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International benchmarking of research and innovation portfolios and their monitoring approaches linked to long-term climate change mitigation efforts

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International benchmarking of research and innovation portfolios and their monitoring approaches linked to long-term climate change mitigation efforts

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Executive summary

This study provides a comparative analysis of national research and innovation (R&I) strategies aimed at climate change mitigation, using Germany as a reference point. It draws on detailed case studies from Austria, France, the Netherlands, the United Kingdom (UK), and the United States (US). Each case study is structured to stand on its own, offering a complete and context-specific overview of political objectives, strategic frameworks, R&I funding portfolios, and monitoring approaches used to assess climate impact. This allows for both individual country insights and cross-national synthesis. All country case studies are structured in the same sections detailing (i) the overarching R&I policy framework, (ii) R&I portfolios linked to climate change mitigation, and (iii) monitoring approaches.

Germany's approach is marked by comprehensive sectoral coverage, a well-developed institutional landscape, and significant investment in cross-cutting foundational technologies such as green hydrogen and battery storage. France offers a model of integrated governance and systemic monitoring, particularly through its France 2030 investment program aligned with the SNBC's carbon budgets. The UK and the Netherlands focus on applied research and innovation deployment, facilitated by strong public-private partnerships and mission-oriented funding structures. Austria employs a clearly defined, mission-based R&I strategy supported by coordinated governance and sustainability evaluation tools. For the US, for which the focus was on analysing the conditions of the Inflation Reduction Act (IRA) in the period 2022-24, innovation was primarily driven through large-scale fiscal incentives, emphasising rapid market deployment and industrial transformation.

While the individual national contexts and approaches differ, a common challenge remains: linking R&I measures to long-term, measurable GHG emission reductions. Germany, with its research-oriented approach and institutional strength, could benefit from enhanced outcome-focused monitoring frameworks to fully realise the potential of its R&I investments. The analysis highlights a set of practices from the case study countries that could be looked at to further improve and strengthen the monitoring of climate impact of R&I policies.

1 Introduction

Public funding for research and innovation (R&I) constitutes a critical instrument in Germany's policy-mix to achieve climate neutrality by 2045. These interventions are aimed at correcting market failures that impede the development and diffusion of technologies essential for reducing greenhouse gas (GHG) emissions over the medium and long term. In particular, such funding is necessary to support innovations that, while currently in early development stages, are expected to become pivotal in the post-2030 period.¹ Examples include next-generation battery technologies, carbon dioxide removal (CDR) technologies, or green hydrogen based production technologies for the industry sector.

This strategic orientation toward the development of key climate technologies is not unique to Germany. In the wake of the Paris Agreement, an increasing number of countries have committed to ambitious climate targets and are now channelling public resources into future-oriented technological innovation to support their realisation. This international mobilisation highlights that innovation policy must be closely aligned with long-term decarbonisation objectives.

This working paper undertakes an international benchmarking focussed on aspects of national R&I systems that are directed at supporting long-term climate mitigation targets. It presents and analyses five country case studies. The selected case study countries exemplify varied yet instructive approaches to climate-related R&I support. Their strategies are examined with the aim of generating comparative insights and informing the evolution of R&I policy internationally.

The five countries are:

1. **Austria**
2. **France**
3. **The Netherlands**
4. **United Kingdom (UK)**
5. **United States (US)**

The scope of this analysis is confined to R&I measures with a long-term relevance for GHG emissions mitigation. Accordingly, the scope is linked to the strategic R&I missions set out in the German Federal Government's Future Strategy for Research and Innovation (2023)² that can be linked to climate change mitigation. The primary emphasis in this report is placed on the climate change *mitigation* dimension of these missions:

- **Mission 1:** Enabling a resource-efficient and on circular economy based competitive industry and sustainable mobility.
- **Mission 2:** Spearheading climate protection, climate adjustment, food security and the preservation of biodiversity.

While Germany's and the investigated EU country case studies R&I policies are embedded within the broader context of Horizon Europe, the European Union's framework programme for

¹ IEA (2021), Net Zero by 2050, IEA, Paris <https://www.iea.org/reports/net-zero-by-2050>.

² BMBF (2023), Future Research and Innovation Strategy (Executive Summary). https://www.bmbf.de/SharedDocs/Publikationen/DE/FS/747580_Zukunftsstrategie_Forschung_und_Innovation_en.pdf?__blob=publicationFile&v=4

R&I, national-level instruments and priorities remain central to implementation. A nuanced understanding of international practices is therefore a relevant dimension for comparison.

The scientific literature broadly agrees that the innovation process is characterized by positive externalities and other market failures, which result in private underinvestment compared to the socially optimal level. Public R&I funding is therefore justified as a means to correct these inefficiencies and align private incentives with societal goals.³ However, given the fiscal implications of public R&I support, there is a growing need to demonstrate the effectiveness and efficiency of such investments. This is particularly relevant in periods of constrained public finances, where spending must be justified not only in terms of economic or technological advancement but also with respect to its contribution to overarching climate policy goals.

However, the evaluation of climate-relevant R&I measures presents significant methodological challenges. Many of the anticipated impacts are systemic, indirect, and realised only over extended timescales. As already detailed in other outputs related to this project, three interrelated limitations are to be acknowledged⁴:

- The **indirect nature of R&I effects**, which complicates causal attribution of GHG reductions;
- **Technological interdependencies** and potential **rebound effects**, which may diminish net climate benefits;
- **Temporal lags** between R&I funding and measurable outcomes, which can extend over decades.

Although these limitations are not the central focus of the international benchmarking, they shape the broader context within which national monitoring and evaluation systems must operate. All countries face the common challenge of designing frameworks capable of tracking the long-term contribution of R&I to climate change mitigation in a credible and policy-relevant manner. Which, in turn, motivates to look at the approaches of other countries.

Structure of the report

In the following section the method for establishing the country case studies is briefly described. In the then following Section 3, the country case studies are presented. Section 4 uses inputs from the country case studies to synthesise the evidence and relate it back to the case of Germany. Section 5 concludes.

2 Methods

The country case studies presented in this report are primarily based on structured desk research conducted by national experts. The desk research involved the review of national policy documents, strategic frameworks, public funding programmes, and other relevant academic and grey literature. The motivation for selecting individual countries also varied, reflecting strategic, comparative, or system-related considerations, which are detailed in the table below.

³ See e.g. Acemoglu, D. et al. (2012) 'The Environment and Directed Technical Change', *The American Economic Review*, 102(1), pp. 131–166. Available at: <https://doi.org/10.1257/aer.102.1.131>. or Cervantes, M. et al. (2023) 'Driving low-carbon innovations for climate neutrality'. Available at: <https://doi.org/10.1787/8e6ae16b-en>.

⁴ Peterson et al. (2025). Möglichkeiten und Grenzen der Evaluation von staatlichen Forschungs- und Innovationsmaßnahmen in Bezug auf ihren Beitrag zur Klimaneutralität. https://technopolis-group.com/wp-content/uploads/2025/05/Chancen_Grenzen_F_I_KlimaF-I-1.pdf.

Where possible, the desk research was complemented and validated through expert interviews. These interviews provided additional insights into national priorities, implementation dynamics, and institutional arrangements. However, the accessibility of suitable experts varied across countries. In some cases, identifying and securing expert interviews proved more difficult than in others. As a result, the number of expert interviews conducted per country ranges between one to five, as shown in Table 1. For the United States no interview could be conducted.

Table 1 Overview of interviews for country case studies

Country	Case motivation	Interviews
Austria	<ul style="list-style-type: none"> Strongly interconnected with Germany through a shared language space Ongoing exchange in the R&I context 	<ul style="list-style-type: none"> Manuel Binder, Austrian Research Promotion Agency (FFG) – Programme Lead, Austrian Climate Research Programme (ACRP) Susanne Meyer, BMIMI – Head of Transformative Innovation Policy and Missions Isabella Plimon, BMIMI – Head of Department for Funding Instruments in Climate and Energy Technology Patricia Schedifka, BMIMI – Policy Officer for Research Programmes (e.g. EU Horizon) Gernot Wörther, KLIEN – Deputy Director
France	<ul style="list-style-type: none"> Has a long-standing tradition of state-led innovation policy France was chosen as one of the two largest EU economies, providing a strong basis for comparison 	<ul style="list-style-type: none"> Michel Eddi, Ministry of Higher Education and Research – Former President and Director General of CIRAD, Former Director General of INRA. Marie H�el�ene Tusseau-Vuillemin, Ministry of Higher Education and Research – Scientific Director Environment, Agronomy, Ecology, Earth and Universe Sciences.
The Netherlands	<ul style="list-style-type: none"> Represents a smaller, highly networked country with a strong record in R&I policy coordination and public-private partnerships. 	<ul style="list-style-type: none"> Interview with senior academic (preferred to remain anonymous)
United Kingdom (UK)	<ul style="list-style-type: none"> Large and advanced economy with strong track record in R&I. Pre-assessment indicated elaborate system in place, also in relation to monitoring progress. 	<ul style="list-style-type: none"> Interview with senior academic (preferred to remain anonymous)
United States (US)	<ul style="list-style-type: none"> Illustrative case of an alternative incentive structure in climate policy compared to the EU Focus on the implications of the Inflation Reduction Act (IRA) 	<ul style="list-style-type: none"> (No interview conducted due to difficulty in securing a suitable US expert)

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3 Country case studies

All country case studies presented in this report adhere to a common analytical structure, enabling systematic comparison across national contexts. Each case study is organised into three parts:

- **Overarching framework:** Political objectives, strategic frameworks, and main actors involved in research and innovation (R&I) for climate change mitigation.
- **R&I portfolio linked to climate change mitigation:** Composition and orientation of national R&I portfolios, including funding strategies and thematic priorities relevant to climate change mitigation.
- **Monitoring approaches:** Monitoring approaches employed to measure the contribution of R&I measures to long-term climate change mitigation goals. Also covers monitoring approaches that are more focused on deployment of technologies.

The country case studies are presented in a tabular structure so that individual aspects can be identified and compared between countries.

3.1 Austria

3.1.1 Austria – Section 1: Overarching framework

Aspect	Questions / Collected evidence
Section 1: Political objectives, strategies, and main actors related to R&I for climate change mitigation	
Overall political objectives related to R&I supporting climate change mitigation	<p>What is the climate change mitigation objective of the case study country?</p> <ul style="list-style-type: none"> • National Energy and Climate Plan (2024): Austria's national climate change mitigation targets for non-EU ETS sectors are outlined in the Integrated National Energy and Climate Plan (Nationaler Energie- und Klimaplan, NEKP), which establishes national GHG emission targets following EU legislation.⁵ Interim and climate neutrality targets are: <ul style="list-style-type: none"> – A 48% reduction compared to 2005 levels in 2030 for non-EU ETS sectors (with up to 2% EU ETS flexibility compensation). – A 62% reduction compared to 2005 levels in 2030 in EU ETS sectors, aligned with the EU ETS Directive.⁶ – Net-zero GHG emissions by 2040.
Strategies and implementation plans	<p>How is this strategic objective translated to the R&I strategies of the country and what are the key documents for their implementation (plans)?</p> <ul style="list-style-type: none"> • Climate Change Act (2011): Expired in 2020 while a novel climate change act is yet to be passed. The former Climate Change Act was renewed in 2013 setting sectoral targets and 2015 by adjusting those targets upwards. In 2017 it was renewed for the third time by incorporating the former national climate counsel into the national climate committee and by adjusting its tasks. • #Mission2030 - The climate and energy strategy was devised by the Austrian federal government in 2018 and sets out the guidelines for climate and energy policy up to 2030.

⁵ Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie. (2024). *Integrierter nationaler Energie- und Klimaplan für Österreich*. https://www.bmimi.gv.at/themen/klima_umwelt/klimaschutz/nat_klimapolitik/energie_klimaplan.html

⁶ Europäische Union. (2023). *Zur Änderung der Richtlinie 2003/87/EG über ein System für den Handel mit Treibhausgasemissionszertifikaten in der Union und des Beschlusses (EU) 2015/1814 über die Einrichtung und Anwendung einer Marktstabilitätsreserve für das System für den Handel mit Treibhausgasemissionszertifikaten in der Union*. <https://data.consilium.europa.eu/doc/document/PE-9-2023-INIT/de/pdf>.

Aspect	Questions / Collected evidence
	<p>Furthermore, it serves as the foundation for the formulation of the Integrated National Energy and Climate Plan for Austria.⁷</p> <ul style="list-style-type: none"> National Energy and Climate Plan (2024): In the absence of a currently effective climate change act the NEKP is the most important document for the coordination and implementation of climate policy in Austria. The NEKP serves as a link between the overarching #Mission2030 and more specific strategies, coordinating the measures of these strategies and ensuring that they are in line with EU requirements. Climate related R&I foci (missions) detailed in the NEKP are: <ul style="list-style-type: none"> – Energy transition – Transport and mobility transition – Circular economy – Climate neutral cities RTI Strategy 2030: The RTI Strategy 2030 (FTI Strategie 2030) was initiated in 2020 and sets RTI non-binding targets for 2030 with three fields of action (technological independence, climate neutrality and basic research). Climate related fields are part of action field 2 and include RTI to reach climate goals. These goals are operationalized through RTI Pacts, which details funds for R&I activities and is renewed every three years. The first RTI pact was for the years 2021-2023 and the current RTI Pact is for 2024-2026. As a relevant partial strategy the Klima- und Transformationsoffensive sets out goals and defines budgets until the year 2030 e.g., 280 Mio. € for the KLIEN (climate and energy fund) between 2023 and 2027.⁸ This covers mostly TRLs of 7 and 8. Additionally, there is approximately 2 billion € in industrial and environmental funding for enterprises. Applicants must indicate the potential emissions reduction in their proposal, and if this reduction does not materialize by the end of the funding period, the money may need to be repaid since this is not classic FTI, which is allowed to fail. RTI-Pact 2024-2026⁹: The RTI Pact (Forschung, Technologie- und Innovationspakt, FTI-Pakt) makes the definition of cross-departmental research and innovation policy priorities a core principle of Austria's RTI policy. This approach aims to improve coordination in implementation and goal achievement while avoiding duplications. <p>What is their time horizon?</p> <ul style="list-style-type: none"> • RTI Strategy (and Klima- und Transformationsoffensive, partial strategy): until 2030 • RTI-Pact 2024-2026: until 2026 • NEKP: until 2030 (2040 goal of climate neutrality) • #Mission2030: until 2030 <p>Is monitoring of the long-term contribution of R&I measures to general R&I goals part of the R&I system?</p> <ul style="list-style-type: none"> • The EU Performance Monitoring (PM) system is based on the collaboration between several ministries and the FFG. It covers and evaluates the efficiency of Horizon Europe for the period 2021–2028 and contains information on the distribution of the programs funds and projects on different countries.¹⁰ • ERA Monitoring Mechanisms (EMM): As part of the RDI Pact the ERA (European Research Area) Portal Austria aims to establish an EMM which should include a dashboard, a scoreboard and country-level reports. However, this has no clear focus on climate-related impacts.¹¹

⁷ Bundesministerium für Nachhaltigkeit und Tourismus. (2018). #Mission2030—Die österreichische Klima- und Energiestrategie.

⁸ BMBWF, BMK, & BMAW. (2024). Österreichischer Forschungs- und Technologiebericht 2024.

⁹ Österreichische Bundesregierung. (2022). FTI-Pakt 2024-2026.

¹⁰ FFG (2025). Horizon Europe - Periodische Berichte Horizon Europe. <https://www.ffg.at/Monitoring/Auswertungen>.

¹¹ European Commission. (2023). ERA Monitoring 2023—18-months-review of the implementation of the ERA Policy Agenda (EU level report). doi:10.2777/499744.

Aspect	Questions / Collected evidence
	<ul style="list-style-type: none"> • RTI Monitor: There is a RTI-monitor¹², which covers a broad range of indicators and also indicators on circular economy, but those are very aggregated and do not give insight into specific projects or direct future impacts of current RTI. • FFG Monitoring: The FFG (Austrian Research Promotion Agency) conducts impact monitoring, focusing on specific outcomes such as the number of patents filed. However, this monitoring is not comprehensive. Instead, it is carried out on a selective, project-specific basis.
Main actors and roles in the R&I system	<p>What are the main actors involved and what are their roles?</p> <ul style="list-style-type: none"> • Funding and strategic governance: <ul style="list-style-type: none"> – Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation, and Technology (BMK): is the central governmental body responsible for climate policy, renewable energy, and sustainable mobility. It focuses primarily on applied research and technology development, making it somewhat similar to Germany's BMWK (Federal Ministry for Economic Affairs and Climate Action). Since 2020, the BMK has taken over environmental topics previously handled by the BML (Federal Ministry of Agriculture), except for agricultural policy and animal welfare. The main driver for climate related technologies within the BMK is the Directorate-General III "Innovation and Technology". The BMK has started a broad reorganisation process along strategic themes, including the launch of an enhanced and transversal monitoring system. In line with a mission-orientated innovation policy, the strategic themes mobility transition, energy transition, circular economy and climate-neutral city are anchored in the BMK as RTI priorities.¹³ – Federal Ministry for Education, Science, and research (BMBWF): is comparable to the BMFTR in Germany (Federal Ministry of Education and Research) and focuses on basic research. The main driver for climate related technologies within the BMBWF is the Directorate-General IV "Universities and Universities of Applied Sciences" and the Directorate-General V "Scientific Research; International Relations; Gender Equality and Diversity Management". • Management, administration and implementation: <ul style="list-style-type: none"> – Climate and energy fund (KLIEN): Established in 2007, KLIEN originates from the climate side and takes a holistic approach rather than focusing on specific sectors. Its programs are typically cooperative, bringing together research and industry partners to link innovation with practical application. – Austrian Research Promotion Agency (FFG): Manages and administers national and EU-funded programs (e.g., Horizon Europe). The FFG provides funding, consulting, and support services for research and innovation projects. The FFG also acts as an implementing agency for KLIEN, placing KLIEN one level above the FFG. • Implementation (Beneficiaries of funding) <ul style="list-style-type: none"> – Research institutions (e.g., Austrian Academy of Science (ÖAW), Austrian Institute of Technology, Joanneum Research) – Universities – SMEs – Also, partnerships with other associations, industry, start-ups, NGOs, citizen's organisations – Research-intensive large corporations (e.g., AVL List, focusing on the automotive sector, fuel cells, and e-mobility)¹⁴

¹² <https://fti-monitor.forwit.at/O/system>

¹³ Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie. (2024). *Integrierter nationaler Energie- und Klimaplan für Österreich*. https://www.bmimi.gv.at/themen/klima_umwelt/klimaschutz/nat_klimapolitik/energie_klimaplan.html

¹⁴ Based on expert interview with FFG expert.

3.1.2 Austria – Section 2: R&I portfolio linked to climate change mitigation

Aspect	Questions / Collected evidence
Section 2: Assessment of R&I portfolio and funding strategies to support climate change mitigation	
R&I focus areas (e.g., research cluster, sectoral focus)	<p>What are the general characteristics and structure of the R&I portfolio?</p> <ul style="list-style-type: none"> • The RTI Pact 2024-2026 includes funds of 5.2 billion €. However not the whole budget goes to climate related areas. 50% of the funds go to bottom-up research to businesses, while the other 50% go top directional research that follow EU and national targets¹⁵. The current RTI Pact mentions the role of R&I activities for the following climate related areas that also fit into the four missions detailed in the NEKP (Energy transition, Transport and mobility transition, Circular economy, Climate neutral cities): • GeoSphere Austria to be the national competence center for climate impact research • Alignment of funding programmes with national and European strategies e.g., EU Green Deal, Hydrogen strategy, mobility masterplan, circular economy strategy, aviation strategy and the climate and transformation offensive (Klima- und Transformationsoffensive) • Funding and targeted application of key technologies for energy and mobility transition and for a circular economy • Development of technologies for climate neutral aviation • Consideration of green budgeting • R&I on avoiding conflicting goals and fostering behavioral changes • Systematically monitoring and evaluating the potential (climate-) effectiveness of innovations • Increasing the impact of new climate relevant technologies through public demand for innovations and technology transfers • RTI plans for a innovative and sustainable transformation of key industries • Building a string hydrogen ecosystem for the implementation of the hydrogen strategy. <p>Are there R&I focus areas defined for the country (e.g., in the strategy)?</p> <ul style="list-style-type: none"> • They are rather broad and cover many different climate relevant fields. Budgetary priorities are agreed upon by the respective ministries, funding agreements with the implementing agencies and central research institutions, in line with the strategic orientation and governance objectives. • All missions are considered equally important, while the funding budget comes from different sources such as the FFG and KLIEN.¹⁶ The FFG assigns each program to one of the four missions outlined in the FTI Pact. <p>How do these R&I focus areas deviate from the approaches in other countries (question for the interviews only)?</p> <ul style="list-style-type: none"> • They stem from the Paris agreement or programmes such as Horizon Europe and do not differ tremendously among EU countries.¹⁷
Strengths of the countries R&I system relevant for climate change mitigation	<p>What are the strengths in countries R&I system related to contributions to climate change mitigation?</p> <ul style="list-style-type: none"> • Transformative, mission-oriented innovation policy. Additionally, Austria's relatively small size makes community building fairly easy - people know each other and collaborate effectively.¹⁸ • The Austrian system emphasizes fostering societal readiness. It addresses the societal impacts of technologies and supports structural transformation processes to achieve climate goals holistically.¹⁹

¹⁵ Based on expert interview with BMK - Section III expert.

¹⁶ Based on expert interview with BMK - Section VI expert.

¹⁷ Based on expert interview with BMK - Section VI expert and FFG expert.

¹⁸ Based on expert interview with KLIEN expert.

¹⁹ Based on expert interview with BMK - Section VI expert.

Aspect	Questions / Collected evidence
	<ul style="list-style-type: none"> • BMK is the most active proponent of climate policy in recent years. Impact on funding activities goes hand in hand with impact monitoring in the ministry. It has reported success in linking R&I agendas in strategies like the Austrian Research Infrastructure Action Plan 2030 or the RTI Strategy 2030 but also to Circular Economy Strategy, the Hydrogen Strategy, Strategy for Adaptation to Climate Change and the Mobility Master Plan. This yields the following advantages: <ul style="list-style-type: none"> – Enhanced coordination and alignment of cross-sectoral issues facilitate the practical implementation of sustainability strategies across diverse sectors. – RTI policy becomes more responsive to the various sector strategies and requirements. – Each mission is accompanied by impact targets which are closely aligned with sectoral targets. • Due to its geographical diversity and Austria's location in the Alps, climate changes are noticeable earlier than in most other countries. This has led to the development of a community that focuses on high-altitude research and glacier studies.²⁰
Weaknesses in the countries R&I system relevant for climate change mitigation	What are the weaknesses in countries R&I system related to contributions to climate change mitigation? <ul style="list-style-type: none"> • Gaps between national and European approaches should be bridged more effectively. There is insufficient consideration of all regions, which hampers comprehensive collaboration and effectiveness. • Successful implementation requires strong political and administrative will, which, while present, takes time. Existing indicators are underdeveloped, covering only specific programs and lacking overarching approaches for unified data structures. Adapting to new data requirements within established processes remains challenging, and there is a need to systematically determine which data should be collected. The potential of artificial intelligence for data analysis is significant but not yet fully utilized.²¹
Scope in technological readiness (basic research vs. deployment focus)	Does the investigated portfolio exhibit specific patterns in terms of technological readiness? <ul style="list-style-type: none"> • Overall, all TRLs are addressed, but through a variety of institutions.²² The FFG also aims to cover all TRLs (Technology Readiness Levels) but places a stronger focus on applied research, targeting higher TRLs. Basic research, on the other hand, is conducted by other institutions such as the FWF.
Type of funding instruments (Focus on specific types, supply side or demand side focus etc.)	What are the primary types of funding instruments that the system relies on (differentiate by R&I focus area if necessary)? <ul style="list-style-type: none"> • Climate and Energy Fund (KLIEN): was founded in 2007 and is an important funding source for projects that aim to contribute to climate neutrality but only part of its funds go to RDI.²³ Since 2007, 1,6 billion Euro of funds have gone to domestic businesses 162,000 realized projects have triggered about four times as much in private investments.²⁴ • Austrian Research Promotion Agency (FFG): has a stronger focus on RDI topics and plays a notable role in several climate related strategies at the federal level. These include the RTI Strategy Aviation 2040+, and the Circular Economy Strategy.²⁵ • Austrian Science Fund (FWF): is primarily focused on basic research and on funding scientific institutions in particular universities but also non university research organisations.²⁶ • AWS – Austria Wirtschaftsservice: is a bank of the federal government with the goal to promote and fund startup businesses.²⁷

²⁰ Based on expert interview with KLIEN expert.

²¹ Based on expert interview with BMK - Section III expert.

²² Based on expert interview with BMK - Section VI expert.

²³ Klima- und Energiefonds. (n.d.). Retrieved November 21, 2024, from https://www.bmk.gv.at/themen/klima_umwelt/klimaschutz/int_klimapolitik/oe_beitrag/klien.html

²⁴ BMK. (2024). *Aufgaben, Themen und Schwerpunkte des Klima- und Energiefonds*. https://www.bmk.gv.at/themen/klima_umwelt/klimaschutz/nat_klimapolitik/klima_energiefonds/aufgaben.html.

²⁵ FFG. (2024). *Ziele und Aufgaben der FFG*. <https://www.ffg.at/FFG/ziele-und-aufgaben>

²⁶ Österreichische Bundesregierung. (2022). *FTI-Pakt 2024-2026*.

²⁷ Österreichische Bundesregierung. (2022). *FTI-Pakt 2024-2026*.

Aspect	Questions / Collected evidence
	<ul style="list-style-type: none"> • Christian Doppler Forschungsgesellschaft: Aims at knowledge transfers between businesses and science and funds application oriented basic research.²⁸
Funding volume (e.g. by R&I focus areas)	<p>What is the overall funding volume of the R&I measures intended to contribute to climate change mitigation?</p> <ul style="list-style-type: none"> • For the four missions (Energy transition, Transport and mobility transition, Circular economy, Climate neutral cities) the funding volume in the current FTI Pact amounts to 170 Mio. €, with each mission receiving between 30 and 50 Mio € per year.²⁹ • 280 Mio. € for the KLIEN (climate and energy fund) between 2023 and 2027 solely for research funding. <p>Can one derive from the funding volume in a specific R&I field the strategic priorities?</p> <ul style="list-style-type: none"> • The funding volumes are similarly distributed among the four missions and are all of similar importance while none of them is strongly prioritized.

3.1.3 Austria – Section 3: Monitoring approaches

Aspect	Questions / Collected evidence
Section 3: Assessment of monitoring approach for contribution of R&I for climate change mitigation	
Key monitoring system (in place / in preparation)	<p>Is there a monitoring system (either dedicated to R&I measures, green budgeting, or monitoring system for the progress to climate neutrality) that involves a measurement or provides guidance on the contribution of R&I measures to climate change mitigation (or more than one system)?</p> <ul style="list-style-type: none"> • There are many monitoring systems, but no overarching, holistic approach. Currently, there is no directive or legal framework to support such an approach. In the list below an overview of existing partial monitoring systems is provided: <ul style="list-style-type: none"> – Green budgeting: An operational agreement between the EU commission and the Austrian Federal government exists based on EU Regulation (EU) 2021/241. This yields an indicator-based monitoring- and evaluation concept of the Green Finance Agenda.³⁰ There are annual Green budget reports on the planned budgets which provide insights into their potential climate and environmental effects.³¹ – Monitoring of climate and energy targets: General overview of the targets set for energy transition and climate targets but no RTI focus.³² – Sustainability criteria: In recent years, a transversal thematic labelling of projects, both in thematic funding schemes and in bottom-up funding was introduced, in line with the thematic orientation in the BMK mentioned above, so that impact on sustainable transition can be better monitored.³³ – Evaluations: For larger funding lines, accompanying research is commissioned to evaluate the long-term impacts of the measures.³⁴

²⁸ Österreichische Bundesregierung. (2022). *FTI-Pakt 2024-2026*.

²⁹ Based on expert interview with BMK - Section III expert.

³⁰ Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie. (2024). *Integrierter nationaler Energie- und Klimaplan für Österreich*. https://www.bmimi.gv.at/themen/klima_umwelt/klimaschutz/nat_klimapolitik/energie_klimaplan.html

³¹ Bundesministerium der Finanzen & Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie. (2023). *Analyse der Untergliederung (UG) 34 Innovation und Technologie (Forschung) im Rahmen von Green Budgeting*. <https://www.bmk.gv.at/themen/innovation/publikationen/Green-Budgeting.html>

³² Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie. (2021). *Klima- und Energieziele: Monitoringreport*. https://www.bmk.gv.at/dam/jcr:85efb0df-d360-468e-95b0-ea6f17aba004/Monitoring2021_Klima-Energie-Ziele.pdf

³³ FFG. (2024). *Ziele und Aufgaben der FFG*. <https://www.ffg.at/FFG/ziele-und-aufgaben>

³⁴ Based on expert interview with BMK - Section III expert.

	<ul style="list-style-type: none"> – In pilot projects, the climate impact is monitored over 10 years. During the application and settlement phases, the funding agency (such as the FFG) reviews the climate impact. – KLIEN Monitoring: currently under development and expected to be completed by the end of 2025. The focus is on the entire ecosystem, comprising evaluations, cluster evaluations, and eventually a more holistic overview. The system is structured like a pyramid: the higher up the pyramid, the more qualitative the approach becomes. It is designed to use a dynamic mix of methods and will draw on data from evaluations as well as FFG monitoring. The data are then verified by experts. Given the broad portfolio, numerous indicators are required to ensure comprehensive coverage, including the social dimension. However, it is still unclear how some of these aspects can be measured effectively.³⁵
Approach for measuring the impact of R&I measures on climate change mitigation	<p>What is the specific approach of the system?</p> <ul style="list-style-type: none"> • Sustainability criteria: This allows to rate all projects in the application process when fundamental data is collected on the projects anyway. <p>What is being measured and how?</p> <ul style="list-style-type: none"> • Sustainability criteria³⁶: The rating is based on a scale from 0 to 100 and depends on the type and context of the project, such as its output or sometimes also its process. In the end it can be evaluated how many projects are above a certain threshold of points. All projects are also associated with SDGs and the EU taxonomy targets.³⁷ Presently, an evaluation is undertaken on the sustainability criteria in the funding assessment process.
Sources of information / methodological approach for monitoring system	<p>What information and data is used for the monitoring system?</p> <ul style="list-style-type: none"> • In pilot projects the funding applicants must provide an assessment of the climate impact, for example by comparing: <ul style="list-style-type: none"> – energy certificates before and after the implementation of a new technology in buildings. – the number of held ETS certificates before and after the implementation of a new technology in industries.³⁸
Actors and roles in the monitoring system	<p>Who are the involved actors in providing and validating the data?</p> <ul style="list-style-type: none"> • Sustainability criteria³⁹: The rating is performed by a jury of experts. • Pilot projects: Funding recipients provide a self-assessment of the expected impact, but they must also present evidence of actual changes. The funding management agency verifies these changes. For larger funding amounts, independent third parties, such as TÜV or other specialized companies, are more frequently involved in the verification process.⁴⁰
Implications	<p>What are the practical implications of the monitoring results?</p> <ul style="list-style-type: none"> • Generally, they highlight which topics are in demand, what works well, and where more effort is needed. Lessons are drawn from this analysis and subsequently implemented. • Pilot projects: If the conclusion is positive, the funding may be extended and otherwise if the conclusion is negative.⁴¹ <p>How are they integrated in the R&I policy cycle (e.g., being on track for the development of key technologies or not)?</p> <ul style="list-style-type: none"> • The results are discussed with the BMK. Past reports are published, and the lessons learned are incorporated into subsequent programs.

³⁵ Based on expert interview with KLIEN expert.

³⁶ Based on expert interview with BMK - Section III expert.

³⁷ Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the Establishment of a Framework to Facilitate Sustainable Investment, and Amending Regulation (EU) 2019/2088 (Text with EEA Relevance), 198 OJ L (2020). <http://data.europa.eu/eli/reg/2020/852/oj/eng>

³⁸ Based on expert interview with BMK - Section VI expert.

³⁹ Based on expert interview with BMK - Section III expert.

⁴⁰ Based on expert interview with BMK - Section VI expert.

⁴¹ Based on expert interview with KLIEN expert.

<p>Other documents used for measuring / validating the impact (evaluations etc.)</p>	<p>Are there other documents used for the measurement of the contributions of R&I measures (e.g. evaluations)? How are their results included in the monitoring process?</p> <ul style="list-style-type: none"> • Impact-oriented assessments are conducted, comparing actual and planned values. Such evaluations, particularly in the context of directives, align with the methods currently in use. Evaluations run independently and are not systematically integrated into a monitoring system.⁴²
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⁴² Based on expert interview with BMK - Section VI expert.

3.2 France

3.2.1 France – Section 1: Overarching framework

Aspect	Questions / Collected evidence
Section 1: Political objectives, strategies, and main actors related to R&I for climate change mitigation	
Overall political objectives related to R&I supporting climate change mitigation	<p>What is the climate change mitigation objective?</p> <ul style="list-style-type: none"> • France's climate change mitigation objective is to achieve carbon neutrality by 2050, a goal that aligns with the international commitments of the Paris Agreement, where the country has committed to limiting global temperature rise to well below 2°C, and striving to cap it at 1.5°C above pre-industrial levels. Under the broader European Green Deal, France's action is positioned within a global policy context. • France has started implementing ecological planning as a key component to fulfilling the Paris Agreement goals. France's ecological planning is coordinated by a Secretariat General for Ecological Planning. • In parallel, the National Low Carbon Strategy (SNBC) ensures that France respects both the Paris Agreement and the Green Deal, with intermediate targets like a 55% reduction in GHG emissions by 2030. The SNBC operates under a phased approach, introducing legally binding carbon budgets that limit GHG emissions over fixed five-year periods. These budgets apply to key sectors such as energy, transport, industry, agriculture, and waste management. For example, France aims to reduce emissions in the energy sector by transitioning from fossil fuels to renewable energy sources, decarbonizing electricity production, and improving energy efficiency across all uses. The industrial sector is targeted through efforts to enhance energy efficiency and the use of low-carbon technologies, while the transport sector is to be transformed through the promotion of electric and hydrogen vehicles, as well as other sustainable mobility solutions. In agriculture, emissions are to be reduced by improving land use, enhancing carbon sequestration, and promoting more sustainable farming practices (version number 3 of the strategy). • Additionally, the Multi-Year Energy Program (PPE) integrates mitigation strategies through energy policy, making energy a transversal lever for all aspects of France's climate strategy. Notably, France is revitalizing its nuclear program as part of this comprehensive strategy to meet its decarbonization targets, recognizing the role nuclear energy plays in reducing carbon emissions in the energy sector. • Complementarily, the National Adaptation Plan for Climate Change (PNACC) complements these efforts by addressing the country's climate resilience.
Strategies and implementation plans	<p>How is this strategic objective translated to the R&I strategies and what are the key documents for their implementation (plans)?</p> <p>R&I serves a crucial role in establishing pathways for achieving France's climate objectives, particularly in areas where existing solutions are either inadequate or non-existent. R&I is seen as instrumental in finding solutions that are compatible with France's commitments to mitigation, adaptation, and a just transition. The goal is to ensure that innovation is at the heart of technological advancements that support the country's ecological and economic shifts, offering breakthrough technologies that can bridge current gaps in key sectors like energy, industry, and agriculture.</p> <p>France's R&I strategies has been conceived in several strategic documents, including the National Low Carbon Strategy (SNBC) and the Multi-Year Energy Program (PPE). They are implemented through the France 2030 plan. France 2030 is the 4th version of the 'Investissements d'Avenir', which has been the country's main instrument to support R&I, including for climate mitigation purposes in France. The General Secretariat for Investment (SGPI), under the authority of the Prime Minister, oversees the deployment of France 2030 investments.</p> <p>The PPE is a comprehensive plan that sets the course for energy policy in France, defining priorities for energy system modernization and decarbonisation for the next ten years. The plan emphasizes the need for R&I to deliver breakthrough technologies in sectors such as renewable energy, energy storage, and grid modernization. The National Energy Research Strategy (SNRE) supports this by identifying specific research areas that will contribute to the decarbonization of the French energy system. These include R&I in nuclear and renewable energy (e.g., wind, solar, bioenergy), smart grids, energy efficiency technologies, and carbon-neutral industrial processes.</p>

Aspect	Questions / Collected evidence
	<p>The France 2030 investment plan is a key driver of the R&I strategy, with €57 billion, half of which dedicated to R&I efforts. The plan promotes research and innovation, encouraging collaboration between universities, research centres, and industry. The R&I component is managed through the Ministry of Research, with support from the General Secretariat for Investment Programming under the Prime Minister's Office. Instruments like the Priority Research and Equipment Programs (PEPR), which receive €23 billion, serve as important tools for structuring these R&I efforts.</p> <p>The Ministry of Research also plays a crucial role in coordinating the broader R&I ecosystem, including managing the National Biodiversity Plan. This plan fosters collaboration among research operators and ensures that actions taken in R&I are aligned with France's overall climate and biodiversity goals.</p> <p>Besides these major plans, other programs such as Horizon Europe, and regional and local funds also contribute to R&I in climate-related sectors. For instance, France leverages the European Innovation Fund and national green bonds to finance projects focused on decarbonization, biodiversity conservation, and pollution reduction.</p> <ul style="list-style-type: none"> - What is their time horizon? Overall, the time horizon for these R&I strategies is generally structured around two main phases: medium-term (2030), and long-term (2050), with clear milestones aligned with the broader carbon budgets set under the SNBC. - Is monitoring of the long-term contribution of R&I measures to general R&I goals part of the R&I system? In terms of monitoring of climate change mitigation achievements, the SNBC includes a robust system for monitoring progress, using carbon budgets as a key tool. These carbon budgets are legally binding caps on GHG emissions for different sectors and are reviewed every five years. <p>The PPE also includes detailed monitoring frameworks, particularly for the energy sector, where metrics such as energy consumption, renewable energy deployment, and GHG emissions are closely tracked. This monitoring is not only a tool for ensuring compliance but also for assessing the effectiveness of R&I measures in contributing to overall decarbonization goals. For example, the High Council for the Climate is tasked with providing independent evaluations of France's progress toward its carbon neutrality goals, including the contribution of R&I efforts. This council assesses whether the technological innovations being developed through R&I programs are having the desired impact on emissions reductions, energy efficiency improvements, and renewable energy deployment.</p> <p>France 2030 also incorporates a robust evaluation mechanism aimed at measuring the impact of investments in green technologies and their alignment with the overarching goal of ecological and digital transitions. This involves regular assessments of technological readiness levels and the market impact of funded projects to ensure that the strategic goals of innovation and sustainability are being met.</p> <ul style="list-style-type: none"> - Specifically to R&I measures, monitoring mechanisms are integrated into each PEPR. These programs include a systemic reporting and monitoring framework that tracks the performance and impact of R&I projects. Such a framework includes: - Definition of clear objectives: each PEPR is designed to address specific challenges, with outlined goals that guide research activities toward measurable outcomes. - Continuous evaluation: the ANR is responsible for the ongoing monitoring of projects, including the analysis of intermediate and final results, to ensure alignment with national strategic objectives. - Involvement of experts and stakeholders: the governance of the PEPRs includes the participation of scientific experts and industrial representatives, ensuring that research activities are relevant and have a tangible impact on the industrial sector and society. - An example is the PEPR "Soutenir l'innovation pour développer de nouveaux procédés industriels largement décarbonés" (SPLEEN), co-piloted by CNRS and IFPEN. It has established advisory boards, including an industrial panel and a European strategic panel, to ensure that research activities align with the needs of the industry and European policies. <p>National agencies for programme implementation, responsible for climate-related R&I programmes, are working to establish a comprehensive monitoring system that evaluates the impacts of R&I measures. However, as of now, there is no</p>

Aspect	Questions / Collected evidence
	<p>standardized methodology for measuring the long-term impact of these innovations, especially in terms of their actual contribution to France's climate goals. This is a recognized gap in the current system, and work is ongoing to develop robust methodologies that will allow for more accurate impact assessments. This gap is recognized in the France 2030 evaluation report, which highlights ongoing efforts by the Comité de Surveillance des Investissements d'Avenir (CSIA) to improve monitoring and impact assessment. The CSIA emphasizes the need for a robust evaluation framework that will not only track economic impacts, such as GDP growth and job creation, but also measure environmental outcomes, like CO₂ reduction and ecosystem benefits.</p>
<p>Main actors and roles in the R&I system</p>	<p>What are the main actors involved and what are their roles (keep brief)?</p> <p>The R&I landscape for climate change mitigation in France involves a diverse array of actors, each playing a specific role in driving innovation and implementing the country's carbon neutrality strategy. The main actors include:</p> <p>Strategic oversight and policy direction actors:</p> <ul style="list-style-type: none"> • Prime Minister's Office: Through the General Secretariat for Investment Programming and initiatives like France 2030, it oversees long-term investments in research and innovation that align with ecological and climate priorities. These efforts are coordinated with other ministries and agencies. • Ministry of Research and Innovation: This ministry is responsible for directing and overseeing the national research agenda, particularly through funding programs that support innovation in sectors relevant to climate change mitigation. It works closely with universities, research institutes, and the private sector to ensure that research efforts align with France's climate goals. • Ministry of the Ecological Transition: This ministry is tasked with leading the implementation of France's climate policies, including the SNBC and the PPE. It ensures that environmental considerations, particularly in the field of climate change, are integrated into broader economic and industrial policies. The ministry also coordinates with research bodies to ensure that scientific knowledge informs policy decisions. • National agencies for programme implementation: Agencies, such as those managing PEPRs, play a critical role in overseeing the research projects funded by the State, including those that address the challenges of climate change. <p>Research funding and program implementation actors:</p> <ul style="list-style-type: none"> • National Research Agency (ANR): Through specific programs like the PEPR, ANR supports R&I efforts that align with State priorities, particularly in areas such as climate change research, energy efficiency, and the development of new technologies that can support the country's transition to a low-carbon economy. • ADEME (French Environment and Energy Management Agency) aids projects in renewable energy, circular economy, and waste reduction through specialized funding and research programs. • Bpifrance (France's public investment bank) supports innovation financing, particularly in green and climate-friendly sectors, offering tools and resources for startups and SMEs focused on sustainability. • The Caisse des Dépôts et Consignations (CDC) finances sustainable development projects, focusing on areas like renewable energy, green infrastructure, and energy efficiency. It collaborates with local governments to fund eco-friendly urban and regional development and invests in strategic sectors such as digital infrastructure and green mobility. Through partnerships with research institutions, CDC helps bridge the gap between research and practical applications in climate technologies. Additionally, CDC issues green bonds to channel funds specifically into climate-focused projects. <p>Public and academic research actors:</p> <ul style="list-style-type: none"> • Public research operators: Key operators include institutions like CNRS (Centre National de la Recherche Scientifique) and the Institut Climat, which are engaged in both fundamental and applied research across a range of climate-related topics. CNRS, in particular, is pivotal in advancing knowledge in areas like renewable energy technologies, carbon sequestration, and climate modeling. • Universities: French universities play a critical role in conducting research and fostering innovation, often in collaboration with research institutions and industrial partners. They contribute to both basic and applied research.

Aspect	Questions / Collected evidence
	<p>Industry and technology development actors:</p> <ul style="list-style-type: none"> • Private sector and industrial partners: Industries are involved in developing and deploying the technologies necessary to decarbonize sectors such as energy, transport, and manufacturing. These companies work closely with research institutions and public agencies to bring innovations to market, especially in fields such as batteries, hydrogen energy, and carbon-neutral industrial processes. • French Institutes of Technology (Instituts pour la Transition Énergétique, ITE): These institutes, dedicated to energy transition, foster collaboration among research institutions, industry, and government to accelerate technological solutions for climate mitigation. Notable ITEs include IPVF (Photovoltaic Institute), IFMAS (Biobased Chemistry), and Vedecom (Mobility and Transport). • CEA (Commissariat à l'énergie atomique et aux énergies alternatives): Focuses on developing nuclear and renewable energy technologies. The CEA plays a crucial role in France's strategy to maintain leadership in low-carbon energy production, particularly through its work on advanced nuclear technology and alternative energy solutions like hydrogen. <p>Regional and sectoral innovation ecosystems actors:</p> <ul style="list-style-type: none"> • Competitiveness Clusters (Pôles de Compétitivité): These energy-focused clusters support regional innovation and collaboration between companies, research labs, and universities. Examples include DERBI (focused on renewable energies), Capénergies (renewable and efficient energy systems), S2E2 (intelligent electrical systems), and Tenerrdis (new energy technologies). These clusters play a strategic role in advancing regional and national energy transition goals by fostering innovation and industrial competitiveness.

3.2.2 France – Section 2: R&I portfolio linked to climate change mitigation

Aspect	Questions / Collected evidence
Section 2: Assessment of R&I portfolio and funding strategies to support climate change mitigation	
R&I focus areas (e.g., research cluster, sectoral focus)	<p>What are the general characteristics and structure of the R&I portfolio?</p> <p>France's R&I portfolio for climate change mitigation focuses on multiple sectors and technologies, driven by key national strategies, the SNBC and the France 2030 Investment Plan. The portfolio integrates renewable energy technologies, such as wind, solar, and bioenergy, and promotes energy efficiency improvements across key sectors like buildings, transport, and industry. The R&I efforts are aimed at fostering innovation not only in the energy sector but also in broader systems like agriculture and manufacturing, ensuring that the transition to a low-carbon economy is comprehensive.</p> <p>A major focus of the portfolio is on the development of energy storage solutions to manage the variability of renewable energy sources. This is crucial for ensuring the resilience and flexibility of the energy system, which is increasingly dependent on intermittent renewable sources. Smart grid technologies are also central to France's strategy, enabling a more efficient and responsive energy system that can integrate various renewable energy sources.</p> <p>The France 2030 plan expands on this by setting a diverse range of focus areas, including nuclear energy, particularly in the development of small modular nuclear reactors, which are expected to play a significant role in providing stable, low-carbon energy. Green hydrogen production is another major focus, recognized as a key solution for decarbonizing industries that are difficult to electrify, such as heavy manufacturing and transport. Furthermore, the plan emphasizes the importance of renewable energy technologies such as wind and solar power, sustainable mobility, and industrial decarbonization. It also supports the advancement of low-carbon aviation and biomedicines.</p> <p>The industrial decarbonization component of the R&I portfolio is particularly significant, focusing on low carbon manufacturing processes and improving energy efficiency in heavy industries like steel and cement. Research into carbon capture and storage (CCS) technologies is also a key part of this effort, with the goal of reducing emissions from industries where decarbonization is particularly challenging. In the transport sector, R&I efforts are geared toward the development of electric vehicles, hydrogen fuel cell technology, and sustainable mobility solutions, including public transport and cycling infrastructure, which are essential for reducing emissions in urban areas, as well as innovation in aviation and maritime transport. For instance, France aims to develop the first low-carbon airplane by 2030.</p>

Aspect	Questions / Collected evidence
	<p>The agriculture and land-use sector plays a critical role in France's climate strategy, with research focused on enhancing carbon sequestration through better land management and promoting sustainable farming practices that reduce emissions of methane and nitrous oxide.</p> <p>These efforts are backed by strong public-private collaboration, which is key to driving innovation across all sectors. Institutions such as CNRS, CEA, and other research bodies work closely with industrial players to ensure that innovations are rapidly brought to market</p> <p>France 2030's R&I portfolio includes the PEPRs, which are dedicated to financing fundamental research at Technology Readiness Levels (TRL) 1 to 4 and which are managed by research institutions such as CNRS, CEA, and INRAE. Two types of PEPRs exist:</p> <ul style="list-style-type: none"> • PEPRs linked to national acceleration strategies: These programs address specific scientific and technical challenges to overcome barriers to decarbonization and ecological transition. For example, sectors such as green hydrogen, sustainable cities, battery innovation, and industrial decarbonation are supported with a total allocated budget of €2 billion within the 2030-time horizon. The aim is to create breakthroughs that can be scaled up to meet national climate goals. • Exploratory PEPRs, which focus on emerging transformations that are still in their infancy but hold significant potential for future climate mitigation and adaptation strategies. These programs receive around a total of €1 billion and explore areas of national and European interest with the goal of unlocking new scientific fields. Examples include projects like FairCarboN, which focuses on understanding carbon cycles in ecosystems, and SOLU-BIOD, which seeks to leverage nature-based solutions for biodiversity conservation and climate resilience. <p>Are there R&I focus areas defined for the country (e.g., in the strategy)?</p> <p>From France's main climate strategies and the PEPRs, it can be deduced the following list of focus areas of its R&I strategy:</p> <ul style="list-style-type: none"> - Renewable energy technologies: France's R&I portfolio focuses heavily on the development of wind, solar, and bioenergy technologies. The goal is to promote energy efficiency improvements in key sectors such as buildings, transport, and industry. These efforts are essential for reducing the reliance on fossil fuels and supporting a transition to a low-carbon economy. - Energy storage solutions and smart grids: A major area of emphasis in the R&I portfolio is the development of energy storage solutions that manage the variability of renewable energy sources. Smart grids are also prioritized to improve the efficiency of energy distribution, allowing for more responsive systems that can handle diverse energy inputs. - Nuclear energy and small modular reactors: France continues to invest in nuclear energy as a key part of its R&I portfolio, especially focusing on the development of small modular reactors (SMRs), which provide a stable, low-carbon energy source. These reactors are seen as an important tool for meeting energy demands while supporting decarbonization. - Green hydrogen production: Green hydrogen is recognized as a crucial energy carrier for industries that are difficult to electrify, such as heavy manufacturing and long-distance transport. France is investing in R&I to overcome barriers to hydrogen production, storage, and use, with the goal of positioning the country as a leader in this emerging field. - Sustainable mobility and low-carbon transport: The R&I portfolio includes efforts to develop electric vehicles, hydrogen fuel cell technology, and sustainable mobility solutions such as public transportation and cycling infrastructure. These technologies aim to achieve the target of producing two million zero-emission vehicles by 2030. In addition, research into low-carbon aviation is supported as part of France's effort to decarbonize the transport sector. - Industrial decarbonization: A critical part of the portfolio is the focus on low-carbon manufacturing processes in industries such as steel, cement, and chemicals. Research is directed at improving energy efficiency in these heavy industries and advancing carbon capture and storage technologies. - Circular economy and recycling: France is prioritizing the circular economy, focusing on recycling technologies and the efficient use of resources. - Agriculture and land use: The agriculture and land-use sector is a critical focus area, with research dedicated to improving carbon sequestration through better land

Aspect	Questions / Collected evidence
	<p>management practices. Sustainable farming practices that reduce methane and nitrous oxide emissions are also promoted, aligning agricultural productivity with climate goals.</p> <ul style="list-style-type: none"> - Bio-based innovations: R&I in bio-based products and industrial biotechnologies is prioritized, supporting the development of sustainable fuels and bio-materials that can replace fossil-based products. - Digital technologies for energy efficiency: The integration of digital technologies, such as artificial intelligence and data analytics, is seen as critical for optimizing energy use, reducing emissions, and supporting smart city initiatives. <p>How do these R&I focus areas deviate from the approaches in other countries (question for the interviews only)?</p> <p>It can be noted that France's approach to intertwining digital and ecological innovation as twin pillars of its R&I strategy may set it apart from other countries that treat these domains as separate or sequential rather than integrated efforts. France also places a strong emphasis on maintaining leadership in specific sectors, such as nuclear energy, where it has traditionally held competitive advantages.</p>
<p>Strengths of the countries R&I system relevant for climate change mitigation</p>	<p>What are the strengths in countries R&I system related to contributions to climate change mitigation?</p> <p>One of France's most significant assets is its strong historical foundation in climate science. French researchers have long been at the forefront of understanding the relationship between greenhouse gases and global warming, and institutions such as the CNRS and CEA continue to play pivotal roles in advancing this knowledge. Furthermore, the country's robust research infrastructure, including advanced platforms like CLIMERI-France for climate simulations and Argo-France for ocean monitoring, provides critical data for understanding climate dynamics. These infrastructures not only generate reliable, continuous data but also enhance France's capacity to respond effectively to climate challenges.</p> <p>Another key strength is France's high level of international collaboration. French researchers and institutions are deeply embedded in global initiatives such as the World Climate Research Programme (WCRP) and the Intergovernmental Panel on Climate Change (IPCC), which amplifies the reach and impact of French climate research on a global scale. France has also made substantial and continuous focused investments in critical areas like green hydrogen, renewable energy, and decarbonization technologies through programs such as France 2030, in partnership at times with international stakeholders such as Airbus, Schneider, Legrand, Areva, EDF and Total (e.g., ADEME-Total programme to support R&I on energy efficiency in 2015). The country's diverse research ecosystem, including major public research bodies like CNRS, INRAE, and ADEME, supports this innovation, with strong public-private partnerships facilitating the translation of research into practical climate solutions.</p>
<p>Weaknesses in the countries R&I system relevant for climate change mitigation</p>	<p>What are the weaknesses in countries R&I system related to contributions to climate change mitigation?</p> <p>One major issue in France's R&I system in relation to its contribution to climate change mitigation is the lack of comprehensive methodologies for measuring the long-term impact of R&I measures on climate goals. Although there are reporting and monitoring mechanisms in place, such as those under the PEPR, there remains a gap in evaluating the real-world effectiveness of these efforts, particularly in terms of emissions reductions and resilience building. Additionally, while there is significant investment in R&I, the system faces coordination challenges across its various research agencies and institutions. Although most of the high level plans are overseen by the Prime Minister (SGPI), the involvement of several actors in the system of funding, carrying out and measuring the impact of R&I may lead to inefficiencies.</p> <p>Despite strong progress in technical fields, there is still a limited integration of social sciences into climate research. This is particularly important for understanding the socio-economic dimensions of climate change and fostering the behavioural changes necessary for effective mitigation and adaptation strategies. More interdisciplinary approaches are needed to create comprehensive climate solutions that include both technological innovations and societal shifts.</p> <p>Finally, the application of research in industrial contexts has been slow in certain sectors, particularly in energy-intensive industries like steel and cement, where decarbonization is essential.</p>
<p>Scope in technological</p>	<p>Does the investigated portfolio exhibit specific patterns in terms of technological readiness?</p>

Aspect	Questions / Collected evidence
<p>readiness (basic research vs. deployment focus)</p>	<p>While basic research remains historically a strong component of France's R&I system, there is a clear and growing emphasis on applied research and solution-oriented programmes.</p> <p>On the one hand, fundamental research plays a critical role, especially in areas such as energy technologies, materials science, and digital transformation. Institutions like CNRS and CEA are driving forward theoretical and applied sciences in these domains. Much of the funding for this work is provided by agencies such as the ANR, focusing on exploratory research that seeks to push the boundaries of what is known and create new avenues for future innovations. However, there is also a strong focus on deployment-oriented innovations. The France 2030 initiative, in particular, is designed to bridge the gap between research and commercialization, ensuring that new technologies are not only developed but also market-ready and capable of making tangible contributions to France's climate objectives. This plan ties research efforts to its direct use in industrial settings, promoting the development of technologies that are close to deployment. This shift is evident in the 47 PEPRs, which are focused on solutions and are specifically designed to address pressing questions and challenges in key sectors.</p> <p>The technological readiness of France's R&I portfolio demonstrates a broad spectrum, varying significantly depending on the sector and the specific technologies involved. On one end, renewable energy technologies, such as wind and solar power, have achieved a high level of technological readiness. These technologies are already in large-scale deployment across the country, with increasing integration into the national grid.</p> <p>In contrast, emerging technologies such as carbon capture and storage and green hydrogen production are still at a lower level of technological readiness. While there are pilot projects and demonstration plants in place, these technologies are not yet ready for widespread deployment. Similarly, energy storage technologies show varied readiness: while battery storage has reached commercial viability and is being deployed, hydrogen-based storage is still in the experimental phase and requires further development before it can be deployed at scale.</p>
<p>Type of funding instruments (Focus on specific types, supply side or demand side focus etc.)</p>	<p>What are the primary types of funding instruments that the system relies on (differentiate by R&I focus area if necessary)?</p> <p>In France, key instruments for financing R&I in climate change mitigation are provided through public funding mechanisms and support innovation from basic research to commercialisation. France 2030 plays a central role in this landscape, providing investments for R&I across strategic sectors, including green technologies. PEPRs are one of the funding instruments introduced under France 2030. These programs focus on financing fundamental research at Technology Readiness Levels (TRL) 1 to 4. The PEPRs support both national acceleration strategies, aimed at removing scientific barriers to technological deployment, and exploratory PEPRs, which explore emerging transformations.</p> <p>The ANR provides funding for basic research and applied research projects, focusing on advancing knowledge in key areas such as renewable energy technologies, sustainable mobility, and carbon capture. The General Secretariat for Investment (SGPI) works alongside the ANR, ensuring that strategic large-scale projects receive adequate funding.</p> <p>There are also specialized instruments aimed at supporting private sector innovation, including direct financial support for start-ups and emerging companies. Instruments for financing innovation within enterprises focus on R&D that can lead to near-market solutions. The government has also recognized the need to bridge the funding "valley of death" for scaling up projects, particularly those that are critical for industrialization.</p> <p>France also integrates European Union funding mechanisms into its R&I landscape, most notably the Horizon 2020 program and its successor, Horizon Europe, which provide financial support for collaborative research across Europe. French research institutions frequently participate in EU-funded projects, allowing for cross-border collaboration and the sharing of resources, particularly in areas such as climate modelling, carbon neutrality research, and energy innovations.</p> <p>Funding for R&I in climate change mitigation relies on a mix of grants, loans, equity investments, and tax incentives tailored to different stages of innovation. Grants are provided by programs like PEPRs and ANR, supporting early-stage research and applied projects in areas such as renewable energy and carbon capture. Bpifrance offers loans and equity investments, especially to startups and SMEs, to help scale near-market solutions in green tech. The EU's Horizon Europe program adds collaborative grants, facilitating cross-border R&I in climate-related fields. Additionally, the Cr�dit d'Imp�t Recherche (CIR) provides tax relief to companies conducting R&D, further incentivizing private sector innovation aligned with climate goals.</p>

Aspect	Questions / Collected evidence
Funding volume (e.g. by R&I focus areas)	<p>What is the overall funding volume of the R&I measures intended to contribute to climate change mitigation?</p> <p>France 2030 allocates €54 billion to support businesses, research institutions, universities, and start-ups across the innovation lifecycle, with a strong emphasis on sectors crucial for the green transition, such as renewable energy, hydrogen, energy storage, and decarbonization of industry, including €1.2 billion specifically for developing low-carbon aviation technology, €2.3 billion for hydrogen technologies, and €5 billion for industrial decarbonization efforts. At least 50% of the funding—around €27 billion—is dedicated to decarbonization objectives, which aligns with national strategies like the SNBC.</p> <p>A total of €3 billion is allocated to PEPRs to support groundbreaking research, with the aim of reinforcing French leadership in areas that are critical for both national and European priorities.</p> <p>Can one derive from the funding volume in a specific R&I field the strategic priorities?</p> <p>The significant investments dedicated to areas like green hydrogen production, nuclear energy, energy storage and industrial decarbonization highlight these fields as top priorities for the country's green transition. Carbon capture and storage, while receiving less funding than renewables and hydrogen, is still considered a critical technology for achieving deep decarbonization in industries like steel and cement.</p>

3.2.3 France – Section 3: Monitoring approaches

Aspect	Questions / Collected evidence
Section 3: Assessment of monitoring approach for contribution of R&I for climate change mitigation	
Key monitoring system (in place / in preparation)	<p>Is there a monitoring system (either dedicated to R&I measures, green budgeting, or monitoring system for the progress to climate neutrality) that involves a measurement or provides guidance on the contribution of R&I measures to climate change mitigation (or more than one system)?</p> <ul style="list-style-type: none"> The primary mechanism used for monitoring progresses in climate change mitigation is embedded within the SNBC, which employs a series of carbon budgets to set legally binding limits on greenhouse gas emissions. These budgets serve as a quantitative tool to evaluate whether specific sectors are meeting their emissions reduction targets. These budgets are reviewed every five years to assess if emissions reductions are aligned with national targets. In addition to carbon budgeting, the France 2030 plan includes provisions for tracking the progress of funded projects in green technologies and innovations. This involves systematic assessments of technological development milestones and market readiness levels to ensure that investments are yielding tangible benefits in reducing carbon emissions and advancing ecological transitions. In the context of France 2030, PEPRs projects include systemic reporting and monitoring frameworks, which track both immediate outcomes and the long-term impacts of R&I measures on decarbonization goals. The High Council for the Climate plays a critical role in providing independent evaluations of France's progress toward carbon neutrality, issuing recommendations on how R&I efforts can be optimized for greater impact. It needs to be noted that there is currently a gap in standardized methodologies for measuring the long-term contribution of R&I on climate change mitigation in France. While immediate outputs of projects are monitored, there is still no fully developed method for measuring the actual impact of R&I innovations on emissions reductions over time. This is an area that national agencies and research organizations are working to address, as effective long-term measurement is crucial for ensuring that R&I investments translate into significant and sustainable climate benefits.
Approach for measuring the impact of R&I measures on climate change mitigation	<p>What is the specific approach of the system?</p> <ul style="list-style-type: none"> The specific approach of France's monitoring system under the SNBC involves the use of quantitative indicators to measure carbon emissions reductions, energy consumption, and the contribution of various sectors to national decarbonization goals. The system tracks the emissions performance of different economic sectors by comparing actual data with predefined targets. For example, it assesses the reduction in energy consumption in residential and tertiary sectors and measures greenhouse gas emissions by differentiating between sources such as methane, nitrous oxide, and CO₂ from industrial activities The approach of the monitoring system under France 2030 is designed to combine both quantitative and qualitative evaluations to track the progress of R&I initiatives. It employs

Aspect	Questions / Collected evidence
	<p>TRLs to assess the maturity of technologies and measures the transition of innovations from the research phase to deployment. To do so, the system employs annual reports, reviews and on-site visits. The High Council for the Climate also carries out independent evaluations on the progress of France 2030.</p> <p>What is being measured and how? Key indicators are employed such as carbon emissions reductions, technological maturity, and market penetration of innovative solutions. Specifically, emissions reductions achieved by projects funded through France 2030 investments are tracked, using data from national emissions inventories to gauge progress against sectoral targets. Technological performance is evaluated through TRL assessments to determine the stage of development of each innovation, while market penetration rates are monitored to see how effectively these technologies are being adopted in relevant industries. Socio-economic outcomes like job creation, skills development, and the overall economic impact on industries involved in the green transition are also measured.</p>
<p>Sources of information / methodological approach for monitoring system</p>	<p>What information and data is used for the monitoring system? The monitoring and evaluation system under France 2030 is based mainly on evaluations of the plan carried out by different institutional actors (e.g., Bpifrance, ADEME), as well as on a comprehensive set of national SDG indicators encompassing various aspects of sustainable development. The monitoring and evaluation of France 2030 primarily utilizes data from national GHG inventories, technological performance reports, and detailed sectoral analyses. These data sources include emissions levels recorded across multiple sectors (e.g., energy, industry, and transport). This includes detailed metrics on emissions reductions, and energy consumption levels by vector (e.g., fossil fuels, renewables). The indicators measure the effectiveness of decarbonization strategies across different industries. These indicators are systematically updated to track both direct emissions reductions and the broader impact on energy use and carbon sequestration efforts. Additionally, the system integrates technological and market data from projects funded under France 2030, tracking factors like technology deployment rates, adoption levels, and the progress of green innovation initiatives. Data on economic and social impacts are also collected to provide a holistic view of the plan's effectiveness in driving both environmental and economic outcomes.</p> <p>What types of assumptions / methods are used? The methods used in the monitoring system involve a range of assumptions that are based on projections about technological development trajectories, market dynamics, and regulatory impacts. For example, the assessments assume specific rates of technological advancement and scalability for innovations like small modular reactors and green hydrogen systems. Economic models, such as macro-sectoral econometric tools, are employed to predict the potential impacts of investments on emissions reductions and GDP growth. The Comité de Surveillance des Investissements d'Avenir (CSIA) also uses scenario analysis to evaluate the possible outcomes under varying conditions, including changes in policy, market shifts, and international developments that may affect France's decarbonization goals. Additionally, the SGPI, through its partner operators, conducts regular evaluations of the program to assess the effectiveness of investments and improve understanding of their impacts on both economic and environmental goals.</p>
<p>Actors and roles in the monitoring system</p>	<p>Who are the involved actors in providing and validating the data? The Ministry of the Ecological Transition is primarily responsible for overseeing the monitoring of carbon budgets and ensuring that climate targets are met across various sectors. It collaborates with the Ministry of Research and Innovation to align technological advancements with these goals. The SGPI oversees data collection and validation for programs under France 2030, working alongside ADEME, which provides expertise and monitors progress on energy and environmental innovations. The ANR gathers and analyses annual project reports. Public research entities contribute data, with significant input from institutions such as CNRS, INRAE and CEA especially on technological readiness and innovation performance. The Haut Conseil pour le Climat provides independent evaluations of France's climate strategies and their alignment with national and international goals. Private companies also report progress on innovations funded under France 2030.</p>
<p>Implications</p>	<p>What are the practical implications of the monitoring results?</p> <ul style="list-style-type: none"> • The insights gained from the evaluations and monitoring of climate and investment strategies (e.g., SNBC and France 2030) help guide future investments and strategic decisions, including on R&I measures contributing to climate objectives. These evaluations also inform new research topics, that research operators are asked to explore.

Aspect	Questions / Collected evidence
	<ul style="list-style-type: none"> France 2030 and, in particular, the PEPRs are subject to the concept of "programmation glissante" (rolling program) which allows for continuous adaptation of R&I strategies based on monitoring outcomes and expectations. Monitoring results contribute to the formulation of corrective actions to reallocate funding to more impactful initiatives, in case specific projects or sectors are found to be underperforming in terms of emissions reductions or technological readiness. This adaptive approach allows the government to respond to the evolving landscape of technological developments and ensure that investments remain focused on the most promising and effective solutions for achieving the country's climate goals. <p>How are they integrated in the R&I policy cycle (e.g., being on track for the development of key technologies or not)?</p> <ul style="list-style-type: none"> The results from the monitoring processes may involve reallocating funds to more promising technologies or revising regulations to better support innovation deployment. Successful technologies identified through the TRL assessments are prioritized for further investment and rapid commercialization.
<p>Other documents used for measuring / validating the impact (evaluations etc.)</p>	<p>Are there other documents used for the measurement of the contributions of R&I measures (e.g. evaluations)? How are their results included in the monitoring process?</p> <p>In addition to the core strategic documents, other evaluation tools are used to measure the contributions of R&I to climate change mitigation:</p> <ul style="list-style-type: none"> Both the SNBC and France 2030 initiatives require the publication of annual reports that outline the progress made towards achieving their goals. These reports provide transparency and accountability by detailing achievements, challenges, and adjustments in the R&I funding strategies. Independent assessments by institutions like the Haut Conseil pour le Climat provide third-party evaluations of the effectiveness of France's climate policies. These audits assess whether the R&I investments are delivering the expected outcomes in terms of emissions reductions and technological advancements. France also participates in international climate and innovation assessments, such as those conducted by the European Union's Horizon Europe program, to compare its progress with that of other nations and to integrate best practices into its national strategies. <p>Additional documents, such as the 2023 Evaluation of France 2030, play a significant role in measuring the plan's impact on decarbonization and economic growth. This evaluation outlines how €14 billion has already been committed to projects that are expected to result in significant reductions in carbon emissions and the creation of thousands of jobs in green industries. The results from these evaluations are incorporated into strategic reviews to adjust focus areas and improve the effectiveness of France's investments in R&I for climate action.</p>

List of sources for French case study

Sources	Documents
	<ul style="list-style-type: none"> Plan National d'Adaptation au Changement Climatique (PNACC), 2017 Stratégie nationale bas-carbone (SNBC), 2020 Stratégie nationale de la recherche énergétique (SNRE), 2016 Horizon Europe and the Green transition: Interim evaluation support study (Final Report) - European Commission DG RTD, 2024 La recherche sur le climat en France, Synthèse 2016/2022 - Ministère français de l'enseignement supérieur, de la Recherche et de l'innovation, 2024 Stratégie française pour l'énergie et le climat, Programmation Pluriannuelle de l'Énergie (PPE) 2019-2023, 2024-2028 France 2030 – Plan d'investissement, 2021 Plan National Intégré Energie-Climat de la France (PNIEC), 2020 France 2030, Lancement maîtrisé d'un plan d'investissements à impacts majeurs, Première évaluation in itinere - Comité de surveillance des investissements d'avenir (Gouvernement Français), 2023 France 2030, Rapport d'Activité 2023 – Premier Ministre Comité d'évaluation du plan France Relance – Rapport final, France Stratégie, 2024

	<ul style="list-style-type: none">• Frontier economics - évaluation de l'impact de France 2030 en matière de décarbonation de l'économie - 2023
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3.3 The Netherlands

3.3.1 The Netherlands – Section 1: Overarching framework

Aspect	Questions / Collected evidence
Section 1: Political objectives, strategies, and main actors related to R&I for climate change mitigation	
Overall political objectives related to R&I supporting climate change mitigation	<p>What is the climate change mitigation objective of the case study country?</p> <ul style="list-style-type: none"> To combat climate change, the Dutch government wants to reduce the Netherlands' greenhouse gas emissions by 55% by 2030, compared to 1990 levels, and achieve climate neutrality by 2050. The new government has fairly strong climate ambitions and places much focus on technological solutions.⁴³ At the same time, at least two of the four coalition partners show climate sceptic beliefs. However, the increased attention to climate change can be exemplified by the fact that for the first time in history there is a separate Minister for Climate and Green Growth. Attention for biodiversity and nature is, with two parties with a strong rural background, secondary to sectoral importance of agriculture and fisheries. The government programme emphasises innovation and the deployment of technological solutions. While there is a strong focus on education and training as a means to integrate these technologies into society, the government programme at the same time outlines budget cuts in funding for science (including the Research Council and research infrastructures). Therefore the current signals send by the Government could be seen as contradictory. The Dutch climate targets are set out in the 2019 national Climate Act (Klimaatwet). Apart from the climate targets, the Climate Act also describes the policy framework around the climate targets. Three policy instruments are included: the five-yearly Climate Plan, the biannual Progress Report and the annual Climate Memorandum (Klimaatnota). The Climate Plan covers a ten-year period, and gets redefined at least once every five years. The second Climate Plan has been published in 2025, covering the years 2025-2035. The Dutch Integrated National Energy and Climate Plan, the National Climate Adaptation Strategy (which will be updated in 2026) and the National Delta Programme are other relevant policy documents in the context of climate change mitigation or adaptation.
Strategies and implementation plans	<p>How is this strategic objective translated to the R&I strategies of the country and what are the key documents for their implementation (plans)? What is their time horizon? Is monitoring of the long-term contribution of R&I measures to general R&I goals part of the R&I system?</p> <p>Much of the implementation of R&I on climate change (mitigation) is driven by EU legislation and through general R&I instruments⁴⁴. These R&I-policies focus on industrial (top)sectors and, since 2019, societal missions. In general, a large portion of the R&I policy and its instruments in the Netherlands has a broad, non-specific focus⁴⁵. This does not imply that climate change mitigation is not targeted in the R&I agenda, but that the degree of emphasis on green innovation varies and that the R&I activities support the societal missions.⁴⁶</p> <p>The main Dutch R&I policy is the 2019 Mission-driven Top Sector and Innovation Policy (MTIB). The MTIB integrated societal missions, including green topics, into the 2011 <i>top sector-policy</i> –</p>

⁴³ Regeerprogramma (government programme) kabinet-Schoof, Retrieved from:

<https://www.rijksoverheid.nl/documenten/publicaties/2024/09/13/regeerprogramma-kabinet-schoof>

⁴⁴ Ministry of Economic Affairs and Climate and the Ministry of Education, Culture and Science. (2022). Letter to the Parliament - Innovation policy, Enterprise policy, and Higher Education, Research and Science policy Kamerstuk 33009, nr. 117 <https://zoek.officielebekendmakingen.nl/kst-33009-117.html>

⁴⁵ Ministry of Finance. (2022). A Broad Social Review no.9 Innovative Society. (Innovatieve samenleving - Een Brede maatschappelijke heroverwegingen). <https://www.rijksoverheid.nl/documenten/rapporten/2020/04/20/bmh-9-innovatieve-samenleving>

⁴⁶ Kabinetsaanpak Klimaatbeleid (Climate Policy Strategy), 2023, <https://zoek.officielebekendmakingen.nl/kst-32813-1287.html>

Aspect	Questions / Collected evidence
	<p>an industrial policy to promote strong and innovative industries of the Dutch economy^{47,48}. The objectives are to strengthen the economy through innovations, capitalise on international opportunities, to improve human capital and invest into scientific research.</p> <p>The MTIB policy is based on collaboration between industry, science and government and is sealed with a Knowledge and Innovation Covenant (KIC). The KIC is a Memorandum of Understanding between the different stakeholders and reflects the commitment and resources that public and private partners pool for research and innovation on the missions⁴⁹. We are currently in the second KIC period (2024-2027), which builds on the structures and experiences of the earlier KIC.</p> <p>The societal mission are translated by the KIC into Knowledge and Innovation Agendas (KIA). At the end of 2023, the Dutch Government presented a revision of the different KIAs. For the period 2024-2027 there are five thematic and three cross-cutting KIAs (please see Section 2 for an elaboration on the thematic scope of the KIAs; the relevant KIAs are Energy transition, Circular Economy, Agriculture, water and food, Key Enabling Technologies and (to a lesser extent) Digitalisation). Each KIAs is subsequently broken down into separate "Meerjaren Missiegedreven Innovatie Programma" multi-annual mission-driven innovation programmes (MMIPs), which set out specific actions to achieve the objectives of the missions.</p> <p>The Dutch research policy is coordinated by the Ministry of Education and Science. The ministry provides direct funding to universities (without restrictions on research topics) and indirect funding by way of Dutch Research Council (NWO). In 2023, NWO updated the Dutch Science Agenda – a strategic document that aims to provide inspiration for into scientific and societal issues. It covers 140 overarching questions that are clustered in 25 routes.</p> <p>Furthermore, at the beginning of 2024 the Dutch government presented a National Technology Strategy in which it sets out the strategic objectives for Key Enabling Technologies for the upcoming period.⁵⁰ This Strategy is aligned with the KIAs.</p> <p>Another influential industrial policy instrument in the period 2021-2023 was the National Growth Fund (NGF).⁵¹ The Dutch government invested ca. € 11 bn in 50 projects in fields which have the highest potential for structural and durable economic growth. While investment into new projects have been halted, ongoing projects will continue. In these projects more than 2,800 companies and 30 knowledge institutes are involved. Initially, the NGF had a budget of € 20 bn and was supposed to last 5 years, but the new government abolished the Fund.</p> <p>One of the other means to reach climate neutrality of the Dutch government through a just transition is the Climate Fund (Klimaatfonds). More specifically, the Fund has a threefold focus: (a) a greenhouse gas-neutral energy supply in 2050; (b) fostering the implementation of energy efficiency techniques, and encouraging renewable energy and other greenhouse gas-reducing and circular techniques and technologies in the industry; and (c) stimulating the application of energy efficiency techniques, renewable energy and carbon sequestration in the built environment. Some of the actions supported through the Climate Fund are R&I focused.</p> <p>In addition to these national R&I programmes, strategies and instruments, programmes at the European/international level, as Horizon Europe, ERDF and JTF, as well as regional and local funds also contribute to R&I in climate-related sectors.</p>
<p>Main actors and roles in the R&I system</p>	<p>What are the main actors involved and what are their roles?</p> <p>A wide range of Ministries are involved in the R&I system in the Netherlands. The Netherlands has no strong hierarchy between ministries, but a very strong tradition in coordination across</p>

⁴⁷ Ministry of Economic Affairs and Climate (2018). Missiegedreven Innovatiebeleid met Impact. Source: <https://open.overheid.nl/documenten/ronl-c0379248-8472-4355-ab72-caa676a273d3/pdf>

⁴⁸ The selected industries are: Agri & Food ; Chemistry ; Creative Industry ; Energy ; Life Sciences & Health ; Logistics ; High Tech Systems & Materials; Horticulture & Starting Materials ; Water & Maritime Industry and ; Dutch Digital Delta (Team ICT).

⁴⁹ The first KIC operated 2020-2023 and was signed by figure heads from the top sectors, the 7 presidents of the umbrella organisations for education and research (e.g. universities (of applied sciences), national research institutes, the Academy of Sciences), 12 ministers, Invest-NL and the umbrella organisations for the 12 provinces and the Regional Development Organisations.

⁵⁰ Rijksoverheid (2024). Nationale Technologiestrategie <https://www.rijksoverheid.nl/documenten/beleidsnotas/2024/01/19/de-nationale-technologiestrategie>

⁵¹ Nationaal groeifonds (n.d.). Source: <https://www.nationaalgroefonds.nl/doel-nationaal-groeifonds>

Aspect	Questions / Collected evidence
	<p>policy domains. Some ministries are responsible for general R&I policy, and others have a thematic focus that is in scope of this assignment. Due to their role in climate, economic, research and innovation policy, the main ministries involved and/or responsible are:</p> <ul style="list-style-type: none"> • The Ministry of Economic Affairs, the Ministry of Education, Culture and Science and the Ministry of Climate Policy and Green Growth (recently spun out from the Ministry of Economic Affairs, coordinator of energy and climate) <p>In addition to that, the following ministries are also involved in R&I for social and environmental political targets related to climate change mitigation:</p> <ul style="list-style-type: none"> • The Ministry of Agriculture, Fisheries, Food Security and Nature (coordinator of biodiversity policy), the Ministry of Infrastructure and Water Management (coordinator of environment policy), and the Ministry of Housing and Spatial Planning. <p>In the Netherlands, many R&I subsidies and instruments are implemented by the Netherlands Enterprise Agency (RVO). Another important agency is RWS (Rijkswaterstaat, the agency of the I&W, actually focussing on infrastructure).</p> <p>The Top sectors bring together the R&I stakeholders (including industry, science and government) per focus sector and play an important role in each industry in developing the strategy and actions (KIA/MMIPs) for the short- to long-term.⁵² Each Top Sector is composed of representatives from science, business and relevant governmental departments and collaborate with Top Consortia for Knowledge and Innovation (TKIs) – which serve as secretariats. The TKIs play a pivotal role as they are tasked with the network activities and the development of the innovation roadmaps.</p> <p>As for scientific research, the Dutch Research Council (NWO) is the most important science funding body in The Netherlands. Other stakeholders involved in conducting scientific research and research into its deployment are the Toegepast Onderzoek Organisaties (TO2) (Applied Research Institutes)⁵³ and all universities in the Netherlands, especially the Universities (including the federation of the four Dutch universities of technology).</p>

3.3.2 The Netherlands – Section 2: R&I portfolio linked to climate change mitigation

Aspect	Questions / Collected evidence
Section 2: Assessment of R&I portfolio and funding strategies to support climate change mitigation	
R&I focus areas (e.g., research cluster, sectoral focus)	<p>What are the general characteristics and structure of the R&I portfolio?</p> <p>Are there R&I focus areas defined for the country (e.g., in the strategy)?</p> <p>As previously mentioned, Dutch R&I policy and instruments are mostly general in nature. The extent to which a green thematic focus is integrated into the policy generally increases going from basic research towards deployment in the product market.</p> <p>The research that is conducted through the MTIB have a thematic focus as the KIAs are central to the R&I portfolio. No specific financial instruments are created for the mission-driven innovation policy. Instead, existing instruments are used. In the KIAs for the period 2024-2027, there is more emphasis on valorisation and market creation as compared to the initial KIAs. The government has defined five thematic missions and three cross-cutting KIAs. The relevant thematic mission are: "Energy transition", "Circular Economy", "Agriculture, water and food".⁵⁴ The relevant cross-cutting KIAs are: "Key Enabling Technologies" and "Digitalisation".⁵⁵</p> <p>In the KIAs, each mission is subsequently refined into concrete innovation programmes: the MMIPs. This process is done through an iterative process between the government, industry (Topsectors) and other stakeholders. The MMIPs make explicit which knowledge and innovation</p>

⁵² There are 10 Top sector entities. The relevant Top sector entities for Climate Change mitigation are: Agri & Food; Chemistry NL; Energy; Holland High Tech; ICT; Logistics; Horticulture & Starting Materials; and Water & Maritime.

⁵³ Deltares, Marin, NLR, TNO and Wageningen Research.

⁵⁴ Dutch Government (2023) Herijkte missies van het missiegedreven innovatiebeleid, Retrieved from: https://www.tweedekamer.nl/kamerstukken/brieven_regering/detail?id=2023709541&did=2023D22850

⁵⁵ The KIAs that are not relevant for Climate Change Mitigation are: Health care (thematic), Security (thematic), and Societal Earning Capacity (cross-cutting).

Aspect	Questions / Collected evidence
	<p>activities are needed for the different aspects of innovation: research, development, pilots/demonstration and implementation.</p> <p>The KIAs and MMIPs are central to achieving the objectives of the missions. For instance, the development of the Integrated Knowledge and Innovation Agenda (IKIA) for Climate and Energy was highly influenced by the Dutch Climate Act and the policies supporting it. Many parties (e.g., the topsectors) were involved in (discussion surrounding) the development of both policies. In this case, the MMIP therefore sets out the R&I actions to achieve the objectives – for instance, making sure that research calls align with the mission.</p> <p>As the different relevant KIAs all have multiple missions, interim targets for 2030, and MMIPs, we will highlight the previously mentioned IKIA as an example of how the R&I portfolios are structured. There are 7 Missions, one separate MMIP focused on the integration of the energy system, and 4 cross-cutting themes⁵⁶. For instance, as the name of Mission C – Industry (A climate-neutral and circular industry in 2050) suggests, the mission aims to make industry circular and climate-neutral, while also ensuring that there are alternatives to current materials and products. Three MMIPs contribute to Mission C. MMIP 6 focuses on innovations leading to closure of industrial raw material/material chains of carbon in industry, which contribute to the sustainability of industry (scope 3 measures) and lead to CO₂ reduction in a cost-efficient way. The sub-programmes of MMIP 6 focus on circular plastics, biomaterials and Carbon Capture and Utilisation. MMIP 7 focuses on CO₂-free industrial energy management. The sub-programmes of MMIP 7 focus on 1. reduce energy dependency; 2. re-use energy; 3 replace energy carriers; 4 produce hydrogen. MMIP 8 focuses on innovations that play a role in energy chain and system aspects, including circular raw materials, infrastructure, transport and storage of CO₂, and digitalisation. The MMIP objectives are operationalised through existing R&I instruments.</p> <p>While the top sectors embody the economically interesting industries, top sectors have limited funding allocated to them. The partners in the KIC, however, have laid down their plans for innovation (R&D to valorisation and attention to market creation). There is no central budget division mechanism: the funding is reallocated within existing (public and private) programmes and budgets. For instance, the KIC 2024-2027, specifies that for the IKIA, two departments from the Ministry of Economic Affairs and Climate (at the time of writing these departments are now part of the Ministry of Economic Affairs and the Ministry of Climate and Green Growth), the Ministry of Infrastructure and Water, and the Ministry of Interior Affairs. The covenant contain the anticipated financial contributions that the partners expect to deploy for innovation driven by the public-private partnership across the KIAs. These contributions therefore concern the innovation funds that are used in coordination to contribute through innovation to the missions and key technologies that are important to the Netherlands, including the green transition. The proposed annual budgets do not constitute (financial) commitments, nor do they give rise to a claim on financial resources.</p> <p>Another influential industrial policy is the previously introduced National Growth Fund. The NGF targeted two areas with significant potential for sustainable economic growth, namely: (i) knowledge development and (ii) research, development and innovation. Generally speaking, the projects with regards to research, development and innovation are structured around the topics: (i) Key Enabling Technologies, (ii) Security and Digitalisation, (iii) Agriculture and the environment, (iv) Life Sciences & Health, (v) Energy and Sustainable Development and (vi) Mobility.⁵⁷</p> <p>As mentioned before, the Climate Fund also includes R&I actions relevant to support climate change mitigation. This include a programme focused on innovation and the early scale-up phase of carbon removal techniques and technologies – the budget allocated to this action is added to current generic R&I instruments (such as the MOOI-instrument). Another set of actions is focused on the transition within the industry. The actions relevant for R&I are more deployment-focused – as it includes the intensification of the DEI+ instrument (a higher</p>

⁵⁶ Mission A: Electricity; Mission B: Built Environment; Mission B+: Built Environment; Mission C: Industry; Mission D:+ Mobility; Mission E: Agriculture; Mission Nuclear Energy. Cross-cutting themes: Hydrogen; Human Capital Agenda; Digitalisation and Socially responsible innovation.

⁵⁷ Examples of relevant NGF projects are: GroenvermogenNL (green hydrogen and chemistry, € 338 m, second round €500 m), Regenerative Agriculture (€ 129 m), Maritime Masterplan 2.0 (€210 m), Material Independence & Circular Batteries (€296 m), Cellulaire agricultuur (€60 m), CropXR (new breeding technique for climate-resistant crops, €43 m), Zero emission inland navigation, battery-electric (Zero Emission Services) (€50 m), Luchtvaart in Transitie (Aviation in Transition, €383 m), NL2120, Het Groene Verdienvermogen (NL2120, the nature-based solutions, €110 m), Circular Plastics NL (€220 m), BioBased Circular (€102 m, €236 m in reserve), SolarNL (max. €412 m).

Aspect	Questions / Collected evidence
	<p>maximum subsidy amount and a broader range of themes for which subsidies can be applied) and a new subsidy instrument specifically focused on scaling up pre-commercial innovative climate technologies for large industrial projects (min. €50m) and an allocation of the subsidy based on the intensity of the EUR/CO2 reduction.</p> <p>As for the scientific research, universities get basic funding for research. Furthermore, NWO selects and funds research proposals based on recommendations from expert scientists and other experts in the Netherlands and abroad. NWO funds more than 7200 research projects at universities and knowledge institutions.⁵⁸ NWO gets its funding from the Ministry of Education and Science but has (almost) full authority on the way it spends the funding. One of the ways, research funding is structured in the Netherlands – aside from the Dutch Science Agenda structures research funding in the Netherlands. The Dutch Research Agenda comprises 25 'routes' that cover 140 cluster questions and are a research agenda to address important scientific, societal and economic challenges facing society, including Climate Adaption topics and the Energy Transition.</p> <p>Horizon Europe, ERDF and the Just Transition Fund are important European programmes that are important for green innovation in the Netherlands – also partially due to the climate mainstreaming target of the EU to spend at least 30% of its budget on climate-relevant objectives.</p> <p>How do these R&I focus areas deviate from the approaches in other countries (question for the interviews only)?</p> <p>While the KIAs provide thematic guidance on the R&I focus in the Netherlands, there is not a clear <i>green/net-zero</i> R&I programme. The system is more open as opposed to other countries where in some cases the government decides on central topics.</p> <p>The approach to the development and the implementation of the large scale public-private collaboration (e.g. the National Growth Fund and the KICs/MMIPs) is unique. This approach is exemplified by the strong focus on a multi-stakeholder consensus-building process and it connects the economic aspects (i.e., industrial policy) with objectives relevant to society (i.e., the missions).</p>
<p>Strengths of the countries R&I system relevant for climate change mitigation</p>	<p>What are the strengths in countries R&I system related to contributions to climate change mitigation?</p> <p>A wide range of stakeholders is involved in the decision-making process, ranging from industry, research institutions, the government and NGOs. As the process of defining research priorities involves many parties, it has a participatory nature. This means that different perspectives are considered for a common goal. Furthermore, the process allows for the optimal use of existing networks, and creates buy-in from the most important stakeholders. The ministry of Education, Culture and Science has always positioned themselves in the field of research as a supportive, non-interventionist ministry: not making decisions on what areas research programmes are, but leaving a lot of those decisions to the universities (which have their triple task of education/research/societal impact) and the Research Council (which has to focus on achieving top quality research with a societal impact). In order to achieve societal impact, the universities and the Research Council participate in different programmes from other ministries , from which they can get additional funding. As mentioned before, ministries in the Netherlands allocate budget towards / co-fund R&I instruments that can help to achieve their objectives.</p> <p>This approach fits in the strong tradition of coordination between ministries and involvement of stakeholders in policy making and policy execution.</p> <p>The amount of direct control from the level of the Ministry on goal achievement is therefore low, but the idea is that stakeholders have internalised the policies which guarantees that they drive themselves towards goal achievement. The extent to which this works, differs per topic.</p>
<p>Weaknesses in the countries R&I system relevant for climate change mitigation</p>	<p>What are the weaknesses in countries R&I system related to contributions to climate change mitigation?</p> <p>The identified weaknesses are more related to the general R&I system, not specifically to the contributions to climate change mitigation. In terms of investments into R&I, in recent years the long-term perspective deprioritised, with more immediate concerns often taking precedence over sustained investment in future-focused projects.</p>

⁵⁸ NWO

Aspect	Questions / Collected evidence
	<p>This can be exemplified by the premature discontinuation of the National Growth Fund and budget cuts from the current/new government for the scientific system, including large budget cuts for NWO.</p> <p>The larger instruments or subsidies are more focused on technology adoption subsidies as opposed to instruments for innovation or development of innovations in the green / climate change mitigation field (e.g. the SDE++).</p> <p>Furthermore, when considering the different stages of the innovation process (i.e. from basic research to mass adoption), there is room for improvement in pre-commercial stage / early stage development. There is considerable focus on basic research and the product market stage, however in between policies and instruments are lacking.</p> <p>Finally, the unique (multi-stakeholder) approach of research priority setting also has its drawbacks, namely that it is more difficult to develop radical innovations as incremental innovations are more likely to come out of the – this is the side effect of the consensus-building process – as a wide range of stakeholders is involved in this process.</p>
<p>Scope in technological readiness (basic research vs. deployment focus)</p>	<p>Does the investigated portfolio exhibit specific patterns in terms of technological readiness?</p> <p>The scientific research is often focused on basic research. However, this also differs (especially, in the context of the KIAs, where public-private-partnerships are central).</p> <p>Generally, R&I policy is more focused on deployment. There is a gap in the early stage research. As mentioned before, market stimulation has been an important part of Dutch green policies. These (and some comparable) subsidies have had significant impact on creating markets for wind energy, solar energy, electric cars and hydrogen.</p>
<p>Type of funding instruments (Focus on specific types, supply side or demand side focus etc.)</p>	<p>What are the primary types of funding instruments that the system relies on (differentiate by R&I focus area if necessary)?</p> <p>Generally speaking, there is a variety of types of funding instruments that are being used. Most of the instruments are grants, subsidies, public-private-partnerships.</p> <p>The major (private) innovation instruments do not specifically target green innovation. Funding goes through a variety of generic grant and funding schemes of Netherlands Enterprise Agency (RVO). RVO provides subsidies for businesses and small and medium-sized enterprises (SMEs) through various subsidy instruments. RVO is commissioned by various government departments. For instance, the WBSO (Wet Bevordering Speur- en Ontwikkelingswerk) is a tax credit for research and development for companies, specifically for development projects or technical-scientific research. The TKIs can use subsidies to foster public-private partnerships aimed to support collaboration projects or innovation activities that are relevant to the Topsectors and the KIAs. The maximum aid intensity of the PPS innovation subsidy programme is higher for the projects with lower TRLs (basic research 80%, industrial research 50%, and experimental development 40%). For SMEs, there is the Mkb-innovatiestimulerend Regio en Topsectoren (MIT) (the <i>Regional and Top Sector Innovation Scheme for SMEs</i>), which funds different types of activities such as knowledge vouchers, R&D cooperation projects and networking activities.</p> <p>There are other smaller instruments focused green or energy innovation or the adaptation of green technologies. For instance, the Missiegedreven Onderzoek, Ontwikkeling en Innovatie (MOOI). The MOOI instrument is a subsidy scheme for mission-driven R&D in multidisciplinary consortia working on integral climate-relevant themes (offshore wind, renewable electricity). Another example is the subsidy instrument Demonstratie Energie- en Klimaatinnovatie (Demonstration Energy and Climate Innovation, DEI+), which focuses on pilot and demonstration projects that contribute to the cost-effective reduction of CO2 emissions in the Netherlands by 2030 through technologies that save energy or support renewable energy. These technologies should be market-ready within 10 years. The Hernieuwbare Energietransitie (HER+, Renewable Energy Transition) subsidy supports innovation projects focused on cost-reductions of different renewable energy sources with the objective to reduce future costs of the SDE++ subsidy scheme. Finally, there is the TSE subsidy (at the moment of writing named the <i>Energie en Klimaat Onderzoek en Ontwikkeling</i> (EKOO) (<i>Energy and Climate Research and Development</i>)). This subsidy scheme is aimed at industrial research or experimental development projects aimed to support the energy transition.</p> <p>Historically, market stimulation has been an important part of Dutch green policies. Main instrument is the SDE++ (Subsidies Sustainable Energy Production and Climate Transition), a subsidy to finance the non-profitable top of investments in sustainable energy production. There are also various fiscal incentives for companies to invest in Energy Saving equipment (EIA) and other 'green' equipment (MIA and VAMIL).</p>
<p>Funding volume (e.g. by R&I focus areas)</p>	<p>What is the overall funding volume of the R&I measures intended to contribute to climate change mitigation?</p>

Aspect	Questions / Collected evidence
	<p>It is difficult to indicate how much spending went into R&I measures intended specifically to contribute to climate change mitigation. Large parts of the Dutch R&I system have a generic focus. This section will therefore provide a general overview and highlight some instruments.</p> <p>The Knowledge and Innovation Covenant was allocated a total annual budget of € 5.7 bn (€ 1.42 bn and € 4.30 bn from respectively private and public sources) for 2024. The public funding for the KIC is for the larger part not 'new' money but concerns re-allocation from existing budgets. For instance, through budget allocated to research institutes, universities or through departments of ministries. Each year, NWO invests almost 1 billion euros for research and research infrastructures.</p> <p>The SDE++ Budget in the past years was approximately €8 bn/year and the total budget for MIA and VAMIL in 2024 is €476mln. Whereas, the budget for the WBSO was € 1 370 m in 2023, for DEI+ €141mln in 2024 and €70mln for MOOI in 2024.</p> <p>For the National Growth Funds ca. € 11 bn was invested in 50 projects, including eight projects are in the Mission area of Energy and Sustainable development⁵⁹, six projects in the domain of Agriculture⁶⁰ as well as three projects in the Domain of Mobility⁶¹ and some Key Enabling Technologies project (esp. M€338, Biobased Circular; M€140, Holo-microbiome) have a focus on sustainability.</p> <p>As for funding from European sources, the Netherlands received €4.50bn from H2020 funding – which amounts to ca. €700 mln per year (i.e. the overall funding, not with a focus on climate change mitigation).</p>

3.3.3 The Netherlands – Section 3: Monitoring approaches

Aspect	Questions / Collected evidence
Section 3: Assessment of monitoring approach for contribution of R&I for climate change mitigation	
<p>Key monitoring system (in place / in preparation)</p>	<p>Is there a monitoring system (either dedicated to R&I measures, green budgeting, or monitoring system for the progress to climate neutrality) that involves a measurement or provides guidance on the contribution of R&I measures to climate change mitigation (or more than one system)?</p> <p>Monitoring is done by various organisations that are central in the system (e.g. RVO). Generally speaking, there is a challenge in drawing (quantitative) conclusions on the extent to which policies achieve impact, i.e., to what extent has a policy or instrument contributed to achieving the climate change mitigation objectives. This also has been concluded by a recent evaluation on the energy innovation instruments.⁶²</p> <p>Evaluation is part of the general Monitoring and Evaluation cycle of policy instruments, as it can provide evidence on the effects of policies and instruments. For example, the National Growth Fund will be evaluated and the projects it has funded will also get evaluated. In some cases, different tranches of funding are dependent on interim evaluations. The MTIB will be evaluated in 2026. Individual subsidy instruments that are part of the mission-driven innovation or energy innovation policy will be or have been evaluated separately. This also holds true for energy policy R&I instruments.</p> <p>Monitoring in the context of MTIB is done on different levels, progress in the missions is monitored by the government, the monitoring of the activities that are being done in the KIAs is done by thematic teams, and the monitoring of projects is done by the implementing organisations. However, in the context of mission-oriented innovation policy, there is the general challenge of measuring impacts (also in the context of the missions relevant to climate change mitigation)⁶³. The KIAs, however, have intermediate goals for certain aspects of the societal challenges. For instance, MMIP2 Renewable Energy Generation has the objective to enable the knowledge</p>

⁵⁹ This includes SolarNL, Material Independence & Circular Batteries, Circular Plastics NL (CPNL), Charging Energy Hubs and Green Steel (total budget approx. €2.2 bln)

⁶⁰ This includes projects on artificial meat, climate resilient crops and regenerative agriculture (budget M€500)

⁶¹ This includes Sustainable aviation; Maritime Masterplan; Zero Emission Services for inland shipping (budget M€643)

⁶² <https://zoek.officielebekendmakingen.nl/kst-32813-1287.html>

⁶³ Ministry of Economic Affairs and Climate. (2022). Durf te leren, ga door met meten: Op zoek naar kaders en methoden voor de evaluatie van systeem- en transitiebeleid.

Aspect	Questions / Collected evidence
	<p>and innovation development for renewable electricity with the highest possible societal and environmental value and at the lowest possible cost. As circularity is important in this context as well, the MMIP has the intermediate goal that at least 90% of the materials of PV systems and wind energy can be recycled. This interim goal is much more quantifiable.</p> <p>More generally, the extent to which the Netherlands will be able to reach the climate change mitigation objectives (i.e., reduce the Netherlands' greenhouse gas emissions by 55% by 2030, compared to 1990 levels, and climate neutrality by 2050) is covered in the Annual Climate and Energy Assessment (Jaarlijkse Klimaat- en Energieverkenning, KEV), which assesses the progress towards reaching the climate change mitigation objectives, and is developed by the Netherlands Environmental Assessment Agency (PBL). The Climate Act set out that the KEV has an explicit role to monitor climate policy progress. Once a year, the KEV reports on implementation of and the expected effects of the climate and energy policies in the Netherlands. This information is currently also published on the online Dashboard Climate Policy (Klimaatbeleid)⁶⁴ – before, this information was published as a separate monitoring report. Information on R&I activities is included.</p> <p>Aside from this general dashboard monitoring the climate policy, there are multiple other monitoring dashboards or report relevant to R&I for climate change mitigation. There is a Regional Climate Monitor (online dashboard)⁶⁵, the bi-annual Integrated Circular Economy Report, the Monitor Sustainability in the built environment (although less focused on R&I), the Monitor Zon-PV (Sun-Photovoltaics), and the Monitor Energy System.</p> <p>As for internal monitoring of the government, RVO has an Innovatie Monitoring Unit (IMU) that on an annual basis monitors the progress on the MTIB missions. An internal tool – the WorkFlowTool Klimaatbeleid is a policy database that forms the basis for the KEV and other reports.</p>
<p>Approach for measuring the impact of R&I measures on climate change mitigation</p>	<p>What is the specific approach of the system? What is being measured and how?</p> <p>The Climate Policy Dashboard presents a wide range of indicators. For instance, the dashboard shows the annual figure of the amount of R&I projects completed. The figure is subsequently disaggregated per industry / per type of technology (e.g., Carbon Capture Storage, or Energy Efficiency projects). In addition to that, based on signed subsidy agreements, the dashboard also displays the amount planned technologies and/or projects per industry. These figures are disaggregated per type of project (i.e., pilot projects, demonstration projects or deployment projects). In the 2021 version of the Climate Monitor, the amount of public funds used was used as the main input indicator.</p> <p>Other relevant indicators presented in the Climate Policy dashboard are related to the <i>Projectenpijlijn 2030</i> – although these figures are more focused on the deployment-side of the R&I spectrum and provide projections. The 'project pipeline' figures shows the steps planned by the 50-60 of the largest industrial companies in the Netherlands until 2030 to reduce their emissions – these companies account for about 60% of the industry's CO₂ emissions. The figures shows the emission reductions already achieved and the planned emission reductions of the scope 1 projects of these companies by each project's degree of (un)certainty. The planned projects (and projected emission reductions) are mapped based on the year the investment decision will be taken and in what stage the process currently is (i.e., idea phase, feasibility study, preparation, financing, realisation or operational). These figures are collected by RVO through interviews with the companies. The figures on the planned emission reductions show the potential of the current plans of the industrial companies.</p> <p>Aside from these monitoring figures, evaluation – both for the MTIB and climate innovation policy – is important. To monitor, ensure and improve the effectiveness and efficiency of climate/energy innovation policy, the MMIPs have been re-adjusted, and the policy instruments have been evaluated. Evaluations can help to overcome the challenge of understanding what they impact a policy or instrument actually had – when it is not possible to quantitatively measure that. Evaluations can validate whether the content of the funded innovation projects aligns well with climate goals, and therefore it is plausible that a realization of the project activities would result in carbon reduction – due to the required alignment with the KIA / MMIPs.</p> <p>In the context of the MTIB and the KIAs, RVO reports on progress towards achieving the objectives on an annual basis at the mission-level, which subsequently feeds into an integral report at the overall level.</p>

⁶⁴ <https://dashboardklimaatbeleid.nl/home>

⁶⁵ <https://klimaatmonitor.databank.nl/home>

Aspect	Questions / Collected evidence
<p>Sources of information / methodological approach for monitoring system</p>	<ul style="list-style-type: none"> • What information and data is used for the monitoring system? • What types of assumptions / methods are used? <p>As for the dashboard, the figures on completed projects, and planned projects as per the subsidy agreements are based on data from RVO on the subsidies DEI+, MOOI, VEKI, and TSE (EKOI). Currently, the figures shown relate to the amount of completed or planned projects. In the future, additional information on completed projects will be added. The figures on the <i>Projectenpijplijn 2030</i> are based on interviews between RVO and the companies – these interviews are held on an annual basis. There is a degree of uncertainty on indicators related to the planned emission reduction of scope 1 projects as they present the potential emission reductions. For this to occur, certain preconditions must be in place. Interviewees mention financing, regulation, infrastructure, technical feasibility, knowledge and market conditions as relevant factors. Therefore, the potential emission reductions of planned projects are mapped not only on the aggregate level, but also per level of uncertainty, the type of technology, and when the project is expected to yield results.</p> <p>The dashboard (and the indicators) are updated on an annual basis. According to the Climate Plan 2025-2035, in 2025 the focus will be on monitoring the long-term transition towards climate neutrality by identifying indicators and which preconditions or systemic issues should be monitored in that context. Another focus point of 2025 will be data accessibility to improve the ability to inform the House of Representatives and the general public about the progress towards achieving the objectives.</p>
<p>Actors and roles in the monitoring system</p>	<ul style="list-style-type: none"> • Who are the involved actors in providing and validating the data? <p>Given the wide scope of actors involved in R&I policy and climate policy, many different stakeholders are involved in data collection and validations. This includes the involved ministries, such as the Ministry of Economic Affairs, the Ministry of Climate and Green Growth, the Ministry of Infrastructure and Water Management, Ministry of the Interior and Kingdom Relations, the Ministry of Agriculture, Fisheries, Food Security and Nature, RVO, CBS (Statistics Netherlands), PBL (Netherlands Environmental Assessment Agency), TNO (the Netherlands Organisation for Applied Scientific Research), and WUR (Wageningen Research).</p>
<p>Implications</p>	<p>What are the practical implications of the monitoring results?</p> <p>How are they integrated in the R&I policy cycle (e.g., being on track for the development of key technologies or not)?</p> <p>The Climate Policy Dashboard provides information on the progress of national climate policy and the development of greenhouse gas emissions. The dashboard has a specific objective to inform interested stakeholders and the general public about climate policy, its progress and the results. The dashboard provides an overview of the current state of affairs and therefore also helps to adjust policy effectively.</p> <p>The evaluations of individual R&I instruments provide evidence on the effectiveness and efficiency of the policies and instruments. This evidence is then used – together with other sources of information, such as the Climate Policy Dashboard and other monitoring reports, for a comprehensive climate policy review. Such a comprehensive policy review will be used for the next Climate Plan to bring coherence between different instrument and improve effectiveness and efficiency of climate policy at the systemic level.</p> <p>In 2024, such a meta evaluation on the effectiveness and efficiency of climate policy (including the R&I instruments) was performed⁶⁶. Similarly, PBL conducted a Learning Evaluation on climate policy to reflect on, assess and strengthen the transformative capacity of climate policy by reflecting on the governance and the extent to which the transformation takes place together with policy stakeholders⁶⁷.</p>

⁶⁶ CE Delft. 2024. Syntheseonderzoek klimaatbeleid - Reconstructie beleidstheorie en inzicht in doeltreffendheid en doelmatigheid van het huidige klimaatbeleid.

⁶⁷ PBL. 2024. Lerende Evaluatie Klimaatbeleid. <https://www.pbl.nl/lekb/lerende-evaluatie-klimaatbeleid>

3.4 United Kingdom (UK)

3.4.1 UK – Section 1: Overarching framework

Aspect	Questions / Collected evidence
Section 1: Political objectives, strategies, and main actors related to R&I for climate change mitigation	
Overall political objectives related to R&I supporting climate change mitigation	<p>What is the climate change mitigation objective of the case study country?</p> <ul style="list-style-type: none"> • Climate Change Act: The United Kingdom's national climate change mitigation targets are set out in the Climate Change Act, implemented in 2008. It sets legally binding targets for transitioning towards a low-carbon economy, including a commitment to <u>reduce the UK Net Carbon account by 100% between the years 1990 and 2050</u>⁶⁸. • The Climate Change Committee, founded under the Climate Change Act, publishes periodic Carbon Budgets that have been legislated to place restrictions on the total amount of greenhouse gases the UK can emit over a 5-year period⁶⁹. These form a pathway with interim targets to track progress⁷⁰, requiring emissions to fall over time rather than just having an end target for 2050.
Strategies and implementation plans	<p>How is this strategic objective translated to the R&I strategies of the country and what are the key documents for their implementation (plans)?</p> <p>A ten-point plan⁷¹ for adopting a Green Industrial Revolution was adopted in 2020. In order to deliver it, £12 billion worth of government money was mobilised. The thematic areas that these plans are set under are as follows:</p> <ul style="list-style-type: none"> • Advancing Offshore Wind • Driving the Growth of Low Carbon Hydrogen • Delivering New and Advanced Nuclear Power • Accelerating the Shift to Zero Emission Vehicles • Green Public transport, Cycling and Walking • Jet Zero and Green Ships • Greener Buildings • Investing in Carbon capture, Usage and Storage • Protecting Our Natural Environment • Green Finance and Innovation <p>Of the thematic areas set out in the plan, the Green Finance and Innovation area has the greatest emphasis on research and innovation. The innovation will feed into the UK's ambition to be the first country in the world to commercialise fusion energy technology, as well as promoting innovation in the transport sector both on sea and land, to deploy new technologies and test new technologies at scale. Moreover, the UK's commitments to advancing offshore wind, set out in the plan, sets out its aim to back new innovations. The point on Jet Zero and Green Ships also sets out an ambition to drive innovation by supporting the production of Sustainable Aviation Fuels through a competition would £15 million.</p> <p>The key areas for research and innovation until 2050 as well as their key challenges are outlined in the UK Net Zero Research and Innovation Framework⁷². They are as follows:</p> <ul style="list-style-type: none"> • Power – renewable energy generation • Industry and low carbon hydrogen supply – importance of continuing innovation to drive resource and energy efficiency, proving feasibility and reducing the cost of low and zero-carbon fuels and feedstocks

⁶⁸ UK Government, Climate Change Act 2008. Available at: [link](#).

⁶⁹ Information gained in an interview with senior academic

⁷⁰ Climate Change Committee, UK Carbon Budgets. Available at: [link](#).

⁷¹ UK Government, Ten Point Plan for a Green Industrial Revolution. Available at: [link](#).

⁷² UK Government, UK Net Zero Research and Innovation Framework. Available at: [link](#).

Aspect	Questions / Collected evidence
	<ul style="list-style-type: none"> • Carbon Capture Utilisation and Storage (CCUS) and Greenhouse Gas Removals (GGR) – support deployment of industrial-scale CCUS technologies, develop other GHG removal solutions such as Direct Air Capture deployment of CO₂ transport and storage infrastructure and the use of captured CO₂. • Heat and Buildings – retrofitting to improve energy efficiency of homes and increase the supply of low carbon heat • Transport – electrification and other low carbon fuels • Natural resources, Waste and F-gases – understanding of trade-offs and synergies between food production, forestry and biomass production, habitat and peatland restoration, biodiversity and urban expansion. • Whole systems approach – understanding the interrelated nature of different sectors and between new technologies, consumer behaviour and business models. <p>In order to deliver the Ten Point Plan, a strategy to achieve Net Zero by 2050 was published in 2021 by the Department for Business, Energy and Industrial Strategy (since renamed as the Department for Energy Security and Net Zero (DESNZ)). Some of the key policies covered in the plan include powering the UK using clean electricity by 2035, launching a new £120 million Future Nuclear Enabling Fund that focuses on exploring options for nuclear technologies and potential sites for nuclear plants, and moving towards 1GW of floating offshore wind by 2030. Moreover, Chapter 4 of the strategy sets out how the Government plans to support the transition across the economy, in which they have made a series of commitments to providing support for innovation, R&D and technology development. The investments include increasing government investment in R&D to £22 billion and increasing the total R&D investment to 2.4% of GDP by 2027⁷³.</p> <p>A Net Zero Growth Plan, called “Powering Up Britain”⁷⁴ was published in 2023 by the Conservative Government. It sets out an updated plan for the delivery of a transition towards clean energy and achieving Net Zero, based on the lessons learnt from an Independent Review of the Net Zero report, and the CCC’s Progress Report to Parliament from 2022.</p> <p>The targets set for achieving net zero differ between the devolved nations of the UK. This is because the challenges facing the devolved nations differ depending on the sectors accounting for the biggest share of emissions. In Northern Ireland, for example, the agricultural sector accounts for 29% of their overall emissions (compared to an average of 11% across the rest of the UK)⁷⁵. Sector-specific greenhouse gas emission targets are set to be introduced in Northern Ireland as part of a Green Growth Strategy. The Strategy, which is still at draft stage, will be Northern Ireland’s first Climate Action Plan and will deliver upon the Carbon budget set out by the Department for Agriculture, Environment and Rural Affairs in Northern Ireland (DEARA)⁷⁶.</p> <p>What is their time horizon?</p> <p>The programmes typically have a short to medium-term horizon, ranging from 2025 to 2030. The strategy to achieve Net Zero by 2050 was published in 2021 however, providing a longer-term perspective.</p> <p>Is monitoring of the long-term contribution of R&I measures to R&I goals part of the R&I system?</p> <p>In 2024, DESNZ published a Monitoring and Evaluation Framework which sets out their approach to measuring the effectiveness of efforts made by DESNZ to build a green economy in the UK and achieve its objectives. DESNZ aims to deliver “effective, impactful and innovative monitoring and evaluation outputs” that “set out a clear picture of long-term ambitions”⁷⁷.</p>
<p>Main actors and roles in the R&I system</p>	<p>What are the main actors involved and what are their roles?</p> <p>The Department for Energy Security and Net Zero (DESNZ) is responsible for implementing green energy strategies in the UK. Its responsibilities include ensuring the security of energy supply, the proper functioning of energy markets and greater energy efficiency. A series of priorities for DESNZ have been set for the period of 2023 to 2030 that are guiding the focus of the policies it is implementing. These priorities include ensuring that the UK is meeting legally binding Net Zero</p>

⁷³ UK Government, Net Zero Strategy: Build back greener. Available at: [link](#).

⁷⁴ UK Government, Powering Up Britain. Available at: [link](#).

⁷⁵ Climate Change Committee, CCC visits Northern Ireland, Available at: [link](#).

⁷⁶ DAERA, A green growth strategy for Northern Ireland. Available at: [link](#).

⁷⁷ UK Government, DESNZ Monitoring and Evaluation Framework. Available at: [link](#).

Aspect	Questions / Collected evidence
	<p>commitments, improving energy efficiency in UK homes, and reforming the energy sector to support energy consumers and improve how the market works for families and businesses.</p> <p>The Department for Environment, Food and Rural Affairs (Defra) has implemented a series of policies relating to the wider environment and biodiversity. The 25 Year Environment Plan (25 YEP) was published in 2018⁷⁸, setting out a series of commitments to government action for achieving cleaner air and water in the UK. Action under the 25 YEP is focused on six key areas, including sustainable land-use, resource efficiency and securing clean and biologically diverse seas and oceans. Other policies implemented by Defra include the Natural Capital and Ecosystem Assessment Programme, a science innovation transformation programme that aims to collect data on the state of England's ecosystems and natural capital⁷⁹.</p> <p>The Climate Change Committee (CCC) is an independent statutory body that is responsible for supporting the UK Government and its devolved governments in achieving its net zero emission targets. It does this by providing recommendations for emission reduction targets set out in the Carbon Budgets (of which there are six to date). Moreover, the CCC take on the role of independently monitoring progress made towards achieving net zero goals.</p> <p>In 2018, the Department for Science, Innovation and Technology (DSIT) launched a non-departmental arms-length public body called UK Research and Innovation (UKRI). The organisation encompasses seven disciplinary research councils that are responsible for ensuring knowledge exchange amongst higher education institutions in England as well as for supporting research and innovation across a series of different sectors and domains. It aims to ensure that the research and innovation landscape in the UK is accurate, targeted and in-depth. The research councils under the UKRI collaborate to provide recommendations to DSIT regarding the allocation and distribution of funding that best supports the UKRI's key ambitions. The research councils adopted under the UKRI include:</p> <ul style="list-style-type: none"> • Arts and Humanities Research Council • Biotechnology and Biological Sciences Research Council • Economic and Social Research Council • Engineering and Physical Sciences Research Council • Innovate UK, responsible for helping companies to grow through their development and commercialization of new products, processes and services. • Medical Research Council • Natural Environment Research Council • Research England, responsible for funding and engaging with English higher education providers to stimulate dynamic research and knowledge exchange within the higher education sector. • Science and Technology Facilities Council <p>The UKRI is a key actor in the development and implementations of green strategies. An example of the types of activities these organizations are undertaking towards climate change mitigation is the research and innovation initiatives in the Climate Change, Ecology, Biodiversity and Marine Environment topic areas that are supported by the Natural Environment Research Council (NERC). Increasing the UK's climate resilience is one of NERC's key areas of investment and support. The UK Climate Resilience programme places a strong emphasis on the importance of green growth and adaptability in the face of climate change.</p> <p>A network of Catapult centres has also been implemented in the UK. These are funded by Innovate UK and are used to provide a unique combination of cutting-edge Research and Development facilities alongside technical expertise that support UK business innovation. The Energy Systems Catapult and the Offshore Renewable Catapult both feed into innovating technologies that deliver the UK's energy and net zero goals⁸⁰. The catapult network was modelled on lessons from the German approach to research and innovation⁸¹.</p>

⁷⁸ UK Government, 25 Year Environment Plan. Available at: [link](#).

⁷⁹ UK Government, Natural Capital and Ecosystem Assessment Programme. Available at: [link](#).

⁸⁰ URKI, Catapult Network. Available at: [link](#).

⁸¹ Information gained in an interview with senior academic

3.4.2 UK – Section 2: R&I portfolio linked to climate change mitigation

Aspect	Questions / Collected evidence												
Section 2: Assessment of R&I portfolio and funding strategies to support climate change mitigation													
R&I focus areas (e.g., research cluster, sectoral focus)	<p>What are the general characteristics and structure of the R&I portfolio?</p> <p>The Clean Growth Strategy⁸² outlines the funding allocation given to different government sectors and departments in the UK Government for research and development purposes. It introduced the Energy Innovation Programme (EIP), which committed to increasing low carbon innovation considerably by investing £2.5 billion between 2015 and 2021. This funding was distributed between a series of different programmes, including for innovations that provide low carbon heat in buildings, innovations that improve energy efficiency, carbon capture and utilisation. Moreover, an Energy Entrepreneurs Fund was introduced in 2012. Since the adoption of the Fund, £47.2 million has been invested in 102 companies, leveraging a further £35 million from the private sector. It is a competitive scheme which supports the development and demonstration of technologies, products and processes in the areas of energy efficiency, power generation and heat and electricity storage⁸³.</p> <p>Since 2021, the Net Zero Innovation Portfolio (NZIP), launched as a result of the Green Industrial Revolution Plan (2020), has replaced the Energy Innovation Programme that was launched under the Clean growth Strategy, providing funding for low carbon technologies and systems. The Portfolio has been allocated a £1 billion fund aimed at tackling climate change by developing green technologies. Its ten priority areas for achieving UK emission targets cover offshore wind, nuclear advanced modular reactors, energy storage and flexibility, bioenergy, hydrogen, homes, direct air capture and greenhouse gas removal (GGR), advanced carbon capture, usage and storage (CCUS), industrial fuel switching, and disruptive technologies.</p> <p>The table below outlines the innovation funding allocated to achieving the goals of the Clean Growth Strategy at sectoral level⁸⁴.</p>												
	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 20%; text-align: left;">Sector</th> <th style="text-align: left;">Projects</th> </tr> </thead> <tbody> <tr> <td></td> <td>(if source of funding information deviates the source is added otherwise source is [9])</td> </tr> <tr> <td rowspan="3" style="vertical-align: top;">Energy</td> <td> <p>Commitment to Invest around £900 million of public funds into delivering Clean, Smart, Flexible power. This includes:</p> <ul style="list-style-type: none"> • £265 million in smart systems to reduce the cost of electricity storage, advance innovative demand response technologies and develop new ways of balancing the grid. • £460 million in nuclear to support work in areas including future nuclear fuels, new nuclear manufacturing techniques, recycling and reprocessing, and advanced reactor design. • £177 million to further reduce the cost of renewables, including innovation in offshore wind turbine blade technology and foundations. </td> </tr> <tr> <td> <p>An Energy Entrepreneurs Fund was introduced in 2012. Since the adoption of the Fund, £47.2 million has been invested in 102 companies, leveraging a further £35 million from the private sector.</p> </td> </tr> <tr> <td> <p>Up to £20 million has been committed to support a new clean technology early-stage investment fund.</p> </td> </tr> <tr> <td style="vertical-align: top;">Transport & Mobility</td> <td> <p>Commitment to invest around £841 million of public funds in innovation in low carbon transport technology and fuels.</p> </td> </tr> <tr> <td style="vertical-align: top;">Industry</td> <td> <p>Commitment to invest around £162 million of public funds in research and innovation in energy, resource and process efficiency, including up to £20 million to encourage switching to lower carbon fuels.</p> </td> </tr> </tbody> </table>	Sector	Projects		(if source of funding information deviates the source is added otherwise source is [9])	Energy	<p>Commitment to Invest around £900 million of public funds into delivering Clean, Smart, Flexible power. This includes:</p> <ul style="list-style-type: none"> • £265 million in smart systems to reduce the cost of electricity storage, advance innovative demand response technologies and develop new ways of balancing the grid. • £460 million in nuclear to support work in areas including future nuclear fuels, new nuclear manufacturing techniques, recycling and reprocessing, and advanced reactor design. • £177 million to further reduce the cost of renewables, including innovation in offshore wind turbine blade technology and foundations. 	<p>An Energy Entrepreneurs Fund was introduced in 2012. Since the adoption of the Fund, £47.2 million has been invested in 102 companies, leveraging a further £35 million from the private sector.</p>	<p>Up to £20 million has been committed to support a new clean technology early-stage investment fund.</p>	Transport & Mobility	<p>Commitment to invest around £841 million of public funds in innovation in low carbon transport technology and fuels.</p>	Industry	<p>Commitment to invest around £162 million of public funds in research and innovation in energy, resource and process efficiency, including up to £20 million to encourage switching to lower carbon fuels.</p>
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⁸² UK Government (2018), The Clean Growth Strategy – leading the way to a low carbon future. Available at: [link](#).

⁸³ UK Government, Energy Entrepreneurs Fund. Available at: [link](#).

⁸⁴ UK Government, The Clean Growth Strategy; leading the way to a low carbon future. Available at: [link](#).

Aspect	Questions / Collected evidence
	<p>Support innovative energy technologies and processes with £14 million of further investment through the Energy Entrepreneurs Fund.</p> <hr/> <p>Land Use, Agriculture, and Forestry</p> <p>Commitment to invest £99 million in innovative technology and research for agri-tech, land use, greenhouse gas removal technologies, waste and resource efficiency</p> <hr/> <p>Buildings</p> <p>The UK Government have launched two programmes related to the Built Environment. They target deployment approaches, consumer engagement and costs. Firstly, the Heat Pump Ready programme tests how domestic heat pumps can be made more accessible, deployable and attractive to the consumer. This programme has been allocated £60 million worth of funding. Secondly, the Green Home Finance Accelerator has been allocated £20 million worth of funding. It develops new consumer finance models to make the initial capital required for building energy efficiency measures more accessible.</p> <hr/> <p>Are there R&I focus areas defined for the country (e.g. in the strategy)?</p> <p>An interview with a senior academic highlighted that the UK approach to climate change mitigation tends to be more focused on the supply and storage of energy. Besides the priority area outlined in the NZIP on homes, which funds innovation to support decarbonizing homes and buildings, and some work being carried out on shifting the nature of industrial fuel, there is not a lot of work being carried out on energy demand. This is an area of longstanding debate amongst energy researchers⁸⁵.</p>
<p>Strengths of the countries R&I system relevant for climate change mitigation</p>	<p>What are the strengths in countries R&I system related to contributions to climate change mitigation?</p> <p>The UK has a strong understanding of energy systems and how they interact with each other. Thus, from an early stage, the approach was to ensure that research was being done in a holistic way, not just on the discrete parts of an energy system. A senior academic expressed in an interview that they understood that they needed to include not only the technical elements, but also the economics and to link that to broader sustainability or environmental impacts. Moreover, the UK also has an outstanding science base that has provided a deep understanding of the technical detail⁸⁶.</p>
<p>Weaknesses in the countries R&I system relevant for climate change mitigation</p>	<p>What are the weaknesses in countries R&I system related to contributions to climate change mitigation?</p> <p>Arnold et al. (2020) argues that there is a need for the UK Government to alter their approach towards implementing innovation programmes and policies. It discusses the growing need for innovation programmes to address complex issues that take socio-technical transitions into account (complex innovation and transition programmes (CITPS)). Arnold et al., (2020) call for greater collaboration in UK policy implementation between government ministries, scientists and other stakeholders (such as consumers). They state that other European countries, such as Sweden, have implemented more effective strategies that are connected to a multi-level governance and have longer-term political commitment. Moreover, they explain that for the strategies to be monitored and evaluated effectively, periodic reviews should be carried out transparently with the use of evaluation data and other evidence⁸⁷.</p> <p>Moreover, an interview with a senior academic outlined that whilst the UK approach's strengths lie in their scientific research and technical ability, there is a weakness in enabling commercialisation. Thus, the scientific knowledge is not being translated into commercial products. They suggested that Germany is often considered a pioneer in this respect⁸⁸.</p>
<p>Scope in technological readiness (basic research)</p>	<p>Does the investigated portfolio exhibit specific patterns in terms of technological readiness?</p> <p>The 2021 UK Net Zero Research and Innovation Framework sets out the research and innovation required to support delivery of the UK's Net Zero Strategy. Moreover, it outlines several viable pathways to net zero and provides an assessment of the technological readiness level (TRL) of relevant technologies and research for policy decisions. The technological readiness of the</p>

⁸⁵ Information gained in an interview with senior academic.

⁸⁶ Information gained in an interview with senior academic.

⁸⁷ Technopolis, How should we evaluate complex programmes for innovation and socio-technical transitions? Available at: [link](#).

⁸⁸ Information gained in an interview with senior academic.

Aspect	Questions / Collected evidence
vs. deployment focus)	majority of technologies required or expected to be deployed in order to meet 2050 net zero targets are perceived to be between the development stage (TRL 4-6) and demonstration stage (TRL 6-9). Some technologies however, in the hydrogen, Carbon Capture and Storage, transport and natural resources and land use pathways are at the research stage (TRL 1-3). The majority of the technologies required or expected to be deployed in the medium term (in the 2030s) in order to meet 2050 net zero targets, are at the development stage, with a significant amount being at the demonstration stage and a few technologies being at the research stage. The technologies expected to be deployed in the longer term (2040s) are mostly either at the research or development phases, with a small number being at the demonstration stage ⁸⁹ .
Type of funding instruments (Focus on specific types, supply side or demand side focus etc.)	What are the primary types of funding instruments that the system relies on (differentiate by R&I focus area if necessary)? The UK Government allocates most of the funding for R&I through grants. They have adopted stringent requirements for grant allocation, such as through the implementation of funding panels that ensure a level playing field amongst businesses and research bodies seeking support. The Government tend to allocate direct funding to initiatives with middle to upper TRLs due to them being closer to commercialisation ⁹⁰ . Research carried out in universities tends to be of a lower TRL and relies more heavily on grants awarded via open tender. Innovate UK offer loans to innovative projects with strong commercial potential that have the potential to significantly improve the UK economy. An example of such initiatives are the catapult centres, that are partly funded by the scheme ⁹¹ .
Funding volume (e.g., by R&I focus areas)	What is the overall funding volume of the R&I measures intended to contribute to climate change mitigation? The Net Zero Innovation Portfolio has allocated £1 billion worth of funding towards the implementation of the green industrial revolution.

3.4.3 UK – Section 3: Monitoring approaches

Aspect	Questions / Collected evidence
Section 3: Assessment of monitoring approach for contribution of R&I for climate change mitigation	
Key monitoring system (in place / in preparation)	Is there a monitoring system (either dedicated to R&I measures, green budgeting, or monitoring system for the progress to climate neutrality) that involves a measurement or provides guidance on the contribution of R&I measures to climate change mitigation (or more than one system)? In 2024, DESNZ published a Monitoring and Evaluation Framework which sets out their approach to measuring the effectiveness of efforts made by the Department to build a green economy in the UK and achieve its objectives. DESNZ aims to deliver "effective, impactful and innovative monitoring and evaluation outputs" that "set out a clear picture of long-term ambitions" ⁹² . Furthermore, the CCC have set out their own monitoring frameworks to determine progress being made generally in both Climate Change mitigation and adaptation in the UK. The Mitigation Monitoring Framework sets out tools to assess UK progress in reducing emissions, whilst the Adaptation Monitoring Framework provides the CCC with the ability to assess the effectiveness of adaptation action across the UK ⁹³ .
Approach for measuring the impact of R&I measures on climate change mitigation	What is the specific approach of the system and what is being measured? A series of Key Performance Indicators (KPIs) are used to monitor and evaluate UK programmes. An evaluation of the EIP, which came to a close in 2021, is currently ongoing. The results of this study are not available at the time of drafting this case study ⁹⁴ .

⁸⁹ UK Government, UK Net Zero Research and Innovation Framework. Available at: [link](#).

⁹⁰ Information gained in an interview with senior academic.

⁹¹ UKRI, Innovation loans. Available at: [link](#).

⁹² UK Government, DESNZ Monitoring and Evaluation Framework. Available at: [link](#).

⁹³ Climate Change Committee, CCC Mitigation Monitoring Framework, Available at: [link](#).

⁹⁴ Energy Evaluation Europe, Evaluating a large energy innovation portfolio. Available at: [link](#).

Aspect	Questions / Collected evidence
	<p>Alongside the programme-level evaluations, individual programmes within EIP, NZIP and UKRI are often evaluated as single programmes with subsequent evaluation reports being published.</p> <p>The UK Government has made a concerted effort to apply more systematic attention to evaluations, they are more rigorous in conducting evaluations for each of their policies than they have been in the past.⁹⁵</p> <p>DESNZ also commissioned the Energy Innovation Needs Assessments to identify key innovation successes, failures and needs across the UK's energy system. The aim of these documents is to inform the prioritisation of public sector funding allocation and investment, including the future phases of Government innovation programmes⁹⁶.</p>
Sources of information / methodological approach for monitoring system	<p>What information and data is used for the monitoring system?</p> <p>The EIP NZIP KPIs are self-reported quantitative and qualitative indicators collecting information on from basic existence of a project, through its activities, outputs and outcomes. The data collection took place annually during the programme and three years after completion of each project.</p> <p>For other DESNZ evaluations, the data sources vary depending upon the specific programme but can include self-reported quant and qual indicators, survey and qualitative data collection with a range of programme stakeholders, wider secondary datasets. Methodological approaches to impact evaluation include theory-based methods such as Contribution Analysis and quasi-experimental methods.</p>
Actors and roles in the monitoring system	<p>Who are the involved actors in providing and validating the data?</p> <p>The Government commissions evaluations of their strategies and policies with external organisations or bodies. Funding recipients are also asked to submit monitoring data on their progress.</p>
Implications	<p>What are the practical implications of the monitoring results?</p> <p>DESNZ uses learnings from evaluation reports and monitoring data to inform the delivery of current and future programmes.</p>
Other documents used for measuring / validating the impact (evaluations etc.)	<p>Are there other documents used for the measurement of the contributions of R&I measures (e.g. evaluations)? How are their results included in the monitoring process?</p> <p>Wider research and evaluation evidence may be reviewed and referred to within DESNZ programme and policy evaluations.</p>

⁹⁵ Information gained in an interview with senior academic

⁹⁶ UK Government, Energy Innovation Needs Assessments. Available at: [link](#).

3.5 United States (US)

3.5.1 US – Context: The Inflation Reduction Act (IRA) as the main instrument in US green and R&I policy amid shifting priorities

Over the past two decades, U.S. climate policy has experienced significant fluctuations. The Obama administration pursued regulatory efforts like the Clean Power Plan, while the Trump administration marked a period of strong deregulatory pushback, including the rollback of major environmental rules and withdrawal from the Paris Agreement. This political oscillation has made sustained federal support for clean technologies challenging.

The Inflation Reduction Act (IRA), enacted in 2022, marks a pivotal shift in U.S. climate policy. It is the most comprehensive clean energy support package in U.S. history, allocating approximately \$392 billion over ten years to climate-related initiatives. The IRA emphasizes long-term investment-led strategies over regulatory approaches, aiming to provide stable market signals for clean technology deployment.

A central aspect of the IRA is its focus on stimulating private sector investment in green research and innovation (R&I). By offering substantial tax credits and incentives, the IRA seeks to accelerate the development and commercialization of advanced clean technologies, thereby embedding R&I policy within the broader climate policy framework.

However, under the current Trump administration, there has been a significant policy reversal. On his first day in office in January 2025, President Trump signed an executive order to halt the disbursement of funds provided through the IRA, pending a comprehensive review. This move has introduced uncertainty into the clean energy sector, potentially undermining the progress made in green R&I initiatives.

Although the IRA remained partially on hold at the time of writing and the future of U.S. green R&I policy is uncertain, it remains a historic milestone. As the most ambitious federal effort to link climate, industrial and innovation policy, it aims to drive private investment in clean technologies through long-term incentives. Many programs benefit rural and conservative regions, underscoring its broad reach. Despite political shifts, the IRA offers a valuable lens for understanding U.S. green innovation policy. Accordingly, it will be also in the centre of our discussion of the U.S. R&I policy.

3.5.2 US – Section 1: Overarching framework

Aspect	Questions / Collected evidence
Section 1: Political objectives, strategies, and main actors related to R&I for climate change mitigation	
Overall political objectives related to R&I supporting climate change mitigation	<p>What is the climate change mitigation objective of the case study country? How is this strategic objective translated to the R&I strategies of the country?</p> <p>The U.S. climate change mitigation objective is to reduce greenhouse gas (GHG) emissions 50-52% below 2005 levels in 2030. Reaching 100% carbon pollution-free electricity by 2035. Achieving a net-zero emissions economy by 2050.⁹⁷ A key element of US climate change mitigation policy is the Inflation Reduction Act passed in 2022.</p>

⁹⁷ U.S. Department of Energy, 2022 'The Inflation Reduction Act Drives Significant Emissions Reductions and Positions America to Reach Our Climate Goals'.

Aspect	Questions / Collected evidence
	<ul style="list-style-type: none"> • The IRA includes three key components: tax reform, healthcare reform, and energy and climate legislation, with approximately \$392 billion allocated to climate-related provisions over the upcoming 10 years:⁹⁸ • The Department of Energy estimates that the IRA and the complementing Bipartisan Infrastructure Law (BIL)⁹⁹ are expected to reduce GHG emissions by 40% below 2005.¹⁰⁰ • Besides climate benefits the IRA addresses the following issues labelled as national priorities:¹⁰¹ <ul style="list-style-type: none"> – Lowering energy costs for households and businesses; – Benefits for disadvantaged communities; – Investments in energy communities; – Workforce development and high-quality jobs; – Domestic manufacturing of clean energy technologies. <p>What is the strategic objective translated to the R&I strategies in the IRA?</p> <ul style="list-style-type: none"> • To stimulate investment in green R&D, the IRA - in line with the American policy tradition - mainly provides production and investment tax credits. These are sometimes combined with a competitive bidding process to ensure support for the most efficient technology. Grants play a minor role.¹⁰² • The \$392 billion is divided into two large items:¹⁰³ <ul style="list-style-type: none"> – Tax credits (SUBTOTAL \$271 billion) <ul style="list-style-type: none"> ◦ \$131 billion: Investment and Production Tax Credits for Clean Electricity Generation and Storage ◦ \$3 billion: Production Tax Credit for Carbon Capture and Sequestration ◦ \$30 billion: Nuclear Power Production Tax Credit ◦ \$19 billion: Clean Fuels ◦ \$37 billion: Clean Energy and Efficiency Incentives for Individuals ◦ \$14 billion: Clean Vehicles ◦ \$37 billion: Clean Energy Manufacturing – Direct Expenditures (SUBTOTAL \$121 billion) <ul style="list-style-type: none"> ◦ \$21 billion: Agricultural & Forestry Conservation and Sequestration Projects ◦ \$17 billion: Energy Loans ◦ \$11 billion: Energy Efficiency ◦ \$5 billion: Industrial Decarbonization ◦ \$66 billion: Other (e.g., Green Bank)

⁹⁸ Committee for a Responsible Federal Budget, 'CBO Scores IRA with \$238 Billion of Deficit Reduction', <https://www.crfb.org/blogs/cbo-scores-ira-238-billion-deficit-reduction> ;

Bistline, J. E., Mehrotra, N. R., & Wolfram, C. (2023). Economic implications of the climate provisions of the inflation reduction act. *Brookings Papers on Economic Activity*, 2023(1), 77-182.

⁹⁹ The estimates are based on the IRA as well as the Bipartisan Infrastructure Law (or Infrastructure Investment and Jobs Act) of 2021 which provided billions of dollars to modernize the electricity grid, build a nationwide network of electric vehicle chargers, strengthen the battery supply chain, ... (The White House, 2023, p. 5).

The White House, (2023). 'Building a clean energy economy: A guidebook to the inflation reduction act's investments in clean energy and climate action.'

¹⁰⁰ U.S. Department of Energy (2022)

¹⁰¹ U.S. Department of Energy (2022)

¹⁰² Meissner, L. P., Peterson, S., & Semrau, F. O. (2024). It's not a sprint, it's a marathon: reviewing governmental R&D support for environmental innovation. *Journal of Environmental Planning and Management*, 1-27.

¹⁰³ Bistline et al. (2023)

Aspect	Questions / Collected evidence
	<ul style="list-style-type: none"> • The most relevant climate and energy subsidies and tax credits can be grouped into three categories:¹⁰⁴ <ul style="list-style-type: none"> – Subsidies for producers of carbon-neutral electricity, as well as hydrogen and other 'clean' fuels; – Production and investment subsidies for manufacturers of clean-tech products, including batteries and components used in renewable electricity generation; – Subsidies for vehicle purchases, including a \$7,500 consumer tax credit for electric cars and a tax credit for companies, including leasing companies, that buy clean vehicles. • Several subsidies, but not all, are conditioned on the content produced in the U.S. and/or North America, e.g., the subsidy on electric cars only applies for cars final assembly in North America. In addition, also restrictions on countries of origin are part of the eligibility demands for subsidies. For instance, any use of batteries and critical minerals from China, Russia, Iran, North Korea will make a vehicle ineligible for the tax credit. • Compared to support schemes from the European Union, the IRA-related green subsidies are more discriminatory and have a strong focus on mass deployment of current generation technologies.¹⁰⁵
Strategies and implementation plans	<ul style="list-style-type: none"> • What are the key documents for the R&I strategy and their implementation (plans)? <ul style="list-style-type: none"> – Do they involve multiple levels of governance? – What is their time horizon? – Is monitoring of the long-term contribution of R&I measures part of the R&I system? <p>Documents available:</p> <ul style="list-style-type: none"> • The White House published a "guidebook" to provide an overview of the IRA programs and how they plan to implement them. As in general valid for the IRA, the document is not tailored on R&I. • In addition, The White House wanted to publish new developments on "CleanEnergy.gov" to keep stakeholders and potential beneficiaries of these programs up to date on the latest deadlines and details.¹⁰⁶ However, when lastly retrieved the homepage, the page was not available anymore. This change aligns with broader shifts in federal climate and energy policy under the Trump administration. • The U.S. Department of Energy (DOE) continues to provide comprehensive resources on clean energy technologies and initiatives at energy.gov/clean-energy. Additionally, the DOE's "Building America's Clean Energy Future" platform offers interactive maps and data on investments driven by the IRA and the Bipartisan Infrastructure Law (BIL), available at energy.gov/invest. • The Inflation Reduction Act Tracker, a joint project of Columbia Law School's Sabin Center for Climate Change Law and Environmental Defense Fund, houses the IRA Database, which compiles information about the climate change-related provisions of the 2022 Inflation Reduction Act (IRA), organized by federal agency. Both, the tracker and the database offer valuable insights on recent developments, for instance it is stated on the 31 March 2025 that Department of Agriculture releases IRA Biofuel grants affected by funding freeze amounting to \$537 million."¹⁰⁷ <p>Levels of governance:</p> <ul style="list-style-type: none"> • The White House delegates the climate change-related provisions of the IRA to several different federal agencies that are responsible for the execution and the transmission to

¹⁰⁴ Kleimann, D., Poitiers, N., Sapir, A., Tagliapietra, S., Véron, N., Veugelers, R., & Zettermeyer, J. (2023). Green tech race? The US inflation reduction act and the EU Net zero industry act. *The World Economy*, 46(12), 3420-3434.

¹⁰⁵ Kleimann et al. (2023)

¹⁰⁶ The White House (2023); last try to access CleanEnergy.gov on 25 April 2025.

for the bill, see <https://www.congress.gov/bill/117th-congress/house-bill/5376/text> (last access 25 April 2025) and for a detailed analysis by the Committee for a Responsible Federal Budget, see <https://www.crfb.org/blogs/whats-inflation-reduction-act> (last access 25 April 2025).

¹⁰⁷ <https://iratracker.org/> (last access 25 April 2025).

Aspect	Questions / Collected evidence
	<p>state and local governments. To name a few, in decreasing order stating the number of programs: the Department of the Treasury (28), Department of the Interior (21), the Environmental Protection Agency (17) or the Department of Energy (17). Even the U.S. Postal Service has the lead on one program in which they get \$1.29 billion to purchase zero-emission delivery vehicles.¹⁰⁸</p> <p>Time horizon:</p> <ul style="list-style-type: none"> The time horizon of the IRA is 10 years (until 2031). Some projects have a longer time horizon or start later, e.g. Investment Tax Credit for Energy Property which provides a tax credit for investment in renewable energy projects. Period of availability: Projects beginning construction before 1/1/25. For geothermal heat property (IRA Statutory Location: 13102), the base investment tax credit is 6% for the first 10 years, scaling down to 5.2% in 2033 and 4.4% in 2034 (The White House, 2023, p. 14). <p>Monitoring of the R&I system:</p> <ul style="list-style-type: none"> To the best of our knowledge, there is no systematic or dedicated monitoring system on the impact of the IRA-related R&I support on environmental outcomes such as emission reductions. Targets and tracking on the progress of the IRA focus on outcomes such as the number of vehicles sold, or energy capacities created. There are no monitoring of long-term R&I impacts. Beyond this, the IRA includes several programs to expand and improve pollution monitoring. For example, 'Fenceline Air Monitoring' (IRA Statutory Location: 60105(a), p. 98) is supposed to enhance and extend community air monitoring at or near the by developing and refining air toxics monitoring methods.¹⁰⁹
<p>Main actors and roles in the R&I and monitoring system</p>	<p>What are the main actors involved and what are their roles (keep brief)?</p> <ul style="list-style-type: none"> Beyond the focus on deployment rather than R&I support for innovations at earlier stages of development, monitoring on the effects of the IRA is fragmented across the multiple federal agencies. For monitoring aspects, the respective federal agency is responsible for the execution of the provision. In some cases, explicitly requires the authorities in the IRA funds to ensure that the reductions are achieved. For example, Section 60107(5) of the Inflation Reduction Act requires EPA (US Environmental Protection Agency) to assess the reductions in GHG emissions that result from changes in domestic electricity generation and use through 2031. It is stated that the IRA for instance reduces emissions from electric power sector of 49 to 83% below 2005 levels in 2030.¹¹⁰ Although the monitoring is not tailored to the impact of R&I support on emission reductions, it at least focuses on the progress in reducing emissions. <p>Are there dedicated bodies from a climate economic or R&I perspective that monitor the contributions of R&I?</p> <ul style="list-style-type: none"> Many monitoring or tracking services are made available by non-governmental organization as the '2024 Sustainable Energy in America Factbook' published annually by the Business Council for Sustainable Energy (BCSE) and BloombergNEF, reports on the macroeconomic trends occurring across clean energy industries.¹¹¹ As outlined before,

¹⁰⁸ Inflation reduction act tracker, Columbian Law School and Environmental Defence Fund; <https://iratracker.org/> (last access 25 April 2025).

¹⁰⁹ 'Knowledge is power, and the Inflation Reduction Act includes several programs to expand and improve pollution monitoring. among other eligible activities, EPA's Environmental and Climate Justice Block Grant Program will support community-led projects to monitor and clean up legacy pollution. EPA also received \$117 million for community air pollution monitoring at or near the fenceline of industrial facilities; \$50 million to help state, local, and Tribal air agencies to add new monitoring sites in communities and replace aging equipment at existing sites; and \$3 million to make special air quality sensors available to low-income and disadvantaged communities.' (The White House, 2023, p. 85 and p. 97)

¹¹⁰ EPA; <https://www.epa.gov/inflation-reduction-act/electric-sector-emissions-impacts-inflation-reduction-act> , last access: 25 April 2025.

¹¹¹ The Business Council for Sustainable Energy; <https://bcse.org/15-best-in-class-inflation-reduction-act-trackers-resources/> and <https://bcse.org/market-trends/> , last access: 25 April 2025.

Aspect	Questions / Collected evidence
	<p>these trackers do not explicitly focus on R&I rather they monitor the outcomes of the IRA-related support, including GHG emission reduction.</p> <ul style="list-style-type: none"> – As before, the focus is rather on deployment, for instance states the factsheet from the BCSE that over the next 10 years, the IRA is expected to drive 48% more solar deployment and increase CO2 emissions offsets from 169 million metric tons (MMT) today to more than 459 MMT by 2033. • Notably, because of all these smaller projects, but also because of the division between federal agencies, there are a lot of different trackers run by the government. As a result of this lack of monitoring coordination, some environmental aspects are not covered or are only partially covered by private organizations. <ul style="list-style-type: none"> – As an example, the White House, which offers monitoring tools as an independent institution. For example, the White House Investing in America Tracker provides a snapshot of the thousands of clean energy, infrastructure, manufacturing and electricity projects that have been launched in the United States since the passage of the IRA.

3.5.3 US – Section 2: R&I portfolio linked to climate change mitigation

Aspect	Questions / Collected evidence
Section 2: Assessment of R&I portfolio and funding strategies to support climate change mitigation	
R&I focus areas (e.g., research cluster, sectoral focus)	<p>What are the general characteristics and structure of the R&I portfolio?</p> <ul style="list-style-type: none"> • As outlined before, the IRA primarily promotes mass deployment of mature clean technologies over early-stage research support. For instance, solar, wind, EVs and – even being at a less mature level - hydrogen are supported. • The institutional structure is diverse and, beyond the federal level, separate from the IRA. For the federal government's R&I structure, see the 'Levels of governance' question. While this case study focuses on the highly fragmented federal level of R&I, we provide some examples from across the portfolio to help understand the bigger picture. <ul style="list-style-type: none"> – 1) Many state governments have their own environmental R&I initiatives, such as the California State Budget Act of 2022-23. The state efforts already increased during the first Trump administration, when state activities led the way in keeping R&I efforts in clean technologies, e.g., the New York State Energy Research and Development Authority (NYSERDA) funded clean energy pilots and supported clean energy R&I efforts or Massachusetts established programmes to continue funding in energy R&I. – 2) In addition to funding, some states even have their own cap-and-trade programme, which is a significant departure from federal environmental policy. California's State Budget Act also includes the second pillar of R&I initiatives, universities and research institutions, which will also fund projects. – 3) Public-private partnerships to scale up innovation. The IRA seeks to stimulate firm-level R&I by creating stable, long-term demand for clean technologies. Examples include investment tax credits, production tax credits, and targeted industrial support (e.g., domestic manufacturing incentives). <p>We focus on the Inflation Reduction Act and the federal R&I structure:</p> <ul style="list-style-type: none"> • Most projects have an indirect effect on R&I. The strategy behind this is to increase the R&I of firms by increasing the demand for cleaner goods, e.g. by replacing school buses or providing tax credits for the installation of electric vehicle charging infrastructure.¹¹² • In addition, a sub-section is dedicated to "Investing in Science and the Department of Energy's Core Research Mission" and aims to provide the necessary scientific infrastructure, e.g. laboratory improvements, for the research of emerging goods. However, these projects account for only \$2 billion out of a total of around \$400 billion.¹¹³ • Direct funding of research is part of some projects, such as the chapter on air pollution, where research on emissions from domestic wood burning should help to better understand key elements including fuel type, wet fuel effects, emissions of air toxics.

¹¹² The White House (2023, p. 46)

¹¹³ The White House (2023, p. 77)

Aspect	Questions / Collected evidence
	<p>However, this funding is not being used to drive innovation, but rather to understand climate impacts.¹¹⁴</p> <p>Are there R&I focus areas defined for the country (e.g., in the strategy)?</p> <ul style="list-style-type: none"> Based on the amount of funding allocated to the projects, the focus is on clean electricity generation and storage (\$131 billion) and on clean vehicles and fuels (\$33 billion). While – as outlined before – R&I plays a minor role, there are still substantially support on technologies at less mature levels, such as carbon capture or hydrogen.¹¹⁵ <ul style="list-style-type: none"> Clean power generation example: Microsoft received a \$1.5 billion loan to restart a nuclear power plant for its energy-intensive AI sector, as well as a \$100 million annual tax credit.¹¹⁶ <p>How do these R&I focus areas deviate from the approaches in other countries (question for the interviews only)?</p> <ul style="list-style-type: none"> IRA deviates from similar approaches in Europe in several ways. RA clean-tech subsidies are: <ul style="list-style-type: none"> No complementary market-based approach by setting prices such the ETS Less fragmented (one central program) More discriminatory (LCRs) Strong focus on mass deployment of green technologies
<p>Strengths of the countries R&I system relevant for climate change mitigation</p>	<p>What are the strengths in countries R&I system related to contributions to climate change mitigation?</p> <ul style="list-style-type: none"> There is a high degree of technological and scientific sophistication in the US. The US represents the world technology frontier in most cutting-edge technologies (AI, Internet, computer hard and software, etc.). Combined with its economic power the US clearly has the potential to be a front runner in the development of technologies for climate change mitigation. Heavy subsidization of the IRA can lead to global welfare improvements by reducing the costs of environmental innovations, increasing their global uptake and thus potentially reducing global emissions. The IRA can increase the competitiveness of mature technologies and accelerate their deployment.
<p>Weaknesses in the countries R&I system relevant for climate change mitigation</p>	<p>What are the weaknesses in countries R&I system related to contributions to climate change mitigation?</p> <ul style="list-style-type: none"> Policy instruments like the IRA are focused mainly on mass deployment of green technologies rather than on innovation (see scope in technological readiness). Given the pivotal role the US plays in the innovation system and that there is an underinvestment in early-stage green innovation at the global perspective to reach carbon neutrality by the mid of the century, this might be problematic.¹¹⁷ The IRA might not fully address the market failure related to knowledge creation.¹¹⁸ Although the list of technologies is numerous and broad, it is not technologically open. For example, the IRA provides production tax credits for solar polysilicon or solar wafers, but not for solar thin film technology. The selection of specific technologies is consistent with

¹¹⁴ The White House (2023, p. 93)

¹¹⁵ Sachverständigenrat (2023). "The Inflation Reduction Act: How should the EU react?". Available via: https://www.sachverstaendigenrat-wirtschaft.de/fileadmin/dateiablage/Publikationen/FGCEE/CAE-SVG_Joint_statement_IRA_2309.pdf

¹¹⁶ Example of tax credit: <https://www.technologyreview.com/2024/09/26/1104516/three-mile-island-microsoft/>, last access: 28 April 2025.

¹¹⁷ OECD (2023). Driving low-carbon innovations for climate neutrality. *OECD Policy Paper*, No. 143.

¹¹⁸ Meissner, L. P., Peterson, S., & Semrau, F. O. (2024).

Aspect	Questions / Collected evidence
	<p>concerns about the limited ability of governments to pick winners. Therefore, the IRA can induce technological lock-in and path dependencies.¹¹⁹</p> <ul style="list-style-type: none"> In general, tax credits run the risk of achieving emission reductions at a higher cost in comparison to carbon pricing.¹²⁰
<p>Scope in technological readiness (basic research vs. deployment focus)</p>	<p>Does the investigated portfolio exhibit specific patterns in terms of technological readiness?</p> <ul style="list-style-type: none"> As the IRA is primarily focused on tax credits, the products covered will by design be mature, deployable products and exclude nascent technologies. The pre-selection of certain technologies may help to advance existing solutions and capture the "low-hanging fruit" of emissions reductions.
<p>Type of funding instruments (Focus on specific types, supply side or demand side focus etc.)</p>	<p>What are the primary types of funding instruments that the system relies on (differentiate by R&I focus area if necessary)?</p> <ul style="list-style-type: none"> As outlined before, there is a strong demand-side focus to stimulate the demand of clean technologies. The main policy instrument is tax credits. However, grants and loans are also applied.
<p>Funding volume (e.g. by R&I focus areas)</p>	<p>What is the overall funding volume of the R&I measures intended to contribute to climate change mitigation?</p> <ul style="list-style-type: none"> Concerning the IRA, the volume of climate related spending in the order of around \$400 billion over 10 years. However, only a small fraction can be considered directly related to R&I. The focus is rather on deployment of mature technologies and to foster private sector R&I activities by stimulating demand for clean technologies. <p>Can one derive from the funding volume in a specific R&I field the strategic priorities?</p> <ul style="list-style-type: none"> Clean power generation, clean vehicles and batteries, carbon capture, hydrogen, industrial decarbonization <ul style="list-style-type: none"> For instance, the IRA de-risks early-stage commercialization of low-carbon hydrogen and CCUS. For hydrogen, the target is to cut costs by 80 percent to \$1 per kilogram in one decade. The BIL included \$9.5 billion. CCUS is a key part of the strategy to decarbonize the industrial base.¹²¹
<p>Placement of recent developments under the Trump (2025) administration</p>	<p>How has federal support for green R&I changed under the new Trump administration (2025-x)? Are states or other institution fill the gap in green R&I support?</p> <p>Clean R&I support under the Trump Administration</p> <ul style="list-style-type: none"> The Trump administration issued an executive order in January 2025 to pause disbursement of IRA funds, creating uncertainty for clean tech R&I investments.¹²² Several agencies (e.g. EPA, DOE) have reportedly delayed or limited implementation of climate-related innovation programs pending political review. The Trump administration is shifting away from the deployment of renewable energies, bonus payments for electric vehicles and other decarbonization priorities toward fossil fuel production and traditional infrastructure is likely. Key technologies such as CCUS and hydrogen might remain in the interest of the administration. Especially regions with strong support for Trump receive substantial funding within the IRA, which results in a support of republicans from the state to keep IRA funding programs.¹²³

¹¹⁹ Meissner, L. P., Peterson, S., & Semrau, F. O. (2024).

¹²⁰ Resources for the Future (2021). Cost analysis and emissions projections under power sector proposals in reconciliation. Issue Brief 21-15.

¹²¹ The White House (2023, p. 67-68, 74)

¹²² The White House (2025)

¹²³ Tagesspiegel Background (2025) Energie & Klima. 14 April, 2025.

Aspect	Questions / Collected evidence
	<p>State and local actors – Filling the gap?</p> <ul style="list-style-type: none"> • States like California, New York, and Massachusetts continue to expand funding for clean tech R&I, including grants, pilot programs and innovation hubs. • Non-governmental institutions (e.g. universities, national labs, philanthropic foundations) and private firms are maintaining momentum, but coordination and scale remain challenges without strong federal leadership.

3.5.4 US – Section 3: Monitoring approaches

Aspect	Questions / Collected evidence
Section 3: Assessment of monitoring approach for contribution of R&I for climate change mitigation	
Key monitoring system (in place / in preparation)	<p>Is there a monitoring system (either dedicated to R&I measures, green budgeting, or monitoring system for the progress to climate neutrality) that involves a measurement or provides guidance on the contribution of R&I measures to climate change mitigation? (or more than one system)</p> <ul style="list-style-type: none"> • No dedicated national system exists that tracks the specific contribution of R&I measures to climate neutrality or emissions reductions. Monitoring is fragmented across federal agencies (e.g., DOE, EPA, Treasury), and primarily focused on deployment outcomes rather than innovation support at early stages.

3.6 Germany (Reference case)

3.6.1 Germany – Section 1: Overarching framework

Aspect	Questions / Collected evidence
Section 1: Political objectives, strategies, and main actors related to R&I for climate change mitigation	
Overall political objectives related to R&I supporting climate change mitigation	<p>What is the climate change mitigation objective of the case study country?</p> <p>Federal Climate Change Act: Germany's national climate change mitigation targets are outlined in the Federal Climate Change Act (Bundes-Klimaschutzgesetz, KSG) which aims to achieve net-zero GHG emissions by 2045. The overarching targets in § 3 National climate protection targets are¹²⁴:</p> <ul style="list-style-type: none"> • 2030: 65% reduction in GHG emissions compared to 1990 levels. • 2040: 88% reduction in GHG emissions compared to 1990 levels. • 2045: Climate-neutral economy. • 2050: Net-negative emissions after 2050.
Strategies and implementation plans	<p>How is this strategic objective translated to the R&I strategies of the country and what are the key documents for their implementation (plans)?</p> <ul style="list-style-type: none"> • Climate Action Plans (Versions 2019 and 2023 see below)¹²⁵: Mitigation targets are translated into climate policies, which are consolidated within the cross-sectoral Climate Action Plan ("Klimaschutzprogramm"), last updated in 2023. The Climate Action Plan aims to implement policy measures that ensure the necessary trajectory to meet the climate targets established in the Federal Climate Change Act. It includes a combination of short-term measures through 2030 and long-term strategies, such as R&I policies or infrastructure expansion targets (e.g., for renewable energy and district heating networks). • Climate Action Plan 2019¹²⁶: Contains dedicated R&I programmes to foster emission reduction and to promote the achievement of Germany's climate goals (See Section 2: R&I Portfolio). It was renewed through the 2023 Plan. • Climate Action Plan 2023¹²⁷: Mentions the role of R&I activities for the following areas: <ul style="list-style-type: none"> – Energy research programme focusing on climate protection and on the security of energy supply. The aim is a "climate-neutral and resilient energy system in 2045" – More research on generally decarbonising the German industry – Explicit research funding and development cooperation for e-fuels – Research for the National Action Plan for Climate-friendly Shipping and the Maritime Research Programme – Research on climate-neutral aviation: The aim of the Aviation Research Programme (LuFo) is to develop aviation technologies based on climate-neutral propulsion systems by 2026 – Research on the application of AI methods: Funding of research projects focusing on the application of AI methods for the sustainable digital transformation of e.g., mobility – More research on timber construction

¹²⁴ Federal Ministry of Economic Affairs and Climate Action. (2024, May 17). *Bundesregierung beschließt neues Klimaschutzgesetz* | Bundesregierung. Die Bundesregierung informiert | Startseite. <https://www.bundesregierung.de/breg-de/themen/tipps-fuer-verbraucher/klimaschutzgesetz-2197410>.

¹²⁵ Bundesregierung. (2023). *Klimaschutzprogramm 2023 der Bundesregierung*. <https://www.bmwk.de/Redaktion/DE/Downloads/klimaschutz/20231004-klimaschutzprogramm-der-bundesregierung.html>.

¹²⁶ Bundesregierung. (2019). *Klimaschutzprogramm 2030 der Bundesregierung zur Umsetzung des Klimaschutzplans 2050*. https://www.bmel.de/SharedDocs/Downloads/DE/Landwirtschaft/Klimaschutz/Klimaschutzprogramm2030.pdf?__blob=publicationFile&v=3.

¹²⁷ Bundesregierung. (2023). *Klimaschutzprogramm 2023 der Bundesregierung*. <https://www.bmwk.de/Redaktion/DE/Downloads/klimaschutz/20231004-klimaschutzprogramm-der-bundesregierung.html>.

Aspect	Questions / Collected evidence
	<ul style="list-style-type: none"> • The earlier version of the Climate Action Plan from 2019 involved a list of specific R&I programmes.¹²⁸ In contrast, the 2023 version of the Climate Action Plan does not specify a list of specific research programmes. In the 2019 version of the Climate Action Plan, a total of 15 research programmes (see Section 2) are mentioned which are supervised by the Federal Ministry for Research, Technology and Space (BMFTR). • Federal Government's future strategy for research and innovation (2023)¹²⁹: Outlines the general strategy and focus concerning R&I activities, which generally are technology-open, systemic and impact-oriented. In total, 6 missions are formulated. Climate relevant missions are: <ul style="list-style-type: none"> – Mission 1: Enabling resource-efficient, competitive industry and sustainable mobility based on a circular economy – Mission 2: Advancing climate protection, climate adaptation, food security and biodiversity conservation – Mission 5: Exploring the oceans, protect and use them sustainably • FONA-Strategy: The general strategy on Research for Sustainability¹³⁰: Outlines the strategy to align German research funding with the United Nations 2030 Agenda on Sustainable Development Goals (SDGs). In contrast to the 17 SDGs, the FONA strategy formulates three goals, which are again in more specific actions: <ul style="list-style-type: none"> – Goal 1: Meeting climate targets, divided into three fields of action: decrease GHG emissions, climate risk adaptation, knowledge on effective climate policy. In particular, actions include carbon capture and usage (CCU), establishing the production of hydrogen in Germany, making regions more resilient to weather extremes, climate impact research etc. – Goal 2: Exploring habitats and use and protect natural resources. Actions include further developing a sustainable food system, avoid water crises, recycling and circular economy etc. – Goal 3: Developing society and the economy. Actions include aligning the financial and economic system sustainably, rural and urban sustainable mobility etc. <p>What is their time horizon?</p> <ul style="list-style-type: none"> • The programmes typically have a short to medium-term horizon, ranging from 2025 to 2030. <p>Is monitoring of the long-term contribution of R&I measures to R&I goals part of the R&I system?</p> <ul style="list-style-type: none"> • The future strategy for research and innovation involves a dedicated monitoring process of the success of the R&I measures (but they are not focused on the effect on emission reduction, see indicators below). The FONA strategy is monitored via the FONA Impact supporting research (see Section 3). Overall, there is no holistic monitoring system in place for R&I goals.

¹²⁸ Bundesregierung. (2019). *Klimaschutzprogramm 2030 der Bundesregierung zur Umsetzung des Klimaschutzplans 2050*.

https://www.bmel.de/SharedDocs/Downloads/DE/Landwirtschaft/Klimaschutz/Klimaschutzprogramm2030.pdf?__blob=publicationFile&v=3.

¹²⁹ BMBF. (2023). *Umsetzung der Zukunftsstrategie Forschung und Innovation*.

https://www.bmbf.de/SharedDocs/Downloads/de/2023/umsetzungsbericht_zukunftsstrategie.pdf?__blob=publicationFile&v=1#:~:text=Mit%20der%20Umsetzung%20der%20Zukunftsstrategie,neue%20Formen%20der%20interministeriellen%20Zusammenarbeit..

¹³⁰ FONA-Strategie. (2023, November 27). *FONA-Strategie Übersicht*. Forschung für Nachhaltigkeit | FONA.

<https://www.fona.de/de/fona-strategie/>.

Aspect	Questions / Collected evidence
Main actors and roles in the R&I system	<p>What are the main actors involved and what are their roles?</p> <ul style="list-style-type: none"> • Funding and strategic governance: <ul style="list-style-type: none"> – The BMFTR mainly focuses on <u>basic research</u>, <u>application-oriented basic research</u>, and <u>experimental research</u> (e.g., Application-Orientated Basic Research in Energy Programme¹³¹) – The Federal Ministry of Economic Affairs and Energy (BMWE) focuses more on applied research with already high technical readiness levels related to energy, industry and buildings – The Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (BMUKN) focusses on research funding dedicated to applied research primarily in the fields of nature and conservation. – The Federal Ministry of Food and Agriculture (BMLEH) focuses on research funding dedicated to sustainable agriculture (e.g., the Bioeconomy Strategy¹³²) • Management, administration and implementation: <ul style="list-style-type: none"> – Project organisers (e.g. DLR project management agency), who support the ministry in administering the funding lines across the various stages of funding • Implementation (Beneficiaries of funding) <ul style="list-style-type: none"> – Research institutions (e.g., Fraunhofer Society, Max Plank Society) – Universities – SMEs – Also, partnerships with other associations, industry, start-ups, NGOs, citizen's organisations – Monitoring (see Section 3)

3.6.2 Germany – Section 2: R&I portfolio linked to climate change mitigation

Aspect	Questions / Collected evidence								
Section 2: Assessment of R&I portfolio and funding strategies to support climate change mitigation									
R&I focus areas (e.g., research cluster, sectoral focus)	<p>What are the general characteristics and structure of the R&I portfolio?</p> <ul style="list-style-type: none"> • In the Climate Action Plan 2019, the R&I portfolio is divided into 4 sectors: Energy, transport and mobility, industry, agriculture. Additionally, cross-cutting topics such as financing and education are also included. <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 30%;">Sector</th> <th>Projects</th> </tr> </thead> <tbody> <tr> <td></td> <td>(if source of funding information deviates the source is added otherwise source is ¹³³)</td> </tr> <tr> <td rowspan="3" style="vertical-align: top;">Energy</td> <td>Research for the Energy Transition in application-oriented basic research: Kopernikus Project (280 million)</td> </tr> <tr> <td>Synthetic Energy Carriers (24 million)</td> </tr> <tr> <td>Battery Research within the Framework Concept "Battery Research Factory" (100 million)¹³⁴</td> </tr> </tbody> </table>	Sector	Projects		(if source of funding information deviates the source is added otherwise source is ¹³³)	Energy	Research for the Energy Transition in application-oriented basic research: Kopernikus Project (280 million)	Synthetic Energy Carriers (24 million)	Battery Research within the Framework Concept "Battery Research Factory" (100 million) ¹³⁴
Sector	Projects								
	(if source of funding information deviates the source is added otherwise source is ¹³³)								
Energy	Research for the Energy Transition in application-oriented basic research: Kopernikus Project (280 million)								
	Synthetic Energy Carriers (24 million)								
	Battery Research within the Framework Concept "Battery Research Factory" (100 million) ¹³⁴								

¹³¹ PtJ: 7. Energieforschungsprogramm / Anwendungsorientierte Grundlagenforschung Energie. (n.d.). Retrieved July 8, 2024, from <https://www.ptj.de/projektfoerderung/anwendungsorientierte-grundlagenforschung-energie>.

¹³² Nationale Bioökonomiestrategie. (2021, December 6). BMEL. <https://www.bmel.de/DE/themen/landwirtschaft/bioeconomie-nachwachsende-rohstoffe/nationale-bioeconomiestrategie.html>.

¹³³ Klimaschutz durch Forschung und Innovation—BMBF. (2022, February 18). Bundesministerium für Bildung und Forschung - BMBF. <https://www.bmbf.de/bmbf/shareddocs/kurzmeldungen/de/forschung-for-future.html>.

¹³⁴ RWTH Aachen University. (2020). 100 Millionen Euro für die Batterieforschung—RWTH AACHEN UNIVERSITY - Deutsch. <https://www.rwth-aachen.de/go/id/iyfxr>.

		BMFTR Contribution to the National Hydrogen Strategy "Research Initiative Green Hydrogen" (180 million for the next three years)
	Transport & Mobility	<p>Research Agenda for Sustainable Urban Mobility, Funding Initiative for Climate-Friendly Mobility (60 million)</p> <p>Key Areas of Mobility:</p> <p>A) Urban Mobility</p> <p>B) Systemic Innovation Barriers to Climate Protection</p> <hr/> <p>Sustainable mobility with synthetic fuels (24 million)</p>
	Industry	<p>Funding Initiative for the Avoidance of Process Emissions in Industry (30 million)</p> <hr/> <p>Research Initiative for SMEs Innovative in Energy Efficiency and Climate Protection (so far 2 million)</p> <hr/> <p>Research and Innovation Agenda for the Material Use of CO₂ (30 million)</p> <hr/> <p>Green ICT: R&D to Reduce the CO₂ Footprint of Digital Technologies (60 million)</p>
	Land Use, Agriculture, and Forestry	<p>Research Initiative for Climate Protection in Agriculture and Forestry (100 million)</p> <hr/> <p>Measures of the New Bioeconomy Strategy¹³⁵ (no unambiguous information)¹³⁶</p>
	Cross-cutting	<p>Finance Sector and Climate Protection (10 million)</p> <hr/> <p>National Implementation of the UNESCO World Programme of Action on Education for Sustainable Development (ESD) (no information)</p> <hr/> <p>Vocational Education for Sustainable Development in the World Programme of Action 2030 (2,5 million)</p> <hr/> <p>Digital Innovation Hub for Climate (no information, still in planning)</p>
		<ul style="list-style-type: none"> • A total of 15 R&I programmes are outlined in the action plan and are primarily implemented by the BMFTR. These programmes include various specific projects. • In general, the focus is on technical innovations and research on key technologies for a decarbonised economy such as hydrogen power or battery technology etc. <p>Are there R&I focus areas defined for the country (e.g., in the strategy)?</p> <ul style="list-style-type: none"> • The BMFTR outlines that for the energy sector, the focus is on green hydrogen and general advancements in the energy transition towards sustainable energy sources. Concerning transport and mobility, the R&I strategy focuses on alternative fuels. For the industry sector the R&I activities focus on the use and reduction of CO₂ in industrial processes.¹³⁷
Strengths of the countries R&I system relevant for climate	What are the strengths in countries R&I system related to contributions to climate change mitigation?	<ul style="list-style-type: none"> • The outline of the programmes is designed to address all relevant sectors to reduce emission and achieve climate neutrality. • There is close collaboration with economic and social stakeholders.

¹³⁵ Nationale Bioökonomiestrategie. (2021, December 6). BMEL. <https://www.bmel.de/DE/themen/landwirtschaft/bioeconomie-nachwachsende-rohstoffe/nationale-bioeconomiestrategie.html>.

¹³⁶ The National Bioeconomy Strategy (NBÖ Strategy) aims to improve the framework conditions for strengthening the bioeconomy. The BMBF and BMEL alone are providing 3.6 billion euros for bioeconomy-related projects and measures from 2020 to 2024.

¹³⁷ Klimaschutz durch Forschung und Innovation—BMBF. (2022, February 18). Bundesministerium für Bildung und Forschung - BMBF. <https://www.bmbf.de/bmbf/shareddocs/kurzmeldungen/de/forschung-for-future.html>.

change mitigation	<ul style="list-style-type: none"> • Clear missions for future R&I measures, outlined in the strategy for research and innovation.
Weaknesses in the countries R&I system relevant for climate change mitigation	<p>What are the weaknesses in countries R&I system related to contributions to climate change mitigation?</p> <p>So far, there is no general monitoring system for the climate impact of current R&I measures although they are considered key to meet the climate targets.</p>
Scope in technological readiness (basic research vs. deployment focus)	<p>Does the investigated portfolio exhibit specific patterns in terms of technological readiness?</p> <ul style="list-style-type: none"> • There is a focus on emerging technologies like hydrogen power or the material use of CO₂ that are not yet fully ready for widespread technical exploitation. This strategic emphasis is evident in several key initiatives and funding programmes aimed at advancing these technologies from the R&I stage to practical application. • Programmes such as the Kopernikus Project also include already established technologies such as solar and wind energy.¹³⁸
Type of funding instruments (Focus on specific types, supply side or demand side focus etc.)	<p>What are the primary types of funding instruments that the system relies on (differentiate by R&I focus area if necessary)?</p> <ul style="list-style-type: none"> • R&I: <ul style="list-style-type: none"> – Project funding: involves grants provided by the government (BMFTR, BMWK), to support specific research projects. These grants are often competitive and awarded based on proposals that align with the strategic priorities of the funding institutions. – Institutional funding: maintaining infrastructure of major research organisations such as Max Planck Society, Leibniz Society, and Fraunhofer Society • Deployment of green technologies: <ul style="list-style-type: none"> – Deployment of already mature technologies based on subsidies (e.g. for electric cars, building refurbishment and heating replacement), guaranteed feed-in tariffs (EEG), and CCfDs for industry (BMW industry programme in 2024)
Funding volume (e.g., by R&I focus areas)	<p>What is the overall funding volume of the R&I measures intended to contribute to climate change mitigation?</p> <p>Can one derive from the funding volume in a specific R&I field the strategic priorities?</p> <p>Based on the funding volume, it can be assumed that there is a priority on energy related fields of R&I. It is important to note that funding for energy is particularly for hydrogen, batteries, and other measures for sector coupling. Thus, the funding also benefits other sectors in terms of energy transition and targets the whole energy system.</p>

3.6.3 Germany – Section 3: Monitoring approaches

Aspect	Questions / Collected evidence
Section 3: Assessment of monitoring approach for contribution of R&I for climate change mitigation	
Key monitoring system (in place / in preparation)	<p>Is there a monitoring system (either dedicated to R&I measures, green budgeting, or monitoring system for the progress to climate neutrality) that involves a measurement or provides guidance on the contribution of R&I measures to climate change mitigation (or more than one system)?</p> <ul style="list-style-type: none"> • Generally, there is no planned quantitative analysis of the effect of R&I activities on climate change mitigation. In the Climate Action Plan (2019) it is stressed "that GHG reduction potentials for R&I measures cannot be reliably quantified (p. 150)." • Also, there is no top-down monitoring system currently in place that covers all programmes together in terms of qualitative assessment. Instead, there are several partial evaluations for individual programmes or over time. • Ariadne - Transformation Tracker¹³⁹: The Transformation Tracker is a comprehensive monitoring tool developed by the Ariadne project to track progress towards climate

¹³⁸ BMBF. (2022). *Kopernikus-Projekte: Die Komplettversion der Kopernikus-Version*. https://www.kopernikus-projekte.de/vision/vision_komplett.

¹³⁹ Ariadne Transformation Tracker. (2024, June 4). Ariadne Transformation Tracker. <https://tracker.ariadneprojekt.de/de>.

	<p>neutrality by 2045. It focuses on a wide range of key performance indicators that reflect advancements in climate policies, and sector-specific transitions. The tool also incorporates indicators that are highly connected to the developments in climate research and technological innovation such as the project pipeline for steel production via hydrogen-based direct reduction or the project pipeline for electrical power consumption of installed and planned electrolysers.</p> <ul style="list-style-type: none"> • DIW – Open Energy Tracker¹⁴⁰: The Open Energy Tracker has been developed in a similar way to the Ariadne – Transformation Tracker. It can be considered a sister project to the Transformation Tracker, offering a set of indicators that is similar but also deviates in some respects. The Open Energy Tracker also displays data on other countries, including France, beyond Germany. • Monitoring approach of the future strategy for research and innovation: To evaluate the success of the future strategy for research and innovation, there are dedicated mission teams that evaluate the process for the six different missions. The mission teams are made up of different ministries to overcome the problem of silo mentality across ministries. These mission teams are supported by the "Forum #Zukunftsstrategie" which consists of 21 experts from science, business, and civil society¹⁴¹. This body places particular emphasis on the measurability of the mission's results using target criteria that are as internationally comparable as possible. There are 17 indicators that are analysed by 2025 to evaluate the process such as the start-up rate in the high-tech sector, the number of academic (spin-off) start-ups and the share of gross domestic product (GDP) that has been invested in research. However, these indicators do not provide any conclusions regarding the extent to which the R&I measures have contributed to actual emission reductions and climate protection. These indicators will be first evaluated in 2025. • FONA Impact: conducts supporting research to the FONA strategy. Uses a combination of proven methods of impact measurement and impact monitoring with methodological developments to determine the impact of R&I strategies. This allows the short/medium-term contribution of FONA to be read at micro and meso level and to determine the long-term SDG impact of the FONA strategy.
<p>Approach for measuring the impact of R&I measures on climate change mitigation</p>	<p>What is the specific approach of the system? What is being measured and how?</p> <p>So far, there is no overall approach to monitor the contribution of R&I on climate change mitigation. For details on partial monitoring see subsection above.</p>
<p>Sources of information / methodological approach for monitoring system</p>	<p>What information and data is used for the monitoring system?</p> <ul style="list-style-type: none"> • The Ariadne – Transformation Tracker uses several national data sources and compares current numbers with target paths from the Ariadne scenarios. The most relevant data source for current numbers is the AG Energiebilanzen e.V. which evaluates available statistics from all areas of the German energy industry from a scientific point of view, regularly compiles an energy balance and makes it available to the public. The target paths are calculated using the REMIND model. REMIND (REgional Model of INvestment and Development) is an analytical integrated assessment model that represents the future evolution of the world economies with a special focus on the development of the energy sector and the implications for our world climate. In this case the model is applied on the German economy only. Note that it does not cover any R&I indicators. <p>What types of assumptions / methods are used?</p> <ul style="list-style-type: none"> • To go into the various assumptions of the large-scale integrated assessment REMIND model (used for the Ariadne Transformation Tracker) would go beyond the scope of this document. The model broadly consists of three main parts: a linear energy supply system, sector specific energy demand representations and a Ramsey-type macroeconomic (endogenous) growth model.
<p>Actors and roles in the monitoring system</p>	<p>Who are the involved actors in providing and validating the data?</p> <ul style="list-style-type: none"> • Mainly research consortia are involved in collection, analysing and presenting results

¹⁴⁰ Roth, Alexander & Schill, Wolf-Peter (2025). Open Energy Tracker. <https://openenergytracker.org/docs/germany/>.

¹⁴¹ BMBF. (2023). Bericht zur Umsetzung der Zukunftsstrategie Forschung und Innovation. https://www.bmbf.de/SharedDocs/Downloads/de/2023/umsetzungsbericht_zukunftsstrategie.html.

	<ul style="list-style-type: none"> Depending on the type of monitoring data is either coming from the funded projects (e.g. FONA-Monitoring) or from wide range of public entities and industry associations (e.g. Ariadne/Open Energy Tracker)
Implications	<p>What are the practical implications of the monitoring results?</p> <ul style="list-style-type: none"> FONA Impact: Through the exchange and accompanying measures with the specialist communities, FONA Impact contributes to the coordination of actors at the strategy level and provides strategic intelligence to strengthen FONA's contribution to achieving the goals of the 2030 Agenda. Ariadne: No direct practical implications. Can be used as a public source by policy makers. Open Energy Tracker: No direct practical implications. Can be used as a public source by policy makers. <p>How are they integrated in the R&I policy cycle (e.g., being on track for the development of key technologies or not)?</p> <ul style="list-style-type: none"> They are not formally integrated into the R&I policy cycle.

4 Synthesis of case study results

4.1 Section 1: Political objectives, strategies, and main actors related to R&I for climate change mitigation

The ambition to reach net-zero GHG emissions has become a defining feature of national climate strategies across countries. Germany has committed to net-zero by 2045. France, the UK, the Netherlands, and the US have converged around a 2050 target, while Austria has adopted a more ambitious goal of climate neutrality by 2040. These targets guide the architecture of national R&I policies for climate change mitigation and serve as a critical policy anchor for long-term planning and public investment.

In Germany, the strategic approach is grounded in a solid legislative framework through the Federal Climate Change Act (KSG), which is operationalized via detailed Climate Action Plans (notably from 2019 and 2023). In the field of R&I, these are complemented by comprehensive strategic frameworks such as the FONA Strategy and the Federal Government's Future Strategy for Research and Innovation, which collectively support a technology-open and systemic R&I policy.

France follows a multilayered governance model, combining the SNBC, France 2030, and the PPE to steer R&I investments. The UK's Net Zero Strategy is implemented via sectoral roadmaps and funding through DESNZ and UKRI. The Netherlands adopts a mission-oriented model emphasizing collaboration across ministries and research-industry consortia. Austria integrates its climate and innovation goals through the NEKP and RTI Strategy 2030, structured around triennial RTI Pacts. The United States has opted for a legislative-led approach, deploying the Inflation Reduction Act (IRA) as a transformative financial mechanism to stimulate clean technology investment through tax credits and grants.

The timelines for strategic implementation generally span from the near-term (2025-2030) to the mid-century targets. Germany, Austria, and France, for example, operate with clearly defined intermediate milestones, reinforcing a programmatic approach to achieving sectoral GHG reductions. France integrates monitoring mechanisms into its policy implementation cycles via carbon budgets. France's High Council for the Climate plays a crucial oversight role.

Institutional configurations also vary significantly. Germany and Austria use a dual ministry system (science and economic/climate ministries) to balance basic and applied research. France centralizes strategic coordination within the Prime Minister's Office (SGPI), supported by a robust network of research institutions. The UK's UKRI combines the mandates of multiple councils under one umbrella. The Netherlands favours distributed governance through thematic 'Top Sectors'. In the US, federal agencies like the DOE and NSF lead the funding, but the structure is highly decentralized, relying on policy instruments rather than a central strategy. This diversity reflects differing historical, institutional, and political contexts that shape how countries organize, govern, and finance their R&I systems in relation to climate policy.

Table 2 Comparison table – Section 1: Overarching framework

Aspect	Germany	France	UK	Netherlands	Austria	USA
Climate change mitigation objective	Net-zero by 2045	Net-zero by 2050	Net-zero by 2050	Net-zero by 2050	Net-zero by 2040	Net-zero by 2050
Strategic documents and implementation plans	Climate Action Programmes, FONA, BMFTR Strategy Future of R&I	SNBC, PPE, France 2030	Net Zero Strategy, Clean Growth Strategy	Mission-driven Innovation Policy	NEKP, RTI Strategy 2030, RTI Pact	Inflation Reduction Act (IRA)
Time horizon of programmes / strategies	2030, 2040	2030, 2050	2030, 2050	2030, 2050	2026 (RTI Pact), 2030 (NEKP)	2030–2050
Monitoring of long-term contribution of R&I	Partial (FONA) Deployment focus: Ariadne, Open Energy Tracker etc.	Integrated in SNBC and PEPRs	Embedded in policy evaluations	Mixed approaches, mission-specific, combined dashboard	Various systems with alternative, promising approaches	Lacks unified approach, mostly fiscal/economic monitoring
Main actors	BMFTR (basic research), BMWK (applied research), PTs, research institutions	SGPI, Ministry of Research, CNRS, CEA, ANR, ADEME	DESNZ, UKRI, Innovate UK	Ministries, top sectors, public research institutes	BMK, BMBWF, FFG, KLIEN	DOE, NSF, ARPA-E

Technopolis & IfW (2025).

Table 3 Comparison table – Section 2: R&I portfolio linked to climate change mitigation

Aspect	Germany	France	UK	Netherlands	Austria	USA
General characteristics and structure of R&I portfolio	Sector-specific focus on energy, transport, industry, agriculture	Systemic and sectoral, includes energy, industry, agriculture	Focus on applied solutions, low-carbon tech	Strong PPI and mission alignment	Balanced focus across 4 missions (see below)	Broad, focused on tech deployment
Defined R&I focus areas	Green hydrogen, battery, e-fuels, CCUS	Renewable energy, nuclear, CCS, hydrogen	Offshore wind, CCUS, hydrogen	Circular economy, smart mobility	Four missions: Energy transition (Hydrogen focus), mobility transition, circular economy, cities	Clean energy, EVs, CCS, DAC
Strengths of R&I system	Sectoral integration, stakeholder involvement	Strong climate science base, public-private R&I	Innovation ecosystem, clear net-zero commitment	Flexibility, strong public-private cooperation	Mission orientation, alignment across actors	Scale and scope of IRA funding
Weaknesses of R&I system	Limited <u>climate</u> impact monitoring	Lack of unified long-term impact methodology	Coordination complexity	Regional differences, coordination gaps	Fragmented monitoring, data standardization issues	No centralized monitoring
TRL focus (technological readiness)	Mix of early and applied research	Full TRL range, strong in early TRLs	Applied focus, innovation deployment	All TRLs, strong deployment push	FFG high TRLs, FWF low TRLs	Strong push to commercialization
Funding instruments	R&I: Grants, institutional support Deployment: Demand-side subsidies, CCfDs	Grants, PEPRs, tax credits, green bonds	Grants, contracts, tax incentives	Competitive grants, PPP funding	Mix of grants (FFG, KLIEN, FWF)	Grants, loans, tax incentives, private sector mobilization

Technopolis & IfW (2025).

Table 4 Comparison table – Section 3: Monitoring approaches

Aspect	Germany	France	UK	Netherlands	Austria	USA
Existence of monitoring system	Partial, FONA with focus on SDGs, other monitoring of technology deployment (e.g., Ariadne-Tracker)	SNBC, PPE, PEPRs integrated monitoring	Independent evaluations, SBTs	Project-level and mission-linked	Decentralized, under development	No unified system, sectoral reports
Approach to measuring R&I impact	Mostly indirect, few quantifiable metrics	Carbon budgets, project KPIs, PEPRs	Outcome and impact-based metrics	Mixed indicators	Sustainability rating, impact audits	Focus on deployment, not emissions
Actors in monitoring	Research consortia, ministries	ANR, CSIA, Ministry of Research	DESNZ, advisory bodies (e.g., CCC)	Ministries, research councils	BMK, FFG, expert juries	DOE, Treasury, EPA
Practical implications of monitoring	Limited, advisory only	Integrated into planning and funding	Influences funding cycles	Feedback into missions	Guides programme changes	Fiscal reporting, limited climate feedback
Integration into R&I policy cycle	Not systematically integrated	Strong integration in PEPRs	Tied to strategic reviews	Direct policy linkage	Incremental feedback loops	Limited integration

Technopolis & IfW (2025).

4.2 Section 2 – Assessment of R&I portfolio and funding strategies to support climate change mitigation

All countries examined maintain a strategic focus on decarbonizing major emitting sectors, particularly energy, transport, and industry, through targeted R&I investments. Germany's sector-specific R&I funding framework features, for example, comprehensive portfolios for hydrogen technology, battery storage, and industrial carbon abatement. Austria aligns its R&I activities with four key missions – energy and mobility transition, circular economy, and climate-neutral cities – underpinned by programmatic agreements and stable funding commitments. France's France 2030 initiative emphasizes cross-sectoral transformation through PEPRs that support both basic research (TRL 1-4) and applied solutions (higher TRL) aligned with national acceleration strategies. The UK's Clean Growth Strategy and subsequent funding streams from UKRI are designed to fast-track deployment-ready innovations, especially in renewables, offshore wind, CCUS, and low-carbon heating. The Netherlands leverages its compact innovation ecosystem to catalyse mission-driven research via public-private partnerships and sectoral transition agendas. The US, through the IRA, adopts a demand-driven, deployment-centric approach that prioritises rapid scale-up of clean technologies via tax cuts and private sector incentives. The IRA includes support for renewable energy, carbon capture, and electric vehicles, with an emphasis on job creation and industrial competitiveness.

Across all countries, research portfolios cover a wide TRL spectrum. Germany, France, and Austria support early-stage research through dedicated ministries/agencies (BMFTR, ANR, FWF) while fostering more applied areas of R&I via other ministries and funds. The UK and Netherlands favour more practice-oriented research and demonstration projects, with a focus on rapid commercialization. Similarly, the US skews even more towards high-TRL innovations, using financial leverage from IRA incentives to drive technology adoption. However, this conclusion is limited in the sense that the IRA was the primary focus of the US country case study.

While strategic frameworks and funding portfolios provide the foundation for national R&I systems, their effectiveness ultimately depends on the ability to assess whether these investments contribute to long-term climate goals. This makes monitoring a critical, yet complex, component of climate-oriented R&I governance.

4.3 Section 3 – Monitoring approaches

Monitoring the long-term impact of R&I on climate change mitigation remains a shared challenge across all the countries analysed. This is not entirely surprising and could have been anticipated *ex-ante*, given the inherent difficulties in measuring the indirect, systemic, and often long-delayed effects of R&I policies. The complexity of technological interdependencies and the time lag between research funding and observable emissions outcomes make causal attribution particularly difficult. Despite broad consensus on the strategic value of understanding R&I's contribution to climate goals, none of the studied countries has established a comprehensive and mature system that consistently links R&I investments to long-term climate mitigation effects.

Germany exemplifies these limitations: initiatives such as the Ariadne and Open Energy Tracker provide valuable sectoral indicators and scenario modelling, but they primarily focus on the deployment and diffusion of technologies rather than the upstream R&I processes driving them. Similarly, the FONA Impact framework offers important qualitative insights into R&I contributions to sustainable development, but its orientation toward the broader Sustainable Development Goals (SDGs) means that climate change mitigation is only one of many focus areas, and not its primary target. Based on this analysis, it makes sense to extract individual aspects from the

country case studies conducted in order to identify elements that could potentially contribute to the further enhance a monitoring system in Germany.

The case studies indicate that France has made more progress through its PEPR program, which mandates structured monitoring and evaluation. SNBC's use of carbon budgets and the oversight of the High Council for the Climate help align R&I outcomes with national targets. Evaluation frameworks include TRL tracking and climate outcome assessments, although attribution remains complex. Austria is currently enhancing its monitoring system with tools like Green budgeting, a collection of the evaluations and monitoring efforts in the KLIEN Monitoring, and sustainability-based project evaluations. These instruments provide insight into potential impacts and societal value, though they are still evolving toward integration with policy feedback mechanisms.

The UK adopts a relatively decentralized but robust evaluation culture, relying on external advisory bodies and impact assessments through UKRI and DESNZ. However, these do not systematically quantify outcomes. The Netherlands uses adaptive monitoring linked to mission implementation, integrating qualitative and quantitative measures. Austria's decentralized approach includes pilot evaluations and expert-led impact verification, reflecting a dynamic but also so far not centralised landscape of approaches.

In the US, the focus is largely on economic outcomes and technology deployment rather than emission reductions per se. Monitoring is often conducted at the agency level (e.g., DOE), with little coordination across programs.

Across all countries, the indirect nature of R&I outcomes, technological interdependencies, and long timeframes create methodological hurdles. Most monitoring systems focus on input and process indicators - such as funding volumes, TRLs, or number of patents - rather than outcome or impact metrics like reductions in the emission intensity or cumulated avoided emissions. There is growing interest in integrating advanced analytics and cross-agency data sharing to enhance policy learning. However, countries remain at various stages of institutional readiness to adopt such innovations.

Integrating monitoring with the policy cycle is still an aspiration rather than a reality in many systems. Based on the research in the case studies, particularly France, Austria and the UK show promising practices.

5 Conclusion

The comparative synthesis of Germany's R&I system alongside that of France, the UK, the Netherlands, Austria, and the US illustrates a shared international commitment to climate neutrality, paired with a variety of strategic approaches. While the ultimate objective – net-zero economies – is broadly consistent across countries, the design and execution of R&I strategies reveal distinct national characteristics, institutional arrangements, and policy cultures.

Germany's R&I framework is notable for long-standing investment in foundational cross-cutting technologies like hydrogen and battery systems. Strategic instruments such as the Climate Action Plans, the FONA Strategy, and the Future Strategy for Research and Innovation demonstrate a robust commitment to integrating scientific excellence with sustainability goals. Germany's emphasis on sectoral coverage and mission clarity targets innovation efforts to be aligned with national climate policy priorities.

At the same time, there are opportunities to further enhance Germany's position by strengthening the connection between R&I activities and their long-term climate impact. While systems like the Ariadne Transformation Tracker and FONA Impact provide valuable insights, they are not yet fully embedded into an outcome-oriented monitoring framework for measuring the contributions of R&I to climate change mitigation efforts. Ideally, by adopting a more dedicated approach to monitoring climate-related R&I measures, policymakers could enhance the long-term climate impact of significant public investments. At the same time, they could communicate the uncertainties surrounding long-term outcomes more openly.

From the case studies, France provides a model of strategic integration, where R&I investments under France 2030 are tightly aligned with carbon budgets and monitored through dedicated programs (PEPRs). This alignment ensures that innovation directly contributes to national decarbonization goals and allows for continuous evaluation. France's efforts to combine digital and ecological transformation also offer a forward-looking blueprint for systemic innovation. The UK and Netherlands emphasize applied innovation and deployment, using agile governance and strong stakeholder networks to accelerate technology diffusion. Through mechanisms like UKRI and the Dutch Top Sectors, these countries promote public-private collaboration and mission-driven funding. While this approach supports rapid uptake of technologies, it also presents coordination challenges, especially where broader system integration is needed.

Austria illustrates how focused missions can steer innovation. By defining four clear climate missions and coordinating across ministries through RTI Pacts, Austria has created a streamlined R&I ecosystem. Tools such as sustainability scoring and targeted funding through FFG and KLIEN help ensure climate relevance, although comprehensive monitoring structures are still under development. The United States, under the Biden Administration, took a different approach, channelling vast resources through the IRA to catalyse market transformation. With a strong emphasis on scale and private investment, the US model underscores the importance of mobilizing deployment at speed.

Together, these case studies demonstrate that there is no single approach to effective climate-oriented R&I policy monitoring. Rather, each country contributes valuable lessons. Germany, with its strong institutional base, strategic coherence and existing R&I monitoring systems, is well-positioned to further advance the measurement of climate-related impacts by systematically attributing research goals to the sectors and technologies they intend to contribute to, and assessing the relative likelihood and magnitude of effects over time.

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