and in what ways do they adapt the projects where necessary? To what extent and in what ways does programme management provide for a coherent portfolio of projects? For example, do they agree data and other standards and/or concepts to be used in the projects? Does programme management have requirements as regards the circulation and aggregation of project results?

In the sections below, we use the two levels to show the extent to which and the ways in which the three organisations put their research programmes to work addressing a societal challenge. In each case, we first provide a brief introduction to the organisation and then cover the activities at both the programme and the project support level. In Section 4, we will formulate points of interest for each of the ten steps in the diagram.

3.2 CGIAR/CCAFS

CGIAR, formerly the *Consultative Group for International Agricultural Research*, has been conducting development research in the field of agriculture since 1971. It is a network of fifteen research centres located around the world. Each centre focuses on a specific area of agriculture. For example, there are centres that do research into rice in the Philippines and Côte d'Ivoire, a centre that focuses on corn and wheat in Mexico, a centre in Malaysia that focuses on fisheries and a centre in Kenya that focuses on forestry. CGIAR operates research programmes that link the research of the fifteen centres, focusing on a topic that goes beyond the scope of the individual research centres.

One of these programmes is the CCAFS programme, which stands for *Climate Change, Agriculture and Food Security*. This programme focuses on the impacts of climate change on agriculture and the food supply and aims to make agriculture and the food supply *climate-smart*. CCAFS contributes to CGIAR's three goals, i.e. reducing poverty, increasing food security and improving natural ecosystems.

CCAFS works with four substantive focus areas *(flagships*): climate-smart agricultural practices; low-emission agriculture; climate information services, weather reports and insurance services; and climate-smart agriculture policy. In addition, CCAFS has two intersecting focus areas: one on gender and inclusiveness and one on upscaling climate-smart agricultural practices.

CGIAR receives funding from a wide range of donor organisations. These organisations include member states such as the Netherlands and non-governmental organisations including the Dutch SNV. The organisation also

receives contributions in kind from universities, including Wageningen University & Research. Its annual budget is between USD 800 and USD 900 million (approximately EUR 680 - EUR 760 million). The annual budget of the CCAFS programme is over USD 50 million (over EUR 40 million).

Programme level
CGIAR aspires to a world free of poverty, hunger and environmental degradation. The management of the CGIAR umbrella group has a key role in aligning the work of the various research centres with the wants and needs of the donors and the host countries in which the research is conducted. Representatives of donors and host countries are involved, having seats on the CGIAR supervisory board. This board oversees CGIAR's strategy, mission, impact and continued relevance.

CGIAR aims to make a substantial contribution to solving the world food problem. To keep activities within the various centres and programmes aligned with this goal, CGIAR operates with (1) central programming of the research conducted by the fifteen centres; (2) a theory of change, goals and outcome measures at every level; and (3) an active commitment to the ongoing dissemination and application of the knowledge and insights developed.

Central programming
To encourage coherent research within the CGIAR network, CGIAR operates centrally determined, results-oriented research programmes in which the various CGIAR research centres collaborate. CCAFS is an example of such a collaborative programme. By developing these programmes, CGIAR aims to bring together work from the various centres and improve its alignment with CGIAR's overarching goals.

CGIAR writes of the CCAFS programme that it is intended to boost CGIAR's research and expertise in climate-smart agriculture, food systems and landscapes. Furthermore, it should ensure the integration and coordination of all CGIAR's climate research to maximise CGIAR's contribution. The CCAFS programme therefore links all the research by the fifteen centres into climate-smart agriculture and, for this reason, can also coordinate it.

CGIAR has to a great extent structured the development and approval of the programmes. For example, in 2015, CGIAR published a 67-page document describing the process of establishing a portfolio of research programmes, including ambitions, requirements and responsibilities. CGIAR expects a coherent set of twelve interrelated proposals, names the programmes and specifies the budget for each programme.

Theory of change at every level
CGIAR works at all levels (organisation, programme and subprogramme or flagship) with theories of change, goals and outcome measures. In recent years, CGIAR has been using the United Nations Sustainable Development Goals as a frame of reference. It has developed precise outcome measures based on these sustainable development goals, on CGIAR's objectives and also on the wants and needs of the donors and host countries involved.

The CCAFS programme consists of a number of subprogrammes known as "flagships". Each of the flagships is assigned a theory of change that defines its vision, assumptions, actions and specific objectives, e.g. the flagship that focuses on the provision of services. This flagship's vision is for effective climate services to be available to farmers in Asia, Africa, and Latin America (weather reports, historical climate data) and for them to be protected with the right financial safety nets (loans for the purchase of commodities, such as seeds, and insurance cover against, for example, damage caused by extreme weather). The assumption is that farmers need this to make the transition to climate-smart agriculture and that it will give them a more resilient income position. Examples of outcome measures for this flagship include "15 key regional and national organisations have developed and improved demand-driven equitable climate services in support of local farming communities, based on CCAFS research" and "8 million farm households have improved access to weather-related insurance - this also benefits women."

CCAFS monitors the progress of the various flagships from the umbrella programme. If the results differ from expectations, there is scope for adjusting the underlying theory of change accordingly.

Dissemination and application
CCAFS anticipates further use of the research results in several ways. The programme actively seeks collaboration with local farming communities and other organisations on the ground, such as cooperatives and agricultural agencies. The programme therefore increases the likelihood of developing solutions that are field-tested and found to be applicable.

Complementarity is a major concern. A good example is the choice of regions in which it conducts research. CCAFS researches and develops solutions for a diverse range of agricultural practices (products, cultivation methods) and climate issues (subsoil, desertification, heavy rainfall). When selecting regions, the programme explicitly takes into account the differences between them. The result is a diverse and complementary portfolio of regions which allows different solutions to be developed *and* tested at different locations in the programme.

Project support
CGIAR uses the CCAFS programme as a means of coordinating the work of the fifteen research centres and focusing it on a number of specific goals. The starting point for programming is the research by challenge-driven research centres and the programme provides an additional dimension. For this reason, CCAFS does not use open calls. We did not find any information as to whether and, if so, how CCAFS attempts to adapt individual projects.

CGIAR and CCAFS spend a lot of time and effort monitoring progress and results and reflecting on their own actions. Responsibility for monitoring management and progress rests with the project, region and flagship. The very precise outcome measures make it clear whether the project, region or flagship is contributing as anticipated. When things change, the question arises whether the theory of change needs to be adapted accordingly.

An example of ways in which the programme is trying to ensure that the projects anticipate large-scale application in practice is the *Learning Platform on Partnerships and Capacity for Scaling Climate-Smart Agriculture.*[36] This is a cross-cutting flagship that exists alongside four substantive flagships in the CCAFS programme. The goal of this platform is to learn what is required to make locally developed solutions applicable elsewhere. The main focus is therefore on disseminating knowledge, training users and developing partnerships.

CGIAR/CCAFS have many ways of trying to ensure that projects are coherent and the portfolio is balanced. For example, projects are expected to do more than just develop and test a solution for the specific situation. The ability to apply this solution elsewhere is an important selection criterion, and complementarity is a major consideration when choosing new regions.

Interaction with stakeholders within CGIAR/CCAFS is also important at project level. The method developed in the programme, the *Climate Smart Village* (CSV), is an example of the participatory approach. In local farming communities, researchers test and develop new approaches and solutions to local problems. When choosing a location, aspects such as the type of issues CCAFS wants to work on, the presence of research capacity and the possibility of working with a variety of local parties - i.e., not only farmers but also agricultural agencies and cooperatives - are considered.

The choice of a CSV location is made in consultation with local parties who have knowledge of local practices and the situation on the ground. CCAFS tries to take

36 https://ccafs.cgiar.org/flagships/scaling-climate-smart-agriculture/approach#.X5vpalAo-Ul

into account the specific knowledge and practices that different parties bring, whether they are farmers, agricultural agencies, agricultural cooperatives, businesses or governments.

When a potential location has been selected, CCAFS researchers approach local parties to jointly determine what the issues are and what they need. Then, a joint workshop is held to choose one or more options to be developed or tested locally. Ideally, some of this testing should also be done by the local parties themselves as, ideally, these approaches will be adopted over time by the farming community concerned. The CSV aims not just to benefit the farming community directly involved, it should also provide an insight into opportunities for scaling up. The results of the CSV will then be further developed, tested elsewhere and, ideally, applied in more locations. The development of the CSV approach illustrates the way CCAFS anticipates its potential application in practice.

Over the course of the programme, CSV proved to be such a successful approach that other parties and organisations showed an interest in adopting the approach. For example, the Vietnamese agriculture ministry wants to apply the CSV approach, which, of course, goes some way towards meeting CCAFS's goals. It has therefore now presented the approach as its own product and developed a "train-the-trainer" guide.[37]

CCAFS operates on a three-thirds principle.[38] One third of the effort is expended on engaging stakeholders to jointly determine what research should be done and how. One third on doing research. And one third on strengthening *next users*, parties who will be involved in the further development and application of the research results. CCAFS has adopted this important principle to facilitate continued use. Close engagement with stakeholders provides a better understanding of the issues, inspiring confidence in CCAFS and in the approach being developed. Any new networks and partnerships needed to follow up the project locally can be established at any time throughout that process.

3.3 DARPA

DARPA, the US Defense Advanced Research Projects Agency, is tasked with funding the development of groundbreaking technologies to provide a powerful impetus. Central to this are the programme managers and the directors, aided by clearly defined programme-specific goals and outcome measures.

37 Gonsalves J, Baguilat I, Bantayan R, Bernardo EB, Sebastian L. (2020) *Eight guide steps for setting up a Climate-Smart Village: A trainer's guide*. Cavite, Philippines: International Institute of Rural Reconstruction.
38 CCAFS (2020) CCAFS 2019 Annual report

DARPA's creation and remit was prompted by what is known as the Sputnik Shock. The US thought it had technological superiority over the Soviet Union and felt caught off guard when the soviets launched their first spacecraft, the Sputnik-1 satellite, in 1957. The US wanted to avoid being overtaken ever again and decided to pursue the development of strategic technological surprises. As a result, then-US President Dwight D Eisenhower established DARPA in 1958.

DARPA explores and pushes boundaries and funds the development of radical innovations. For example, in the first half of the 2010s, it funded the development of a new type of vaccine based on mRNA technology, which is used in a number of vaccines that combat coronavirus. In 2013, Moderna, one of the pharmaceutical companies that produces coronavirus vaccines, received USD 25 million from DARPA to develop mRNA vaccines.

DARPA is a relatively small and flat organisation, headed up by a small executive team (directors). In 2020, it employed about 220 staff working in six departments and each department is focused on a particular type of technology, i.e. Biology Technology Defense Sciences, Information Innovation, Microsystems Technology, Strategic Technology and Tactical Technology. Each department in turn has its own small executive team (office directors) and is also staffed with programme managers.

Programme level
The challenge that DARPA is called upon to address is the promotion and monitoring of national security. To this end, DARPA has been designated as funder of technological developments that the US military may eventually deploy to safeguard national security, based on the contribution of the various priorities, departments and programmes.

The US Department of Defense (DOD) sets the context within which DARPA operates. DARPA's directors and staff have very regular and intensive consultations with representatives of the military, both formal and informal, both ad hoc and through scheduled meetings. This is to ensure that DARPA is fully aware of the developments affecting the military and the challenges it faces.

It does not mean that DARPA programmes are focused on off-the-shelf solutions; quite the reverse. DARPA programmes aim to develop groundbreaking, innovative technological solutions that contribute to national security in general. Incidentally, the DARPA director does not report to the Department of Defense but directly to the Senate.

DARPA programme managers play an important part in developing and implementing programmes. It is the programme manager's vision for the goals and design of the programme that is the deciding factor. From this role, the programme manager develops a programme in close consultation with various parties: the DARPA directors and office directors, representatives of the military, research organisations and industry.

This approach allows the programme manager to get in touch with potential applicants as early as at the programme development stage. DARPA regards this as an advantage, as these contacts help it to arrive at a clear, agreed formulation of the contribution expected from the programme.

In some cases, the directors may wish a new programme to build on previous programmes, which creates a portfolio that builds on experience and insights gained from previous research. In addition, the directors also focus on the different technologies required for a particular development. For example, programmes on materials, processors, chips, software and system architecture have been developed during DARPA's long-standing commitment to information technology.

Because DARPA focuses on funding groundbreaking technologies at the early stages of development, networks and relationships between research and industry are often not yet in place. Programmes at DARPA therefore also give specific consideration to developing new *communities of practice* necessary to ensure the (further) development of a new technology.

DARPA operationalises goals at programme level, not at organisation-wide level. Within a programme, it is up to the programme manager to formulate programme-specific goals, conditions, and indicators. These goals and indicators are not static, but can cause the programme to be adapted.

Project support
A characteristic of DARPA is the guiding role played by the programme manager during the programme. The programme manager also intervenes in response to quantitative indicators during the development and implementation of individual projects.

Programme managers find their bearings at the development stage and consult with many parties, including possible project implementers. Objectives and constraints are clearly described in the call for proposals (Broad Agency Announcement). The programme manager is responsible for the selection of proposals and may seek advice in this regard. The deciding question in the selection process is: do the projects contribute to the programme manager's vision?

DARPA contracts *performers*, i.e. research organisations and companies, to carry out the projects. In other words, DARPA does not work on the basis of grants, like, say, NWO, but based on contracts, which allows DARPA to become deeply involved in the implementation of the projects it funds. The programme manager may propose changes in the composition of the consortium and the research design, visit sites, adapt projects, invite representatives from different projects, ask for presentations, require attendance at meetings and involve new parties. The programme manager therefore acts more as an influential additional member of the consortium, rather than as a party to whom projects have to be justified.

Monitoring at programme level is important at DARPA, based on the goals and indicators established by the programme manager at the outset. If a project fails to meet its stated goals, they want to know why. For example, this may be due to unforeseen problems that again provide an insight into what is possible under a particular set of circumstances, which, in turn, provides opportunities for learning. But a project may also turn out to be unviable or a competing project may be more successful.

In such cases, the programme manager may revise goals and indicators, terminate projects prematurely or develop additional activities. Failure is not regarded as a problem so long as those involved actively learn from it and take action based on the lessons learned. The programme manager is likely to decide to discontinue one or more projects during the lifetime of a programme.

When developing a programme, a DARPA programme manager also considers coherence between projects and within the programme. What this coherence looks like will depend on the situation. A programme may consist of one major project, a number of complementary projects or a number of very similar and competing projects. The latter involves a number of options being developed in parallel where the potential of the various options is not yet sufficiently clear.

The programme manager is expected to become actively involved in developing new *communities of practice*. It is common for there to be contact between the different projects. The programme manager can organise meetings at which all the projects must be represented. Performers must participate and share their progress with other projects. The programme manager may also invite to meetings parties who are not directly involved in a project but are deemed relevant in some other way.

3.4 VINNOVA/challenge-driven innovation

Vinnova (*Verket för innovationssystem* or Agency for the Innovation System) was created in 2001 as a spin-off from NUTEK, the Swedish Agency for Economic and Technological Development. Vinnova's remit from the government is to promote sustainable growth by funding demand-driven research and developing efficient innovation systems. Innovation systems are networks of public and private actors within which new knowledge and innovations are developed, disseminated and utilised. As part of its remit to achieve sustainable growth and strengthen Sweden's competitiveness, the agency has a challenge-driven innovation programme: the *Utmaningsdriven innovation programme* (UDI).

The UDI programme was developed in response to the Lund Declaration, which was drawn up during the Swedish Presidency of the European Union. This declaration states that research should focus on major and current societal challenges (then referred to as Grand Challenges) and that this requires approaches to move beyond rigid thematic programming of research and innovation. The declaration goes on to state that public and private parties should be involved in research and innovation. The challenge-driven UDI programme is part of VINNOVA's attempt to put these ambitions into practice.

At the start of the programme, VINNOVA chose four societal challenges. In 2017, it changed course from the four challenges to the United Nations Sustainable Development Goals.

VINNOVA has about 200 employees and a budget of SEK 3 billion (about EUR 300 million). The UDI programme is led by a single programme manager who manages a team of project assessors (who work for other VINNOVA programmes as well as UDI) and staff who support the practical implementation of the programme. The budget varies from year to year and is around SEK 220 million (about EUR 22 million), which makes the programme a small part of VINNOVA's overall portfolio of activities.

Programme level
Each year, VINNOVA and the Swedish government discuss the results achieved by the organisation and its goals for the coming year. Examples of goals include getting more women into leadership positions, increasing collaboration with international organisations and incorporating the sustainable development goals into the funding of scientific research.

Within VINNOVA's wide remit and these kinds of more specific goals, the UDI programme is specifically aimed at encouraging challenge-driven innovation. It is

based on the UN's sustainable development goals in this regard, but the contribution of the entire programme to these goals is not really further developed or operationalised at programme level.

As we describe below, the individual projects in the UDI programme are responsible for this operationalisation. The sustainable development goals are central to the selection of project proposals: a key criterion during selection is the expectation that a project will contribute to one of these goals.

Project support
The UDI programme focuses on individual projects. This means that the programme funds several stand-alone projects that are expected to contribute to one of the sustainable development goals. The responsibility for justifying the choice of content and the project design rests with the applicants, who have to describe the problem they want to solve, how they intend to solve it and with whom. Projects are assessed on the basis of their internal consistency: does the proposed project match the challenge identified by the applicants?

As a result, individual projects set and pursue different goals. The programme's societal contribution therefore unfolds in the individual projects. Programme management does not aim for coherence between projects. During the implementation of the projects, the contact between VINNOVA and the implementers is mainly of an administrative nature, i.e. through mandatory reports. The VINNOVA programme manager does not adapt the content as a result.

The UDI programme explicitly focuses on internal coherence within a project over time. A project may receive funding in three phases, creating coherence over time. Within the UDI programme, the innovation process is broken down into three sequential steps that will ideally lead to practicable solutions: (1) initiation, (2) collaboration and (3) implementation. Each phase has its own type of project for which an application can be submitted after each phase. Different rules and requirements apply to each type of project. An initiation project runs for about nine months and focuses on developing an idea. A collaboration project runs for about two years and focuses on developing collaboration between different partners and developing and testing innovative solutions. Finally, an implementation project runs for about three years and is designed to test results on a larger scale and put them into practice.

VINNOVA funds a smaller percentage of the project cost at each step. The closer a project is to actual application and therefore commercialisation, the more involvement and co-funding is expected from the applicants. The reviewers, some of them VINNOVA staff and some externals, decide by mutual agreement which

proposals meet the requirements and are therefore eligible for funding, and which do not. The programme does allow some flexibility in the sequential steps. A side issue may become the main issue in a subsequent project step, if it is more promising.

The UDI programme does not focus on coherence between different projects pursuing a common objective. However, there are a number of embedding characteristics on which projects are assessed. These characteristics stem from the notion that concrete innovative solutions to long-term challenges require a focus on embedding in practice from the outset.

The embedding characteristics include:

- *Systems perspective*: The programme requires that projects be developed from a systems perspective. Different aspects of a challenge have to be viewed and addressed in context. The lack of a systems perspective could result in a project having unintended undesirable consequences.
- *More broadly based than technological innovation*: The programme requires that a project be more broadly based than a purely technological solution, but also considers other aspects such as reward systems, organisational context, policies, behaviours or processes.
- *Focus on follow-through and application*: The programme requires that applicants sufficiently anticipate further development and application. This question is present from the outset and becomes increasingly important in the sequential steps. Projects must have a clear application in mind, where it is considered likely that there will be tangible results within five years and the application can be used more widely.

A recent evaluation found that the UDI programme is still failing to achieve these ambitions. In practice, projects funded from the programme to date have had a technical focus with little thought given to other aspects, such as social embedding and incorporation into legislation. In addition, the programme funds a wide range of projects lacking a clearly defined problem at programme level. The evaluation of the UDI programme therefore argues that there is a need to integrate and elaborate the systems perspective more explicitly at programme level in order to be truly challenge-driven and to be able to realise the stated ambitions.

3.5 Comparative analysis

In this concluding section, we look at the programmes from a comparative perspective. What mutual differences and similarities do we see in the way the programmes design and manage their activities at two levels (programme level and

project support)? How is the contribution to be made by the programme reflected in the way the programme is organised?

Objective
Each programme has a different type of objective. The UDI programme is the least focused of the three programmes, where projects within the programme have to contribute to one of the sustainable development goals. CCAFS and DARPA have a more specific goal at programme level. These goals are challenge-driven, as a contribution to addressing a specific societal challenge. CCAFS aims to reduce rural poverty, increase food security, improve health and nutrition and make natural resource management more sustainable. DARPA's remit is to fund and drive the development of breakthrough technologies for the US military. Compared to CCAFS, DARPA's objective is therefore more technology-oriented.

Programme level
Consistent with our expectations of challenge-driven programmes, CCAFS and DARPA run their programmes taking into account the way they relate to developments in the field for which the knowledge and solutions are intended. The context within which DARPA operates is clearly defined: this agency develops innovative technology for defence purposes within the US. DARPA therefore maintains close contact with the US military so that it can match their needs and capabilities.

The context to which CCAFS has to relate is more diffuse. The CCAFS programme is part of CGIAR, a global research partnership, which depends on several donors and operates in multiple countries. Under this umbrella, the CCAFS programme itself aims to strengthen the links between different CGIAR research centres. Active coordination between the umbrella organisation, the various centres and the practitioners is therefore an important part of CCAFS's work. The theory of change formulated by CCAFS at programme level helps to provide direction for the implementation of the programme and its associated activities.

Unlike DARPA and CCAFS, UDI does not appear to give much thought to programme-level coordination. Because the programme's goal has been formulated in broad terms, without explicit stakeholders, it is not straightforward for the programme management to coordinate with other parties.

All in all, we find that the two examples that are most strongly oriented towards a specific societal challenge (CCAFS and DARPA) coordinate most actively at programme level.

Project support
The programme-level objective is also reflected in the extent to which the various programmes actively coordinate the programme with individual projects. CCAFS and DARPA manage all the programmes and projects they fund in an interrelated way. At this level too, the work they do is more in line with a challenge-driven theory of change.

Both during the start of the programme and in its implementation, programme management actively focuses on the coherence between different parts of the programme, e.g. by pushing for knowledge integration or adapting the substantive direction of the programme. At DARPA, the programme manager manages the individual projects *with a firm hand* using quantitative indicators.

CCAFS closely monitors the progress of programmes using its theory of change at programme level. It also has a dedicated *learning platform* to organise knowledge synthesis. We do not know whether programme management also adapts individual projects. What is also special about CCAFS is that it reserves a large portion of its resources for interacting with stakeholders and for empowering *next users* who have to put the new solutions into practice.

Again, the UDI programme is different. It only considers the relationship between the programme and individual projects when selecting project proposals, which allows for a wide variety of issues, as the programme addresses all of the United Nations' sustainability goals. Similar to innovation- or knowledge-driven programmes, programme management hardly manages at all during implementation of the project.

Whereas the UDI programme consists of a series of projects, each of which contributes *separately* to the programme's goals, CCAFS and DARPA also aim for coherence *among* the projects. CCAFS and DARPA take interrelationships into consideration when managing their projects. DARPA sometimes chooses complementarity between projects and sometimes competing projects with the same goal. CCAFS focuses on complementarity so that practical solutions are created for as many regions of the world as possible. In the UDI programme, we see coherence develop over time in a series of successive projects but no bridges are built between individual projects.

In addition, the programmes give varying degrees of consideration to the embedding of individual projects. This is hardly an issue at DARPA, where alignment with DARPA's remit takes place at programme level. At CCAFS and UDI, however, we do see a focus on the societal contribution of individual projects.

Furthermore, CCAFS actively develops the relationship between projects and the societal challenge. Collaboration with local communities and knowledge integration between science and practice are a matter of course within parent organisation CGIAR. All projects are expected to base their work on these principles and CCAFS sets aside a substantial budget to make this possible.

Because UDI's societal contribution is primarily through individual projects, it is mainly developed at project level. To be eligible for funding, projects must demonstrate they have the potential to be a real-world application, adopt an interdisciplinary approach and draw up an intervention logic. The UDI programme level seems to provide little support in this regard.

Summary

UDI: least challenge-driven

We see relatively few programme-level activities in the UDI programme. Probably due to the rather general focus on the UN sustainable development goals, we see little coordination between the programme and other programmes or developments in the outside world. The UDI programme is primarily a collection of individual projects that have little mutual coherence. The programme's societal contribution mainly takes on form and content within the individual projects. However, little support for this is provided by the programme. Programme management coordinates projects on the basis of a broadly defined goal and rarely intervenes except during the selection of project proposals. During implementation, the programme maintains a primarily administrative relationship with the projects. Consequently, this programme is only marginally in line with our expectations about challenge-driven research programmes.

DARPA: Focus on technological development

At DARPA, the focus is on the programme level, where projects are coordinated and accounted for with the main potential user of the programme's results, the US military. Within the clearly defined frameworks of each programme's remit, programme management is given a great deal of leeway to shape a programme and select projects as it sees fit. Programme managers actively intervene to monitor the theory of change. The projects within the programmes can evolve in a protected environment. At project level, the focus is on technological development and there is little interaction with the context of use.

CCAFS: most challenge-driven

Of the three programmes, CCAFS has the most typical challenge-driven objective, which is to contribute to a global societal challenge through research and innovation while also developing directly applicable insights within individual projects. This translates into a comprehensive structure in which relationships are actively sought

with potential and current stakeholders at both programme and project level. The organisation (CGIAR), the programme (CCAFS), and the individual projects each have their own theory of change. These theories of change are continuously monitored and aligned with each other and their environment.

This comparison shows that each programme has different emphases based on its purpose and positioning. It is worth noting that the more specific the objective of the programme, the more active the programme management is, in terms of managing, adapting and supporting projects within the programme. All in all, these examples show that active programme management is needed if a challenge-driven approach is adopted.

4 Implications for challenge-driven research programmes

In this section we summarise our findings from the literature and the workshop and from the three international cases and translate these findings into specific suggestions for the practice of programming research aimed at addressing societal challenges. We first highlight the two most important insights and then make specific suggestions for putting a challenge-driven approach into practice in the various phases of the programme cycle.

4.1 The essence of challenge-driven programming

Our analysis shows that challenge-driven innovation policy requires the adoption of a new design and approach for research programmes. Overall, we see two important differences between innovation-driven programmes and challenge-driven programmes, which affect programme design, organisation and management.

Active programme management
Our analysis of three international cases has shown that challenge-driven research programmes require active and decisive management to organise and monitor their orientation towards societal challenges. Different interventions are needed in different phases of the programme, e.g. bringing parties together, encouraging knowledge exchange, monitoring and adjusting specific projects and integrating results. This is different from innovation-driven programmes consisting of self-contained project consortiums with their own agendas. In these programmes, the level of attention shown by programme management declines sharply once the projects begin.

We found a good example of active programme management in the DARPA case. DARPA employs programme managers with expertise, authority and perseverance. To play their role effectively, managers of challenge-driven programmes need a strong affinity with the subject of the challenge in question. In addition, they must possess the social skills needed to communicate a compelling vision and mobilise the parties involved. Finally, they also need a formal mandate to intervene actively when the dynamics of the programme or the social environment demand it.

Reflexivity
A challenge-driven programme must constantly reflect on the way it functions in relation to a dynamic social environment. What adjustments, if any, are needed to deliver the desired impact? The challenge-driven nature of the programme means that it has to develop reflexivity to ensure that it finds and maintains a connection with the societal context in which the envisaged system changes are to take place.

This societal context is constantly changing and is often characterised by diverse and, to a greater or lesser extent, conflicting values and interests. What this means for a challenge-driven programme is that it is not enough to set goals at the starting line and wait until the finishing line is reached to determine whether these goals have been achieved. Reflexivity means giving consideration throughout the programme to whether both the activities and the goals of the programme are still relevant. This requires constantly taking care to embed the programme in an ongoing innovation and transition process, even after the programme ends.

At CGIAR/CCAFS, we see this concern for aligning with societal dynamics in their focus on *next users* and scaling-up. There are cross-cutting learning paths on these types of subjects that transcend individual projects. At DARPA, there are constant interactions with the military to ensure that knowledge and technology become part of its ongoing modernisation. DARPA sets intermediate goals that are monitored and may prompt redirection of the programme and projects within it. In the UDI programme, the phased approach to projects is a way to be flexible when responding to change.

Reflection
Active programme management and reflexivity require time and money. These two characteristics mean that challenge-driven programmes will incur significantly higher overheads than traditional programmes, with the result that a smaller proportion of total resources can be devoted to the primary process. It is therefore important to properly monitor and evaluate how an active and focused mobilisation of research is paying off in terms of better or faster contributions to addressing a societal challenge.

4.2 Building blocks for challenge-driven programmes

What do these findings mean specifically in terms of designing and organising challenge-driven research programmes? Based on the assumption that there is a growing need for this type of research programme, in this section we provide building blocks for programme managers and policymakers who would like to set up a challenge-driven research programme. To provide an insight into the

requirements, we use the programme model described by Flurina Schneider and colleagues as the gold standard. This model consists of ten phases in a programme cycle in which activities take place at both programme and project levels. Their model (see Section 3.1 for a more detailed explanation) helps to show the kind of innovations needed to put research programmes to work addressing a societal challenge. Below we discuss each of the ten different phases of the model in turn. In the process, we supplement the insights provided by Schneider and colleagues with results from our own research.

We use the model to outline a number of specific possibilities for adopting a challenge-driven approach to research programming. It is definitely not meant to be some kind of recipe or checklist. The objective for challenge-driven research programming is precisely to design appropriate approaches based on a well-developed theory of change. The design, organisation and management of these types of programmes have to be tailor-made to mobilise research for a challenge effectively. For example, depending on the level of controversy surrounding a challenge and the goals of the programme, in one programme it may be useful to have as many parties as possible actively participate in projects (as in CCAFS), while in another it may be more effective to give stakeholders a role in the governance of the programme (such as DARPA).[39]

1. Programme preparation
Work with stakeholders to develop a clear theory of change that can serve as the basis for the research programme. It is important that the steps between programme results *(outputs*), their use by target groups *(outcomes*) and the ultimate impact on the societal challenge are well thought through. Complex societal challenges involve so many uncertainties and unknowns that a first version of the theory of change cannot yet be worked out in detail. During the course of the programme, the theory of change will continue to be fleshed out and adapted in interactions with the projects and intended users.

A challenge-driven theory of change does not start out from new technological or scientific opportunities but a complex societal challenge. Therefore, make sure that the focus is on those who are experiencing the problems and those who are needed to address the problems. Often an integrated approach will be required for which knowledge and expertise must be brought together from different sources. Ideally, then, the theory of change should be drafted in consultation with both those

39 Previous research suggests several possible solutions for dealing with conflicting interests in a research programme. A programme that focuses on a specific solution that is relatively uncontroversial may keep substantive opposition out of the programme, but a programme that seeks a substantive breakthrough on a controversial issue must bring the opposing voices into the conversation within the actual programme itself (Hessels, L.K., de Jong, S.P.L., Brouwer, S., 2018. Collaboration between Heterogeneous Practitioners in Sustainability Research: A Comparative Analysis of Three Transdisciplinary Programmes. Sustainability 10, 4760.).

parties who have a good understanding of the issues and the changes needed and those parties with an understanding of the possible solutions and the current state of the art.

Design the program not as a one-time, stand-alone intervention, but as an intermediate step in a broader and ongoing dynamic. Concrete design questions that can help with this include:

- How can the programme be linked to other programmes that want to contribute to addressing the challenge in question?
- How can the programme build on results from previous programmes?
- How can you ensure that the programme has a follow-up that uses results?
- What opportunities are available to develop the programme as part of an overarching whole (portfolio of programmes)?

Also use the programme to (further) develop challenge-driven ecosystems for research and innovation. A challenge-driven programme does not intend to mobilise one-off consortiums but to contribute to sustainable and vital knowledge ecosystems. Ensure that the ecosystem has sufficient diversity in terms of participants and knowledge practices (as with CCAFS). In addition to researchers and industry, users, private individuals and other stakeholders can be important co-producers of knowledge and innovation.

Therefore, use a broad definition of knowledge, knowledge activities and research. Where appropriate, give space to the input of practical knowledge, for cocreative forms of knowledge production, for transdisciplinary research and for linking and coordinating activities aimed at circulation, integration, aggregation and implementation of existing and new knowledge.

Also use a broad interpretation of innovation. In this context, an innovation is only successful if it becomes socially embedded and part of a system innovation. So focus on non-technological aspects of innovation, such as revenue models, arrangements for collaboration, regulation, behaviour and standardisation.

2. Proposal elaboration

Provide project developers with a clear picture of the (preliminary) theory of change at programme level and ask them to position themselves within it with their own *nested* theory of change for their own project.

Make project development an iterative phased process in which project goals and approaches are gradually aligned with the programme's theory of change and vice versa. In this way, combine top-down direction with bottom-up, concrete implementation.

Ask project developers to involve relevant stakeholders in project development. Stakeholders contribute (practical) knowledge and expertise. In addition, they are important for anticipating the follow-up phase and using project results. If necessary, approach relevant researchers and civil-society parties in a targeted manner (see the DARPA example) to motivate them to develop a project proposal if it follows from the theory of change that certain knowledge and expertise is essential.

3. Interactions with applicants
Use an iterative and phased process to ensure that the project proposals fit well into the programme's theory of change in terms of research questions and approaches.

Provide programme managers with sufficient capabilities and skills to engage in a conversation about refining the research question or approach, or about the composition of a project consortium (following DARPA's lead).

Find a balance between competition and collaboration. In some cases, it may make sense to combine different project ideas into a joint project proposal by creating a broader consortium.

4. Project selection
Select projects based on the persuasiveness of the (nested) theory of change and how it is translated into a project plan.

Arrange selection in multiple rounds to ensure a good portfolio of projects. Provide feedback after each round to give project developers the opportunity to refine their proposal and better position it in the programme's theory of change.

Use a wide range of knowledge and expertise during the selection process. Ensure that there is sufficient expertise in interdisciplinary and transdisciplinary research and in the integration and implementation of knowledge into innovations in practice.

Scientific quality is obviously important, but *excellence* need not be a decisive criterion. Sometimes combining or recombining existing knowledge is more important than producing groundbreaking knowledge.

Evaluate project proposals not only on their own merits, but also based on their position in the portfolio and on how they build on previous programmes and projects. The example of the UDI programme shows how projects can build on each other.

5. Research activities
Ensure that projects sufficiently facilitate interdisciplinary or transdisciplinary research and cocreation with users or local communities, e.g. in living labs or field labs.

As well as focusing on developing new knowledge, ensure that there is a focus on other (connecting) activities. Examples include:
- Combining, recombining, integrating and implementing knowledge.
- Establishing and maintaining connections with *next users* and anticipating upscaling once the programme has ended.
- Establishing and maintaining connections with other projects in the programme to work on integrating knowledge and partial solutions.

Ensure the project is appropriately staffed for the type of activities needed. Some activities may require greater seniority or flexibility than is possible within four-year PhD tracks.

Require programme management to ensure that project consortiums receive support where appropriate when designing and organising activities that are not yet mainstream in science, such as co-creation with users or local communities or anticipating upscaling. The CCAFS example illustrates the added value of this action.

6. Joint agenda-setting
Once the projects and consortiums have been selected after several iterations, this is followed by the phase where all those involved at portfolio level start looking at how the projects can be even better aligned with each other and with the programme. Programme management has a directing role in this process.

To make the mutual exchange and integration of knowledge more effective, it may be necessary to change the way the research question or methods are developed, e.g. by systematically using regional diversity in research locations (as per CCAFS), by involving certain stakeholders in multiple projects, by using the same frameworks or by synchronising certain activities. Integration of knowledge at programme level is only possible if there are shared frameworks and common goals (as illustrated by DARPA).

Organise activities and meetings to ensure that all participants feel part of a larger, common programme and are able to communicate with each other. It is important to have all participants commit to a shared theory of change and agenda.

7. Networking and integration
It is an important task for programme management to ensure that there is a programmatic approach to the exchange of knowledge and experiences between projects during the lifetime of the programme. Therefore, ensure that there is a part of the programme in which the integration of knowledge - and thus the targeted contribution to system innovation - is the primary, shared goal.

Ensure that the role of integrator of knowledge and partial solutions is well provided with people and organisations with appropriate skills, powers and authority. The process of sharing and aggregating knowledge from different projects does not happen automatically.

8. Interaction with participating projects
Ensure that programme managers remain actively involved in the projects throughout the lifetime of the programme. This is necessary for several reasons:

- To assist projects in the design and use of unconventional research methods, such as the use of living labs. For example, courses or workshops can be organised through the programme to develop new skills.
- Along the way, project participants will encounter unexpected situations and problems for which solutions have to be found. They can agree to make interim adjustments to the original project plan if necessary.
- To monitor progress and make adjustments to the original project plan if necessary - or even to end a project early if it can no longer be expected to contribute to programme goals (see DARPA). This requires the establishment of a clear monitoring and evaluation framework based on the programme's theory of change.
- To assist projects in organising activities aimed at knowledge sharing and knowledge integration, e.g. networking activities or making knowledge accessible and shareable.
- To assist projects in developing and implementing their communications strategy.

9. External communication and implementation
Making and maintaining connections with organisations and communities that will have to start using the knowledge from the projects and the programme to develop innovative solutions to complex problems is a key factor in making the programme a success. It is therefore important to have a programme-level communications and liaison strategy. Sufficient funds also have to be budgeted for this purpose.

Organise communication as two-way traffic to benefit from the input of different target groups. Communication involves more than just disseminating knowledge products. It is also about shared learning about what is feasible, permissible and

desirable and ensuring that knowledge ends up being used in practice and policy. Therefore, make sure that communication happens throughout the lifetime of the programme.

10. Programme conclusion and evaluation

Evaluation is an integral part of challenge-driven programme management. The theory of change provides the basis for considering what the desired effects and impact will be before the programme begins. The theory of change is the basis for monitoring the progress of the projects and their interrelationships during the period concerned. On completion, it is the basis for evaluating whether the intended project and programme goals have been achieved. Of course, immediately after a programme ends, it is too early to judge whether the intended impact will be achieved. What can be done, however, is to evaluate whether the follow-up process has been effectively set in motion, i.e. by involving organisations and communities in the projects and programme in a timely manner. In addition, it is possible to evaluate whether it succeeded in mobilising a diverse ecosystem for research that will continue to benefit challenge-driven research after the programme ends.

5 Concluding remarks on roles of government

This report aims to contribute to the development of the new genre of *challenge-driven* innovation policy. The report focuses on research programming. In this concluding section, we consider what kind of government involvement and intervention is needed for this type of research programme to actually contribute to the system changes needed to tackle societal challenges. Provided they are carefully and appropriately organised, challenge-driven research programmes can become a powerful tool for actively mobilising research and innovation in a targeted way to address societal challenges. But the coordination and cocreation required also makes them costly. Investing in challenge-driven programmes only makes sense if government also invests in the capacities that programme managers need to actively manage such programmes and if it invests in its own capacity to translate their results into policy and implementation.

Roles of government

A typical feature of challenge-driven research programmes is that government itself is also part of the underlying theory of change - often in different ways. This is also evident from the food transition case study that we discussed in the interlude between Sections 2 and 3.

Creating the right conditions

First, government is involved in creating the right conditions that will enable a programme to thrive. They include clear legal frameworks, a policy culture open to knowledge and innovation, good infrastructure and facilities for research and knowledge exchange, and political legitimacy to experiment with radical solutions.

Democratic legitimacy

Second, government must ensure democratic legitimacy. Challenge-driven programmes are by definition politically charged because of their objectives with regard to societal change. Government cannot therefore afford to take a hands-off approach, but must actively continue to put the public interest first. This means that government also has a duty to ensure that challenge-driven programmes contribute to an equitable and democratically legitimised transition process.

Mobilising resources

Third, government has an important part to play in terms of providing the programme with adequate funding and other resources. Government is not only a

major funder of research, it is also a provider of knowledge and expertise. Government employs professionals who themselves can contribute a great deal of practical knowledge that may be relevant to tackling societal challenges.

Participating in projects
Fourth, policymakers and public sector professionals can participate in specific activities within the projects. For example, civil servants - in addition to employees of companies or non-profit organisations - can actively participate in the research as an authority or professional with expert knowledge. This is especially true when the research is intended to develop new arrangements for policy or governance.

Encouraging knowledge use
Fifth, government has a role in ensuring that the results of the programme will be used and actually lead to changes in policy and practice. Government often has a dual role in this regard. On the one hand, government itself is a knowledge user who translates knowledge into new policies. On the other hand, government can take steps to encourage others to use the knowledge and innovative solutions. For example, as a stimulator of knowledge use, government can create rules that phase out old, unsustainable solutions. Government can also set standards that enforce innovative solutions or act as a *launching customer* itself.[40]

In short, challenge-driven research programmes depend for their success (social impact) on an active and repeated involvement and direction from policy. This is where challenge-driven research programmes differ from conventional innovation-driven research programmes used to stimulate technology development or the innovation capacity of industry. In that kind of programme, government can assume a more facilitating and detached role.

Programme cycle
In the preparatory phase of the programme cycle, this involvement by policymakers takes the form of a contribution to the development of the theory of change. Officials in relevant ministries and perhaps also the implementing bodies in the public sector or decentralised governments should actively participate in the design of the underlying theory of change. This is necessary for two reasons: safeguarding public values and making the division of roles explicit.

Safeguarding public values
Active participation by policymakers is needed first of all to ensure that the research programme is guided by public values. Depending on the degree of public and

40 For a discussion of the roles of government in addressing societal challenges, see Borrás, S., Edler, J., 2020. The roles of the state in the governance of socio-technical systems' transformation. Research Policy 49, 103971.

political consensus on the societal challenge and the transition path to be followed, a research programme can be used as part of a search process to gain more clarity on which transition paths are feasible and desirable or to help create a transition path which has already been chosen. In both cases, the active involvement of policymakers is important, e.g. to ensure that the partial interests of researchers (scientific impact) and industry (competitive advantage) do not dominate programme design. Or that parties with vested interests will not use the research to thwart or delay overly radical changes, a risk we identified in our interlude on the food transition.

It helps when there is a widely supported social agreement on the course of action to be taken to tackle a challenge, as in the case of the Climate Agreement or when the UN sustainable development goals can be translated into specific goals to which a programme is to contribute. Creating *a sense of direction* cannot be left to the programme itself.

Making the division of roles explicit
Second, proper government involvement in the creation of a theory of change is necessary to make the division of roles within it explicit. This is particularly true with respect to the roles that the government itself should play in order to achieve social impact with the programme. Unlike in the case of innovation-driven research programmes, government itself is often an indispensable part of the theory of change in several ways (see above).

Taking an active part in the drafting of the programme theory itself can ensure greater awareness and responsibility in policy because it is clear from the outset what government input and involvement is needed before, during and after the programme. Particularly when the government itself is an intended user of the programme results, it is important to ensure that the programme is well aligned with policy practice.

In brief
In the preparatory phase of a challenge-driven research programme, government cannot afford to take a hands-off approach. It is jointly responsible for ensuring that the programme is well aligned with developments in policy and the dynamics of society. In fact, it must ensure that the program's theory of change is well embedded in the vision and strategy in its own policy.

In addition, it is important for the government, as the client and funder of the programme, to ensure that programme management has sufficient capabilities and skills to actively manage the programme, as described in the previous section. Also

the reflexivity that is needed according to our analysis requires adequate resources and skills.

Investing in suitable capacities and expertise, incidentally, also applies to all the roles government has to play to ensure that challenge-driven research programmes have an impact. Investing in this type of programme only makes sense if government also invests in the capacities that programme managers need to actively manage a programme and if it invests in its own capacity to translate its results into policy and implementation.

During the lifetime of a programme, government should in particular assume the roles of participant in projects and stimulator of knowledge use. These roles ensure that the programme produces relevant results and anticipates the follow-up phase in which these results must begin to impact on policy and practice. Here government should also cooperate in the reflexivity needed to monitor the relevance of the programme to the challenge it is intended to help address.

Even after the programme ends, there is a crucial role for government, particularly as a stimulator of knowledge use as new knowledge does not automatically lead to new (sustainable) behaviour or to successful innovations, especially when vested interests are at stake. It is precisely in the translation of *outputs* into *outcomes* that government can play a decisive role by introducing targeted measures, such as updated legislation, market incentives or information campaigns.

Challenge-driven research programmes are part of a social search and change process. In this sense, they constitute only a temporary intervention in a larger movement. They will only flourish when used in conjunction with and as part of a continuous development process. It is up to government as the funder and commissioner of these types of programmes to monitor continuity and also to ensure that they contribute to a just and democratically legitimised process of social change.

By writing this report, the Rathenau Instituut wanted to underline the potential of challenge-driven research programmes. In the cases we examined we found appealing routines and practices that fit into a repertoire for developing and managing research programmes in a challenge-driven way. It is only a small step in building a rich arsenal of options for action for a new genre of innovation policy. It is now important to allow scope for experimentation with new forms of challenge-driven research programming. This will help funders, implementers and participants learn about what approaches work best for different societal challenges.

6 Bibliography

Borrás, S., Edler, J., 2020. The roles of the state in the governance of socio-technical systems' transformation. Research Policy 49, 103971.

Folke, C., Hahn, T., Olsson, P., Norberg, J., 2005. Adaptive governance of social-ecological systems. Annu. Rev. Environ. Resour. 30, 441-473.

Frenken, K., Hekkert, M.P., 2017. Innovatiebeleid in tijden van maatschappelijke uitdagingen, Sturen in een verweven dynamiek. Ministerie van Economische Zaken.

Guston, D.H., 2014. Understanding 'anticipatory governance'. Social Studies of Science 44, 218-242.

Hessels, L.K., de Jong, S.P.L., Brouwer, S., 2018. Collaboration between Heterogeneous Practitioners in Sustainability Research: A Comparative Analysis of Three Transdisciplinary Programmes. Sustainability 10, 4760.

Janssen, M., Hekkert, M., Frenken, K., 2020. Missiegedreven innovatiebeleid: een nieuw perspectief op vernieuwing en vergroening Wetenschappelijk Bureau GroenLinks, Utrecht.

Kuhlmann, S., Rip, A., 2018. Next-generation innovation policy and grand challenges. Science and Public Policy 45, 448-454.

Kuhlmann, S., Stegmaier, P., Konrad, K., 2019. The tentative governance of emerging science and technology—A conceptual introduction. Research Policy 48, 1091-1097.

Larrue, P., 2021. The design and implementation of mission-oriented innovation policies.

Mazzucato, M., 2015. The entrepreneurial state: Debunking public vs. private sector myths. Anthem Press.

Mazzucato, M., 2018. Mission-oriented research & innovation in the European Union. Brussels: European Commission.

OECD, 2015. Innovation, Agricultural Productivity and Sustainability in the Netherlands.

OECD, 2020. Addressing societal challenges using transdisciplinary research. OECD, Paris.

Rathenau Instituut, 2019. Voorbereid op de praktijk: anticiperen op de maatschappelijke inbedding van innovatie bij onderzoeks- & ontwikkelprogramma's. Rathenau Instituut, The Hague.

Rathenau Instituut, 2020a. De belofte van opgavegericht innovatiebeleid: Een analyse van Europees innovatiebeleid voor de Green Deal en kunstmatige intelligentie. Rathenau Instituut, The Hague.

Rathenau Instituut, 2020b. European research and innovation in a new geopolitical arena. Rathenau Instituut, The Hague.

Rathenau Instituut, 2020c. Maak werk van opgavegericht innovatiebeleid (Message to the Dutch Parliament). Rathenau Instituut, The Hague.

Schneider, F., Buser, T., Keller, R., Tribaldos, T., Rist, S., 2019. Research funding programmes aiming for societal transformations: ten key stages. Science and Public Policy 46, 463-478.

Schot, J., Steinmueller, W.E., 2018. Three frames for innovation policy: R&D, systems of innovation and transformative change. Research Policy 47, 1554-1567.

TNO, 2018. The State of Dutch Innovation 2018: Missions and ‘new’ mission-driven policy.

Von Schomberg, R., 2013. A vision of responsible innovation, in: Owen, R., Heintz, M., Bessant, J. (Eds.), Responsible Innovation. John Wiley, London.

Appendix 1: Methodology

In Section 3 of this report, we analysed three international cases. These cases give an impression of the working methods of three programmes that try to put into practice characteristics of a challenge-driven approach, as outlined in Section 2. As such, the cases are primarily used for illustration and inspiration.

The case descriptions were produced on the basis of desk research and, for VINNOVA, on the basis of a number of additional interviews. The sources we consulted for the various cases are listed below.

Defense Advanced Research Projects Agency (DARPA)
For the case description of DARPA, we primarily relied on two sources:

1. Information provided by DARPA itself via the web page www.darpa.mil.
2. Several chapters from the book 'William B. Bonvillian, Richard Van Atta, and Patrick Windham (eds.) (2019). The DARPA Model for Transformative Technologies Perspectives on the U.S.: Defense Advanced Research Projects Agency. Cambridge, UK: Open Book Publishers', viz
   a. Michael J. Piore, Phech Colatat and Elisabeth Beck Reynolds (2019) “NSF and DARPA as Models for Research Funding: An Institutional Analysis”;
   b. Jinendra Ranka (2019) “DARPA - Enabling Technological Innovation”;
   c. Riochard Van Atta (2019) “Fifty Years of Innovation and Discovery”;
   d. Larry Jackel (2019) “Program Management at DARPA: A Personal Perspective”.

To complement this, we consulted the following scientific articles:

- Pierre Azoulay, Erica Fuchs, Anna P. Goldstein, and Michael Kearney (2019) “Funding Breakthrough Research: Promises and Challenges of the “ARPA Model”” Innovation Policy and the Economy (19), pp 69-96.
- Erica R. Fuchs (2009) “Cloning DARPA successfully” in *Issues in Science and Technology* XXVI (1) fall 2009.

Climate Change, Agriculture and Food Security Program (CCAFS) of the Global Research Partnership CGIAR

The CGIAR case description is mainly based on primary information provided by CGIAR about the organisation and the CCAFS programme.

We used the following sources for this purpose:

- CCAFS (2020) CCAFS 2019 Annual report.
- Gonsalves J, Baguilat I, Bantayan R, Bernardo EB, Sebastian L. (2020) *Eight guide steps for setting up a Climate-Smart Village: A trainer's guide***.** Cavite, Philippines: International Institute of Rural Reconstruction.
- CGIAR (2016) CCAFS Phase II Proposal 2017-2022 Summary.
- CGIAR (2016) Agreement establishing the CGIAR System Organization as an International Organization.
- CGIAR (2011) The CGIAR at 40 and Beyond Impacts that Matter for the Poor and the Planet.
- CGIAR (2011) Research Program on Climate Change, Agriculture and Food Security (CCAFS). Program Plan. Copenhagen, Denmark.
- Philip Thornton (2011) Future Selection of Additional CCAFS Target Regions.
- CCAFS (2009) *Climate Change, Agriculture and Food Security. A CGIAR Challenge Program*. The Alliance of the CGIAR Centers and ESSP, Rome and Paris.

Challenge-driven innovation programme *(programmet Utmaningsdriven innovation, UDI*) of VINNOVA, the Swedish innovation agency

The UDI case description is based on a comprehensive case description prepared by Technopolis Group in October 2020 on behalf of the Rathenau Instituut. Technopolis Group's report is based on document study and three interviews.

The following sources were used for the description:

- Vinnova's annual accounts.
- Vinnova's publications on UDI.
- The annual government contracts received by Vinnova.
- The reports of two external evaluations of UDI conducted by Ramboll.
- Wikipedia for some historical data.
- Vinnova's webpage.
- Information on legislative texts, from various ministries.

Interviews were conducted with:

- Jens von Axelson, UDI manager at Vinnova.
- Charlotte Brogren, director general of Vinnova (2009-2017).
- Maria Jonsson, independent expert and reviewer of UDI funding applications.

Open Access
The Rathenau Instituut has an Open Access policy. Its reports, background studies, research articles and software are all open access publications. Research data are made available pursuant to statutory provisions and ethical research standards concerning the rights of third parties, privacy and copyright.

Contact details
Anna van Saksenlaan 51
Postbus 95366
NL-2509 CJ The Hague The Netherlands
+31 (0)70-342 15 42
info@rathenau.nl
www.rathenau.nl

Rathenau Instituut Board

The Rathenau Instituut supports the formation of public and political opinion on socially relevant aspects of science and technology. It conducts research on this subject and organises debates on science, innovation, and new technology.

Rathenau Instituut