Tracking Public Investment in Energy Technology Research – A Roadmap

International Energy Agency

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Abstract

A wide range of countries make efforts to track their entire national public energy research, development and demonstration (RD&D) activity on an ongoing basis, also sharing the collected data with the IEA through a standardised template. However, the approaches adopted to collect data vary significantly across countries. This roadmap describes the variety of country approaches, also identifying the most important common components: the institutional arrangements; the methods for collecting, classifying and validating the data; the data management and technology processes; and, finally, the dissemination. It is intended not only as a guide for countries near the beginning of their journeys towards the collection of energy RD&D, but also for countries with more advanced systems looking to strengthen specific areas. The roadmap is the product of interviews held with representatives of 20 governments between November 2021 and March 2022, and it is indebted to their generosity in sharing their experiences with tracking national energy RD&D spending. Case studies based on the interviews are used to highlight noteworthy methods, while complete national systems descriptions are included in the annex. It is hoped that this publication will serve as a reference and inspiration for experts in this important area of tracking clean energy transitions and that new experiences can be added in the future.

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Tracking public energy research development and demonstration

Reducing global CO_2 emissions to net zero by 2050 is consistent with efforts to limit the long-term increase in average global temperatures to 1.5 C. This calls for nothing less than a complete transformation of how we produce, transport and consume energy. Without a major acceleration in clean energy innovation, reaching net zero emissions by 2050 will not be achievable. Estimations show that technologies that are available on the market today could provide nearly all of the emissions reductions required by 2030 to put the world on track for net zero emissions by 2050. However, reaching this target will require the widespread use after 2030 of technologies that are still at the research, development and demonstration (RD&D) stage today. This need is even bigger in sectors such as heavy industry and long-distance transport. Major innovation efforts are vital so that the technologies necessary for net-zero emissions can reach markets as soon as possible.

Additionally, energy technology innovation is a key tool for oil- and gas-importing countries trying to improve their energy security. New technologies can reduce dependency on fossil fuel imports: firstly, by decreasing energy demand with improvements in energy efficiency, and secondly, by replacing fossil fuels with other energy carriers produced locally. Leadership in new energy technologies can also create long-term value for today's energy exporters as they transition to new sources of income. Furthermore, the developers of successful new technologies will be at the heart of future innovation ecosystems and economic prosperity as the energy transition accelerates. Ensuring that the push for clean energy innovation is sufficient to reach net zero by 2050 requires comprehensive tracking.

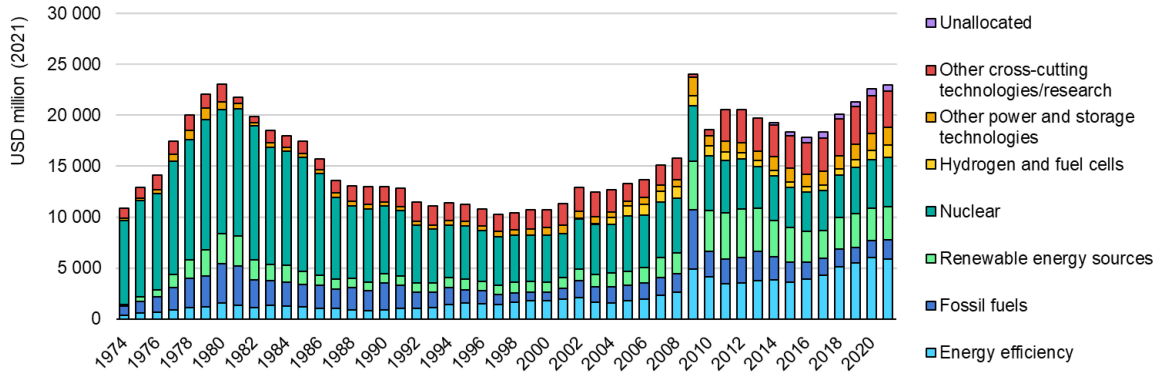
Tracking clean energy innovation progress encompasses several critical elements of effective energy innovation policy: identifying gaps and opportunities, evaluating the effectiveness of programmes and policies, and understanding the market readiness of key technologies, nationally and globally. One of the policy tools available as part of national energy research policies and support programmes is direct public expenditures on RD&D, and the only way to accurately track them is to have robust and reliable statistics. These data provide the quantitative basis to design, evaluate and adjust those policies. They also generate valuable insights for government ministries and departments that are not directly responsible for energy research spending – including those concerned with energy strategy,

industry and education – as well as many regional and provincial institutions, private industry and others in the research and innovation ecosystem.

In this context, the IEA acts as an energy policy adviser to promote reliable, affordable and clean energy globally. As such, one of its priorities is to collect data on RD&D spending in the field of energy. Uniquely, the IEA has been collecting data on government funding of energy technology RD&D activities across countries since 1974 from its members, within the broader set of energy statistics requirements. These data provide invaluable information to policy makers across the globe to help their decisions on energy RD&D investments as well as their formulation of other policies affecting innovation, including market pull policies. The private sector can also benefit from a deeper understanding of government activities in energy RD&D.

The IEA collects annual energy RD&D data using a standardised questionnaire that classifies energy technologies into four levels of detail within seven high-level categories: energy efficiency, fossil fuels, renewable energy, nuclear, hydrogen and fuel cells, other power and storage technologies, and cross-cutting. Based on this data collection, the IEA releases its dataset of public investment in energy RD&D online. For example, the latest data show that the global investment of IEA members in 2021 was almost USD 23 billion. Since 2021, the dataset also includes data shared by Brazil, the first non-member country of the IEA to contribute to the database.

Total public energy RD&D budgets in IEA member countries, 1974-2021



The IEA dataset is made possible through the significant efforts of governments to compile energy RD&D data. While each government has historically designed its most appropriate approach to collecting and sharing national energy RD&D data, the IEA has seen the value in exchanging knowledge across country experts. To accurately track all flows of funds, a number of common steps must be followed regardless of the national context. They include identifying the funders and

spenders and classifying projects by topic and research stage. Additionally, accessing and maintaining the right channels to disseminate the data are important. While each country's data follow the structure and scope set out in the IEA Guide to Reporting RD&D Budget/Expenditure Statistics (hereafter, the Energy RD&D Manual), to which they have contributed, the precise data collection approaches vary.

There is no single approach that perfectly fits the needs of all the countries, and governments have designed processes for their institutional contexts and refined them over time. This creates extensive potential for countries to share effective practices and learn from each other's experiences. However, the different approaches have never been documented or shared until now.

As such, this roadmap has been produced to help countries design or redesign a robust data collection, validation, and dissemination process based on the experience of IEA member and association countries.

The example of the European Union has been taken to showcase the importance of energy innovation and its tracking. In 2008, the European Union launched the Strategic Energy Technology Plan to support research and innovation and established the Strategic Energy Technology Plan Information System (SETIS) to track and monitor its implementation.

European Union case study: Strategic Energy Technology Plan

The Strategic Energy Technology (SET) Plan is an initiative of the European Commission to support the research and innovation actions in the European Union. It is not a funding programme, but it aims to help co-ordinate national research and innovation activities for developing low-carbon energy among the EU member states and four associated countries (Iceland, Norway, Switzerland and the Republic of Türkiye) and to align national research and innovation programmes with its agenda. Its main objective is to maximise the impact of research and innovation by co-ordinating national efforts. To do this, the programme establishes a governance model, setting priorities and key actions and promoting different working groups. The SET Plan was first launched in 2008.

Since 2008, energy innovation has moved closer to the centre of the European Union's vision for its 21st century economy. In fact, the transition towards climate neutrality by 2050 gives energy a central role, and to reach climate neutrality, the European Union will need to decarbonise at least six times faster than anything realised globally so far. To accomplish this challenging task, the European Union considers innovation, including R&D, a key enabler of new synergies in the energy

system. Relying on clean and innovative processes and tools, the path towards system integration will also trigger new investments, jobs and growth and strengthen EU industrial leadership at a global level.

In 2016, the European Commission presented a research, innovation and competitiveness strategy to support energy innovation with new policy strategies. These strategies outline a vision for energy technology and have three goals:

Energy efficiency first. Making energy demand and supply more efficient by means of cost-effective initiatives that respond to end-use energy savings demand and more efficient conversion, transmission and distribution of energy.

Europe: a global leader in renewables. The European Union has a firm commitment to becoming a global leader in renewable energy.

A fair deal for consumers. The European Union is committed to diversifying Europe's sources of energy and ensuring energy security through solidarity and co-operation among EU countries.

To track and monitor the implementation of the SET Plan, the European Union created the SET Plan Information System. It is the open access information, knowledge management and dissemination system for the European strategic energy technology plan. The SET Plan Information System provides information on the state of low-carbon technologies. It also assesses the impact of energy technology policies, reviews the costs and benefits of various technological options and estimates implementation costs.

Apart from the annual SET Plan implementation progress report, the SET Plan Information System includes a dashboard with energy RD&D data. The dashboard presents a quick overview for each EU member state of two key indicators: the level of investment in research and innovation, both private (expenditure by businesses and industry) and public (member states' national programmes and instruments), and trends in patents for the Integrated SET Plan Actions. This information is useful for European industrial initiatives, private companies, trade associations, the European Energy Research Alliance, international organisations and financial institutions.

Sources: European Commission, Energy Research and Innovation Strategy; European Commission, Energy Research and Innovation; European Commission, Energy Efficiency First; European Commission, SETIS - SET Plan Information System.

What does it mean to collect public RD&D spending data?

Governments have a particularly central and wide-ranging role in determining the success of energy innovation that goes far beyond the provision of funds for RD&D. They set overall national objectives and priorities and play a vital role in determining market expectations, ensuring, for example, that government funding has a positive impact on technological innovation in the private sector without any crowding out effect. They also have unique responsibilities for ensuring the flow of knowledge, investing in enabling infrastructure and facilitating major demonstration projects. Many policy tools are at their disposal, including but not limited to tax credits, loan guarantees and direct funding.

To activate all these levers effectively and to ensure that governments can make informed decisions, it is vital to produce reliable and accurate statistics, focusing in this report on public energy RD&D budget statistics. Collecting, validating and disseminating these data is a complex process. To undertake these tasks, the responsible government departments are often tasked with allocating appropriate levels of resources and promoting collaboration among institutions. In many cases, these collaborations are formalised, for example in data-sharing agreements.

To navigate the language used in this field, it is important to have a common understanding of some key terminology. For more detailed information on definitions, see the OECD's Frascati Manual, which describes the internationally recognised methodology for collecting and using R&D statistics, and the Energy RD&D Manual, specific to the process described in this handbook.

Glossary

Public: This refers to government funds, either at the central/federal or provincial/state level. State-owned enterprises are also included.

Energy RD&D: Energy RD&D covers research, development and demonstration related to the production, storage, transportation, distribution and rational use of all forms of energy. RD&D covers basic research when it is clearly oriented towards

the development of energy-related technologies, applied research, experimental development and demonstration.

This definition of energy RD&D is quoted from the Energy RD&D Manual, which was elaborated in 2011 through a consultation among experts and the IEA.

The **Frascati Manual** defines general **R&D** as follows: "Research and experimental development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge."

Energy RD&D data: This refers to both public energy technology RD&D budgets and expenditures, reported from the performer's perspective as expenditures or from the funder's perspective as budgets.

Funder: Funders of energy RD&D are institutions that provide funds to performers to undertake RD&D in the energy sector.

Performer: Performers of energy RD&D are institutions that undertake RD&D. They can be a business enterprise, government institution, higher education institution or private non-profit institution.

Co-ordinating team: The co-ordinating team is the group of people that co-ordinates the national effort to collect and classify the energy RD&D data and possibly complete the IEA questionnaire.

Process (of data collection, classification, validation and/or dissemination): In this report, the word "process" is used to describe the methodologies followed by countries to collect, classify, validate and/or disseminate energy RD&D data.

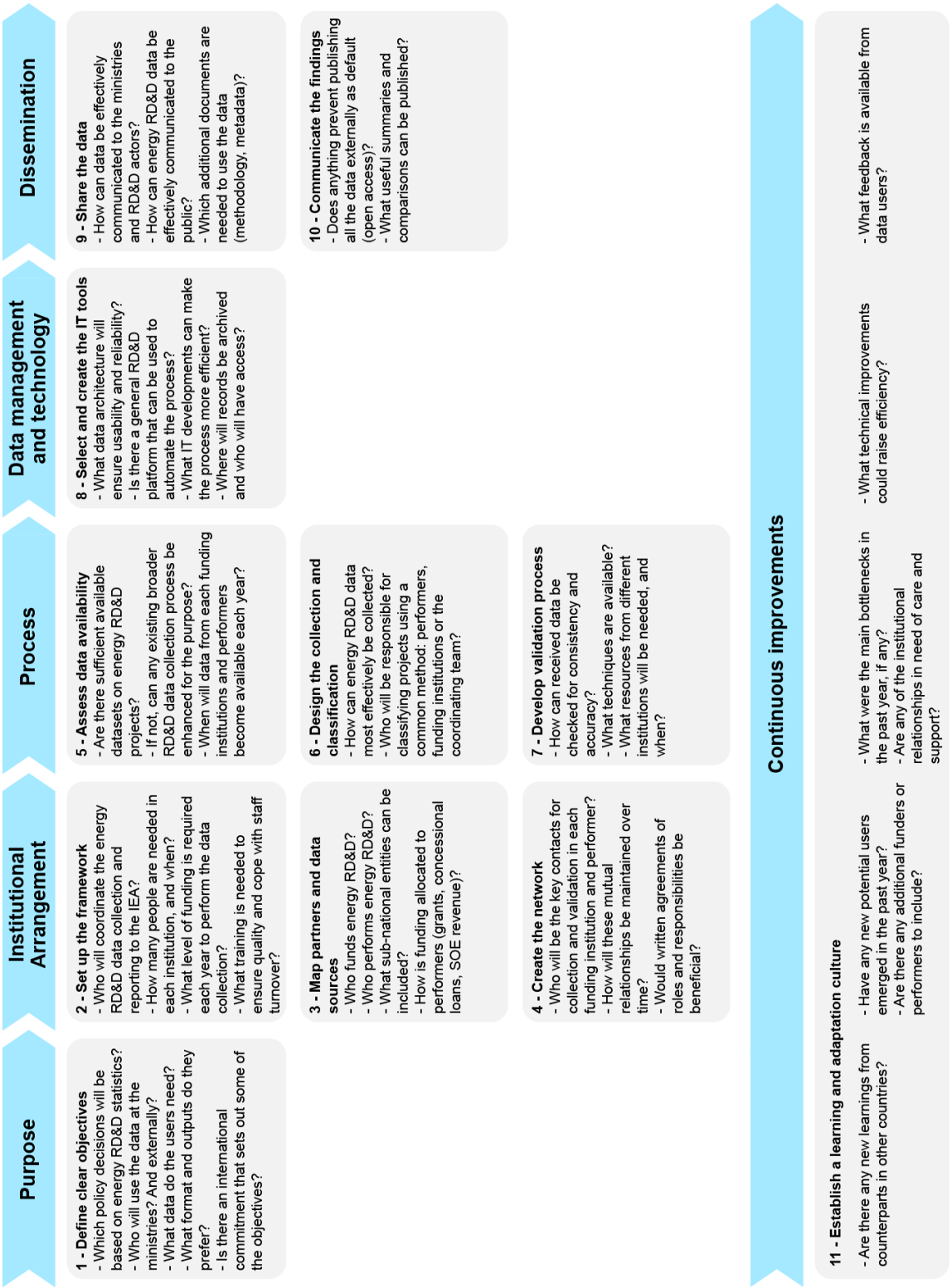
Cycle (of data collection, classification, validation and/or dissemination): In this report, the word "cycle" is used to describe the annual execution of the methodology (process) to collect, classify, validate and/or disseminate energy RD&D data.

Network of institutions: This is the connected group of institutions that interact in the effort to produce energy RD&D statistics.

(Data) Contacts: These are the peers who work in the network of institutions and interact to carry out the energy RD&D data cycle.

The RD&D data collection process can be understood in terms of its six phases and 11 steps. As a real-world example, Lithuania has built an energy RD&D process from scratch in parallel with its accession process to the IEA.

Roadmap to collecting energy RD&D data



Notes: SOE = state-owned enterprise; IT = information technology.

Lithuania case study: Creating an energy RD&D collection process

Lithuania started to collect energy RD&D data in 2020. Before 2020, all the energy RD&D data available were the general RD&D data produced by the national statistics office. However, these were much simpler statistics, without a breakdown by technology. This significant effort was undertaken by a combination of three main drivers:

- An important push from the Lithuanian government to have solid data to make informed policy decisions on energy research. This was the main driver for launching the initiative to establish the data collection system.
- Within the process to become a member of the IEA, energy data submissions are an access criterion for all countries. Lithuania set a clear objective of submitting energy RD&D data to the IEA in 2020.
- EU requirements for data collection.

Additionally, there was already an immediate and relevant use case for these statistics by the Ministry of Energy. Lithuania is part of the Nordic-Baltic co-operation format with a joint energy research funding programme. In the framework of this programme, the study report “Baltic-Nordic Roadmap for Co-operation on Clean Energy Technologies” has been financed, with an aim to identify, prioritise and suggest energy-related technologies for shorter-term and longer-term investment to achieve the climate and energy objectives of the country. The energy RD&D data collection is a good indicator to track compliance with this roadmap.

Once the motivation was clearly identified, Lithuania created a team of four people dedicated to this project, and after one year, they submitted energy RD&D data to the IEA for the first time with good coverage and data quality. The team is a combination of people from the Ministry of Energy of the Republic of Lithuania and the Lithuanian Energy Agency. The Lithuanian Energy Agency is responsible for the collection, processing and submission of the energy RD&D data to the IEA, with oversight from the Ministry of Energy of the Republic of Lithuania

The first task of this team was to screen the national energy RD&D ecosystem. The team identified 19 organisations involved in energy RD&D in Lithuania. The institutions included four ministries, two public agencies, one science and technology research centre, four state-owned enterprises, the research council of Lithuania, the Lithuanian energy institute, one organisation of research and technology and five universities. The team contacted all these institutions to ask for available information and agree on a contact to receive a template, provide the data, and solve any doubts and inconsistencies. Where possible, the target contact was the person with the technological knowledge to classify different projects and complete the questionnaire. Additionally, the co-ordinating team assessed the availability of public databases, but even where some were in place, they decided

to launch a separate data collection process as these databases were arranged differently from the IEA questionnaire.

From this exercise, they discovered that it was easy to identify the high-level energy RD&D landscape, but it was more challenging to ensure data availability in all these institutions. For now, the process is entirely voluntary, but Lithuania is working on the introduction of a legal background to define the specific responsibilities of each of the institutions and formalise the data collection.

Once the institutional arrangement was set, Lithuania ran a test data cycle in the fourth quarter of 2020 and then repeated the cycle in the first half of 2021 to align with the IEA's reporting. Data were collected through voluntary questionnaires sent by email directly to the different institutions involved in energy RD&D using the IEA template. The questionnaire was sent with a link to the Energy RD&D Manual.

The reporting institutions were responsible for compiling all the project funds they received from public institutions to finance energy RD&D. Most of the institutions could report their actual spending for the year of study and not budget or fund allocations. The classification of projects was a challenge in many cases, but the Ministry of Energy and Lithuanian Energy Agency collaborated with the institutions to resolve any issues.

An additional problem was the differences in data availability among different organisations as there is no standardised methodology to collect data across institutions. For this reason, out of the 19 questionnaires sent, 10 responses were received in 2020 and 15 in 2022. It is important to highlight that most of the national energy RD&D funds were covered because the main spenders reported good-quality data. Once all the answers were received, the team aggregated all the data in a questionnaire and submitted it to the IEA.

Regarding the technology to support the process, Lithuania did not deploy a data platform to manage the data collection and relied on Excel spreadsheets shared across institutions by email. The small number of institutions made it feasible to manage this task by email.

Finally, there is no specific national RD&D publication in place. For now, the IEA report is used to disseminate the data, which are widely used internally to inform policy decisions. Lithuania is currently assessing the internal interest in preparing a publication once the entire process is well established and actively engaging with the institutions to receive more questionnaires with data.

Sources: Lithuanian Energy Agency; Ministry of Energy of the Republic of Lithuania.

Purpose

Energy RD&D is a strategic field for many countries. In fact, successful national strategies in RD&D have achieved the mobilisation of enough resources to make those countries the leaders in some sustainable energy technologies, creating national welfare and qualified jobs. For this reason, governments across the world are important actors for pushing innovation and supporting projects with public funds.

To allocate public funds to specific projects and technologies, public institutions design and implement effective RD&D funding programmes. Apart from the already challenging definition of these finance schemes, each country might have specific policy objectives that need to be tracked and assessed to ensure that the outputs meet the needs of all the relevant stakeholders.

In this regard, energy RD&D data are a key element for setting a quantitative basis for informing governments' decisions on energy RD&D. Energy RD&D data provide invaluable information to policy makers to help their decisions on energy RD&D investments as well as their formulation of other policies affecting innovation, including market pull policies. Additionally, these data can be beneficial for private companies to define their own strategies.

1 - Define clear objectives

Defining the specifics of the desired output from the beginning of the design or redesign of the RD&D data process is a prerequisite for a well-constructed system. If these objectives are not clearly defined, the final process may not be appropriate for the data users, and this can lead to inefficient parallel energy RD&D data processes.

Before starting any project on energy RD&D data, it is very important to identify and define the specific national needs for the energy RD&D data collection process, including the changes relating to the evolving technology and stakeholder landscapes as well as the main data users. This can be achieved with a broad consultation of users and interested parties. To do this, the main data users may consider presenting and explaining any initiatives to design or redesign the energy RD&D process to every stakeholder in the network and establishing and actively maintaining open communication with them. There are different

methodologies for collecting the requirements and prioritising them, but the assessment of these inputs from the stakeholders can positively influence the different components of the data collection system. It is important to keep in mind that maintaining good data quality can be very resource-intensive, so identifying the data user and data owner for requested data can bring substantial cost savings to a project.

The requirements in this phase of the process are the same whether governments are designing a new collection process or updating an existing process to adapt to new policy priorities. Articulating clear objectives is key to ensuring that the work fulfils its intended purpose and that the right tools are in place to evaluate its progress and results. In fact, governments could consider drafting this motivation on a regulatory framework to formalise it.

In most cases, these objectives are the main driver for launching a project. However, it is key to delve into these drivers and identify the exact policy decisions to be informed by the energy RD&D data. Then, it is possible to design a process and system to compile high-quality statistics to inform those decisions. Some of the decisions might be:

- to assess the funds needed to develop a certain technology
- to track the trends in spending by energy technology
- to assess the performance of technology policies
- to identify gaps in funding to meet national energy and climate objectives.

The specifics of the requirements can be identified by interacting with the main data users, who are probably the main promoters of the design or redesign of the process, in many cases the ministries in charge of energy and innovation policies. In addition to the motivations, it might be interesting to list the data requirements and start designing the format of the output. In some cases, a report with key highlights might be enough, whereas in other cases, the ministries may need a database with project-level information to be autonomous in their analysis. Additionally, it is also important to assess the interest of potential data users outside the ministries and design the data dissemination with those external users also in mind. Some of these external data users may include performers and international organisations.

Many countries have already in place some quantitative basis to assess and design energy RD&D funding programmes. However, the alignment of these data with the reporting of energy RD&D statistics to the IEA may vary by country. Although countries are committed through the IEA energy RD&D data cycle to collaborate in the international effort to create a global dataset, the process of reporting to the IEA is, in some cases, imperfectly aligned with the process of the compilation of data to assess the RD&D funding programmes that are in place. For this reason, it is important to disseminate the work done to compile the IEA

statistics because there might be synergies between such processes and the IEA data cycle.

In other cases, there might be additional interests not covered by the IEA questionnaire. These could be, for example, additional demographic indicators, such as the number of RD&D personnel, the regional distribution of funding or a specific technology interest that is more detailed than the IEA questionnaire (e.g. a particular battery technology) or outside of the scope (e.g. critical minerals and digitalisation) or the readiness level or average efficiency of specific technologies (e.g. solar PV cells).

In these cases, there is also a potential increase in efficiency when the country builds these interests on top of the IEA survey, rather than creating separate processes in parallel, bringing a reduction in the burden on respondents.

Brazil is an example of a country that has drafted clear objectives in the framework of a broader project that has led to a well-defined energy RD&D data collection process.

Brazil case study: Energy Big Push project

In 2018, Brazil launched an ambitious project to improve its process for collecting and compiling energy RD&D data. The main objectives in boosting this effort were to guide public policy and fill gaps to efficiently compile investment in energy RD&D statistics.

In May 2018, during preparations for the third Mission Innovation Ministerial, Brazil focused on enhancing data collection on public and publicly oriented investment in energy RD&D and identified a lack of data in this field. For this reason, the country acknowledged the objective to develop a robust, integrated, comprehensive and structured database with all the information required to produce statistics that could guide public policy.

In parallel, the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) launched its Big Push for Sustainability in 2016. This was an approach to support countries in building more sustainable development styles. To accomplish this transition towards sustainability, RD&D in clean energy is vital. For this reason, the Center for Strategic Studies and Management (CGEE) joined forces with ECLAC's Big Push for Sustainability in Brazil.

In this context, in 2019, ECLAC, the CGEE and the Brazilian Energy Research Office (EPE) created the Energy Big Push Brazil project. Synergies were then

identified, and the IEA also joined the project within the scope of its Clean Energy Transitions Programme.

The project was structured around four axes of activity, each with a specific objective:

- Axis 1 – Development of a process for collecting, structuring and managing data on public and private investments in energy RD&D.
- Axis 2 – Survey of technical, economic, social and environmental performance indicators associated with low-carbon energy solutions.
- Axis 3 – Identification of strategic guidelines and key policy instruments to accelerate investments in energy innovation.
- Axis 4 – Innovative and effective communication strategy of project results, targeted at decision makers.

The results of actions taken around axis 1 had the methodological support of the IEA from the beginning, as international comparability was one of the objectives of this project. The results of the first three axes were published in 2020 on the ECLAC website and were also disseminated at an event organised by the IEA with ECLAC, the EPE and the CGEE.

In 2020, when the first phase of the project ended, the Ministry of Mines and Energy instructed the EPE to build a platform on its website to make the results obtained so far available to a diverse audience and enable their annual update. Thus, with the technical and financial support of the United Kingdom's Prosperity Fund and the Brazilian Energy Programme, and under the co-ordination of the EPE, execution from the CGEE and technical support from Adam Smith International, the digital platform Inova-e was developed and launched in 2021.

By 2021, project data have already been used to assist in public energy policy decision making. Examples of this are two recent resolutions launched by the Brazilian National Council for Energy Policy that prioritises strategic areas for RD&D investments.

Sources: Brazilian Energy Research Office; Brazilian Centre for Strategic Studies and Management.

Institutional arrangements

The process of innovation in every country involves a significant number of actors: governments, researchers, private investors, entrepreneurs, corporations and civil society. They all play an important role in generating ideas for new technologies, performing research at all stages from basic research to demonstration projects, and financing projects. They all share the common goal of bringing new technologies to the market.

Capturing and understanding this complex network of institutions is a challenge in the design or redesign of a process to produce energy RD&D statistics. In many cases, the institutions involved in the process are devoted to doing creative work and they are focused on increasing the stock of knowledge. They usually work under tight deadlines on challenging projects with considerable financial pressure. For this reason, it is key to design the process carefully, limiting the transfer of information to the essential and minimising the administrative burden on respondents.

To overcome these challenges, governments may consider dedicating effort at the beginning of a project to ensuring the teams and individuals participating in the data collection are appropriately involved, resourced and informed to create connections and socialise the process specificities across the network. Identifying the right set of skills for the members in the working groups and establishing bidirectional communications between different institutions is essential at this point. This investment may have secondary positive impacts, and the energy RD&D data process can promote or create new collaboration streams between different institutions and departments. In some cases, a specific legal framework can boost the creation of the network. The Dutch Climate Act in the Netherlands is an example, but such a regulation is not always necessary to have a strong network of institutions.

2 – Set up the framework

One of the key elements of the design or redesign of the energy RD&D data collection and reporting process is the team that co-ordinates the annual cycles (the co-ordinating team). The co-ordinating team interacts with contacts in other institutions, making sure that the data they manage are correct and comply with international definitions. Bringing the right set of skills into this team contributes to the compilation of high-quality energy RD&D statistics.

In most countries, the unit in charge of the co-ordination of data collection and reporting usually belongs to the primary ministry for energy topics (the Ministry of Energy or similar). For instance, this is the Ministry of Economy, Trade and Industry in Japan and the Ministry of Petroleum and Energy in Norway. Nonetheless, depending on the capacity of the ministry to dedicate resources to this type of project, in some cases, a big part of the work is done by the national energy agency. This agency is often an institution that depends on the primary ministry for energy topics and has the duty of providing technical advice on energy issues.

Even if the collection and reporting are co-ordinated by the ministry responsible for energy topics, the process requires awareness of the related data collection activities and potential collaboration with other ministries, such as that responsible for science and innovation or the national statistics office, which often compiles general RD&D statistics across domains, for example in their submission of data on Government Budget Allocations for R&D to the OECD. These RD&D statistics generally consider energy as a high-level socio-economic objective, might have a different definition and boundaries for the data (e.g. excluding demonstration that does not qualify as R&D) and may not provide any disaggregation by technology. It is, therefore, generally difficult to align the energy RD&D data process with cross-sectoral R&D statistical work, although some countries have worked to define an integrated approach.

When this alignment happens, there might be benefits of appointing a team in the ministry responsible for science and innovation instead of the ministry responsible for energy to co-ordinate the compilation of the energy RD&D statistics. For instance, in Hungary, the co-ordinating team in charge of compiling the statistics and submitting the questionnaire to the IEA directly is the National Research, Development and Innovation Office.

The staff of this ministry might need training on energy technologies, but they will likely be well aware of the broader national RD&D landscape and familiar with RD&D statistics. In fact, in the case of Spain, even though the questionnaire is submitted to the IEA by the Ministry for the Ecological Transition and the Demographic Challenge, which acts as a central focal point for the IEA, the energy RD&D questionnaire is completed by the Ministry of Science and Innovation.

Every year, the co-ordinating team interacts with data contacts from other institutions, so it is important to raise this need from the beginning of the project and include the time dimension in the analysis. As the effort from each institution may vary considerably but predictably along the annual cycle, the institutions can plan and allocate the resources required and avoid issues from placing a burden on overloaded people.

The number of full-time equivalents (FTEs) needed in each of the institutions and the co-ordination team varies greatly from country to country. It is extremely dependent on the type of data collection, the availability of data, the maturity of the process and the number of institutions to co-ordinate. In general, governments may consider sizing the team for the annual cycle and allocate more resources for specific periods when there is a redesign of the energy RD&D data process, such as increasing the scope and coverage of the existing process or creating a new collection process from scratch. Additional resources might be needed to carry out data revision activities for past years as well.

Once the co-ordinating team is set up, the government may consider training on both energy technologies and statistical methods for the team members. Even if the good distribution of tasks according to the skills of the team members can guarantee the success of the data cycles, this is often a sector with a high staff turnover. For this reason, it is especially important to make sure that knowledge is shared across the team and that training materials are available to deal with this turnover without disrupting the cycle.

Additionally, there is a continuous risk of the restructuring of ministries due to changes in the political landscape. This restructuring can lead to the data collection process not being allocated to any ministry or it being moved to a completely different section or department. For this reason, to avoid a break in the data collection it is essential to involve higher management to show the value of the data collection and ensure its prioritisation and document the process properly so that it can be transferred to another team more easily. Austria is an example of a country that has externalised the co-ordinating team using a competitive mechanism.

Austria case study: Externalising the data collection

The responsibility to collect and report energy RD&D data in Austria lies with the Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology. However, instead of dedicating internal resources to the collection and reporting process, the ministry has externalised this activity. The contract specifies the outputs and quality required and provides the awardee with the resources to undertake the tasks needed to collect the data, with the requirement to minimise the burden on respondents.

Currently, the Austrian Energy Agency is carrying out work to collect, process and validate the energy RD&D statistics. The Austrian Energy Agency is an energy research and policy organisation through which a group of institutions co-operate, such as the federal and provincial administrations and important corporations from

a variety of economic sectors. The board of directors comprises the federal minister dealing with environmental affairs, the federal minister charged with energy affairs and the chairman of the provincial governors.

The Austrian Energy Agency has been doing this activity for the last 18 years. Each cycle, the Austrian Energy Agency dedicates around 0.3-0.4 FTEs to this process. The main effort is dedicated to validation, analysis and data dissemination and preparing a 100-page report for the ministry and presenting it at different forums.

The data collection is done differently for each institution and includes structured surveys, unstructured Excel files and extractions from private and public databases. This heterogeneity makes it difficult to develop a conventional legal framework to formalise the relationships between different institutions. However, the general interest in appearing in the national statistics, and the fact that the cycle has been repeated for many years, has resulted in a robust process with high coverage. Additionally, there is an important effort by the Austrian Energy Agency to perform a continuous screening of the institutional landscape to quickly identify new actors in the energy RD&D arena.

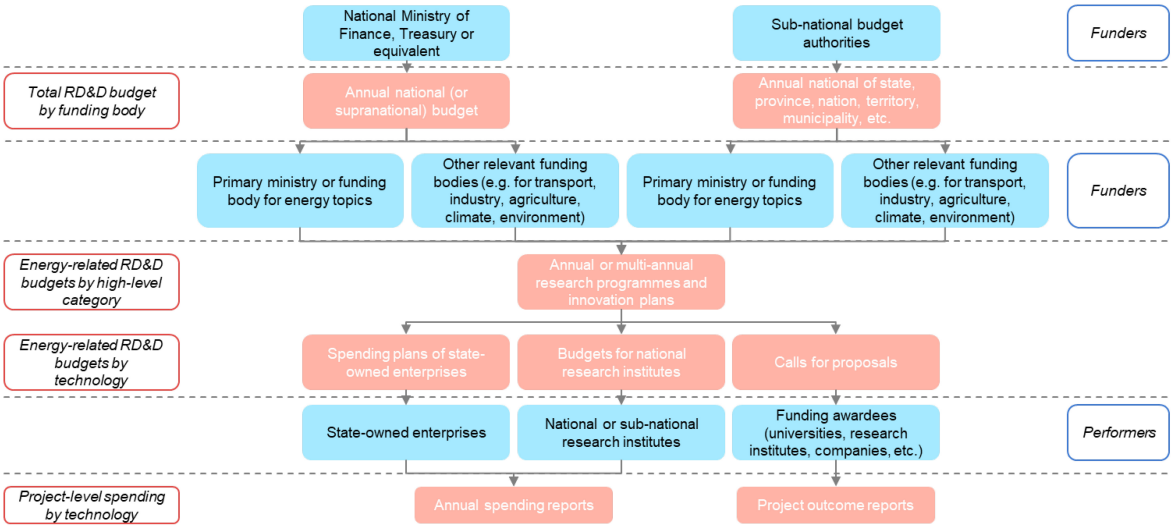
Source: Austrian Energy Agency.

3 – Map partners and data sources

Drawing the full landscape of the national energy RD&D institutions and datasets is necessary to make sure that the compiled energy RD&D statistics are complete. Additionally, the results of the analysis provide key information for designing the collection, classification and validation process.

Once the team for co-ordinating the energy RD&D data collection and reporting is created, their first task is usually to screen the entire energy RD&D ecosystem. The co-ordinating team may consider tracking the energy RD&D money flows to make sure that all the institutions are identified and considered. In most cases, it is easier to use a top-down approach because the number of institutions involved in energy RD&D funding is much smaller than the number of performers doing RD&D.

Typical institutional landscape of an energy RD&D funding ecosystem



In general, the functions along the flow of the public funds for energy RD&D are split among different institutions. An institution dealing with national finance prepares the annual budget for all public institutions. A part of this budget is allocated to support energy RD&D usually through two institutions: one that is responsible for energy topics and another one that is responsible for science and education, for example the Ministry for Energy Transition and the Ministry for Higher Education and Research in France. In addition, there can also be institutions that are more specialised than ministries that solely focus on research, such as the Research Council of Norway or the National Centres for Research and Development and Science in Poland, or solely focus on energy, such as the Lithuanian and Austrian energy agencies.

In addition, there are independent public bodies that fund the national energy RD&D directly from consumers and not through the annual national budget, and these are, therefore, not captured by the ministry of finance. The Office of Gas and Electricity Markets in the United Kingdom is an example.

In parallel, many countries have subnational authorities (state, provincial and territorial – municipal authorities also participate but they are out of the scope of the IEA definitions) funding energy RD&D. The specific weight of these institutions in the national energy RD&D varies between countries. For example, in Canada, the share of provincial and territorial expenditures was almost 30% of the total in the 2019-2020 period. Including all these institutions in the process can increase the complexity of the process. However, every effort should be made to increase the coverage and data quality of the statistics, especially when the budgets are significant. There is a compromise between resources and coverage to be addressed by countries.

The national and subnational authorities are the funders of energy RD&D. They launch programmes and innovation plans to channel the funds to the performers. In addition, it may happen that some public bodies that are focused on non-energy topics fund some energy RD&D, such as the Research Institute for Exploitation of the Sea in France or the Federal Ministry of Food and Agriculture in Germany. For this reason, it is also important to bring these institutions into the network.

In most cases, the number of performers is larger than the funders, so a greater effort to identify performing institutions is required. These institutions include science and technology research centres, state-owned enterprises, organisations of research and technology, universities and universities of applied sciences, among others.

4 – Create the network

As part of the process, every cycle, the co-ordinating team communicates with different data contacts from all the institutions involved. Appointing these contacts from each institution, creating regular communication streams and assigning sufficient resources to the departments of these data contacts to undertake the tasks involved in the process are critical for producing high-quality energy RD&D statistics.

After the effort produced by the co-ordinating team to identify all the institutions involved in the national energy RD&D landscape, the network of institutions is mobilised to perform the annual data collection cycle. The co-ordinating team might consider appointing stable contacts in all the institutions, both funders and performers. These contacts are usually responsible for the co-ordination within the institutions to ensure that the data are available on an agreed date. Additionally, they are generally the contact points to answer questions about the data and solve or clarify inconsistencies. Even if the data collection process was designed to minimise interactions between members of the network, identifying working-level contacts in all the institutions can bring substantial efficiencies when a problem or inconsistency is identified.

The formalisation of the network and the appointment of contacts are usually agreed upon in working groups or committees for senior officers and directors. The involvement and commitment of these senior officials are relevant for ensuring data continuity. The co-ordinating team might consider including the annual revision of the energy RD&D data collection and validation process in the agenda of these working groups and committees. Additionally, another tool to strengthen the links between the people participating in the network is to conclude the annual

cycle with meetings or emails with the working-level contacts to showcase results and address the challenges and problems that were identified during the previous cycle.

Creating a legal framework that defines the roles and responsibilities of each partner might be beneficial, especially for new processes, but it is not always necessary for the success of the process. This legal framework can activate the process in all the institutions effectively and provide them with a very powerful argument to ask for additional resources to participate in the compilation of the statistics. For more mature data collection processes, the commitment of the existing network might be enough to move the process forward. Additionally, when planning the annual activities of the ministries and departments, governments should consider including the reporting of energy RD&D data in the assignment letters for the relevant institutions so that the resources to do this task are accounted for in their budgets.

Canada is an example of a country with a high number of institutions, both federal and provincial, that requires intense work to create and maintain the network to successfully conduct the annual energy RD&D data cycle.

Canada case study: A collaborative framework to produce energy RD&D statistics in a federal country

Canada has a federal system of governance with one federal, ten provincial and three territorial governments. Natural Resources Canada (NRCan) is the federal government department responsible for reporting energy RD&D data to the IEA and representing Canada at the international level to meet the country's global commitments related to the sustainable development of natural resources. NRCan has the mandate to develop policies and programmes that enhance the contribution of the natural resources sector to the economy and to conduct innovative science in facilities across Canada to generate ideas and transfer technologies.

This federal-provincial governance structure has a big influence on the institutional arrangement of the Canadian system to produce energy RD&D statistics, as some of the energy-related jurisdictional responsibilities are divided between federal and provincial institutions and others are shared between them.

Share of responsibilities between federal and provincial institutions in Canada

Federal responsibilities	Shared	Provincial responsibilities
International energy Interprovincial energy	Environmental regulation of new energy projects (including indigenous consultation)	Regulation of natural resource development on provincial lands
Trade and investment	Scientific research and development	Land-use and project planning
Nuclear energy and uranium	Offshore petroleum in Atlantic Accord areas	Royalty design and collection
Energy resources on federal Crown land, offshore and north of 60º latitude	Infrastructure security and resiliency	Intra-provincial energy resource infrastructure, distribution and storage
Regulations and standards relating to energy efficiency	Energy efficiency	Electricity generation

One of the reasons for NRCan to co-ordinate this data collection effort across institutions is that it is a focal point for federal energy RD&D and also one of the main energy RD&D funders in Canada. Nonetheless, there are a considerable number of other federal departments and provincial and territorial governments who fund energy RD&D across the country. In total, there are approximately 30 federal departments and agencies (e.g. Environment and Climate Change Canada, Innovation, Science and Economic Development Canada and NRCan itself) plus 13 provincial and territorial governments funding energy RD&D projects. In this context, NRCan interacts with all these federal, provincial and territorial institutions to collect and compile the energy RD&D data and submit them to the IEA.

In the process of compiling statistics, they generate two different sets of data.

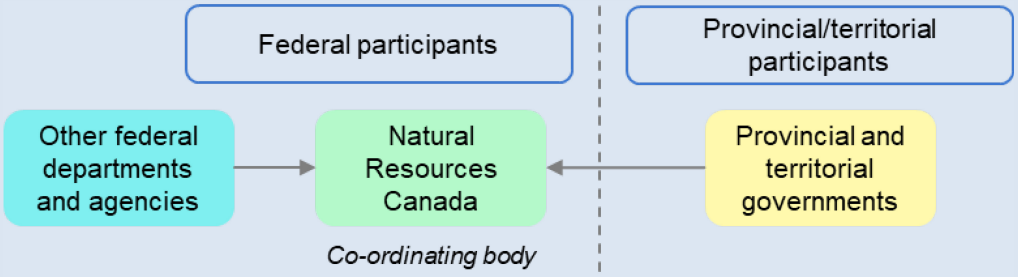
Federal data include energy RD&D projects funded by federal departments and agencies. NRCan co-ordinates the data collection and compilation efforts of around 30 departments and agencies. Generally, each federal participant collects and consolidates at the departmental or agency level. Consolidation efforts vary depending on how each department or agency is structured (e.g. one consolidated dataset versus three individual datasets for one department). Prior to consolidating all the federal data, NRCan takes several steps to review, validate and verify the individual data submissions.

Provincial data include energy RD&D projects funded by provincial and territorial governments. Each provincial government has a similar structure to the federal

government, with different ministries managing the funding programmes. There is one ministry with a similar co-ordinating role as NRCan at the federal level in every provincial and territorial government. These co-ordinators collect and consolidate the data from all the ministries in the province or territory. They are the contact points for NRCan to collect the entire provincial or territorial dataset.

In summary, maintaining federal, provincial and territorial official and working-level contacts is important to ensure accurate and consistent datasets are produced annually.

Energy RD&D data collection flows between institutions in Canada



Regardless of the complexity and diversity of the federal, provincial and territorial participants, there is no obligation for the different institutions to collect and share the information with NRCan. However, the commitment as a country to collaborate with the IEA and the good relationships between departments and institutions make the process very robust. To formalise this process, official letters from the director general of NRCan are sent annually to the individual federal departments and agencies and to all provinces and territories. Apart from this formalisation of the process, NRCan makes a substantial effort every year to engage with all the participating institutions. For example, NRCan prepares guidance documents and conducts information sessions for the survey participants to help ensure accurate and consistent data are collected. In addition, NRCan also shares the data results in the form of a presentation with all the participants.

In all cases and regardless of the institution, the tasks for the energy RD&D data collection are done using internal resources, covered by the budgets of each institution. There is no role 100% dedicated to these tasks, and, considering the number of institutions involved, it is difficult to estimate the FTE per year needed to carry out the data collection, processing and dissemination.

Source: Natural Resources Canada.

Collection, classification and validation

Once the network is created, it is time to design the methodologies to collect, classify and validate the energy RD&D statistics. Each country may use a different methodology, depending on the reality of their national energy RD&D landscape. To design and implement the right procedures, it is important to assess the data availability and analyse the size and roles of the network. The design of the process presents two main trade-offs:

- between data quality and the resources to compile the statistics
- between the completeness of the data and the time lag between the end of the year and the publication of the data.

5 – Assess data availability

Reporting data to other institutions is often a challenging task. Using already available data to compile energy RD&D statistics can reduce the burden on data providers. This way, the resources in the network can perform more complex data checks and increase the quality of the dataset.

Before designing and implementing new reporting processes with other institutions, the co-ordinating team may consider undertaking a thorough assessment of the energy RD&D data already available. This includes both online databases, accessible to the general public, and private databases internal to the institutions, which can easily extract the data.

In some cases, there are publicly available accounting data for the public funds supporting energy RD&D. Leveraging all the available information minimises the burden on data providers, easing implementation and strengthening the engagement of the network. In addition, it can reduce the dependency on data providers, reducing the time needed to undertake the process and problems derived from staff rotation.

In some cases, the information available is already sufficient to meet all the objectives defined in the first phase. In these cases, the co-ordinating team can perform the data extraction and classification independently and limit interactions with other institutions in the network to resolve doubts and issues. However, for

most countries, this is not the case. At this point, governments may consider extending the scope of the existing collection processes to meet the objectives, for instance, adding specific energy-related tags to the project reporting. This may be a good way to reduce the burden on reporting institutions.

Another important factor to consider is the time lag. Different institutions have their data available at different times of the year. For some institutions, this might be almost real time when there is already a reporting system in place and the performers register and classify the projects in a system as soon as they receive the funds. For example, the Netherlands Enterprise Agency receives and processes data continuously throughout the year as companies apply for subsidies. For other institutions, the co-ordinating team may wait 3-6 months until the accounting of the reporting institution is consolidated.

Portugal is an example of a country that has modified an existing survey to collect energy RD&D data. This is notable as the data collection is not limited to public institutions but also covers the private sector.

Portugal case study: Leveraging an existing survey to collect public and private energy RD&D data

Portugal has collected RD&D data from both public and private organisations through the Survey of the National Scientific and Technological Potential (IPCTN) since the 1960s. The survey was biannual until 2008, after which it became annual.

Every March, the Institutions Directory, which includes the institutions that receive a request to answer the IPCTN on an annual basis, is updated. Portugal uses information from the previous inquiries and consults various institutional sources, such as:

- Websites of universities, colleges, polytechnic institutes, higher schools and research centres.
- The Tax Incentive System for Business R&D.
- The Foundation for Science and Technology, a funder of RD&D projects.
- A list of companies with RD&D and innovation projects financed under Portugal 2020, which includes general and regional operational programmes.
- Companies participating in projects within the European Union (Framework Programmes for R&D and H2020).

- Companies with investment in RD&D or in declared development in the various items of Simplified Business Information.
- Companies with primary or secondary economic activities classified in division 72 of the Portuguese Classification of Economic Industries (CAE)-Rev. 3 (scientific research and development activities).
- Companies located in technology parks or RD&D incubator technology centres and other institutions that interface with companies, among others.

After this, the platform for the survey (IPCTN) is opened, and companies and public institutions are required to provide their RD&D data. This platform includes a digital version of the questionnaires. There are two different questionnaires, one for private companies and one for public institutions. The survey is completed by both funding agencies and performers.

In 2019, globally, 12 049 potential RD&D executing entities were surveyed, of which 10 518 answered, representing a response rate of 87%. Among the respondents, 4 707 were entities that carried out RD&D.

Summary of 2019 respondents by type of organisation

Organisation	Surveyed	Answered	Response rate	Active in RD&D
Company	10 540	9 112	86.0%	3 761
State entity	816	721	88.0%	310
Higher education unit	623	620	99.5%	599
Private non-profit institutions	701	65	93.0%	37

The energy RD&D data are sorted based on the responses to question 5 (energy) of the survey. In this question, the nomenclature of socio-economic objectives is based on the Nomenclature for the Analysis and Comparison of Scientific Programmes and Budgets (NABS 2007). Starting from the 2019 survey, the IPCTN questionnaire form disaggregated the energy objective in order to comply with the one-digit level of the IEA questionnaire.

The platform is open until December. Then, the collected data are processed through the platform. Once the Portuguese Directorate General for Energy and Geology receives the request from the IEA to answer the questionnaire, the consolidated energy RD&D data for the government and the private sector are collected from the Directorate for Education and Science Statistics.

Source: Portuguese Directorate General for Energy and Geology.

6 – Design the collection and classification

Selecting the right methodology to collect and classify energy RD&D data according to international standards is at the core of compiling complete and high-quality statistics. There are three potential methods, depending on the resources in place and the availability of the data sources identified in the previous step: data extraction from a public database, an unstructured survey and a structured survey.

In some cases, the data are not readily available, or it is not straightforward to extend the processes in place to capture the desired scope. When this is the case, it may be necessary to design and implement the entire data collection process from scratch. It might be interesting to repeat the assessment described above but consider all the RD&D data collection processes. This might be beneficial for the performers, as integrating the new reporting requests with other RD&D data collection cycles can bring synergies to the process overall. In addition, the network of institutions might be reluctant to effectively engage if they feel that they are being asked for similar information by different institutions at different times. It might, however, make it difficult to adapt and improve the process as it would be dependent on a data request that would not have the same considerations.

In any case, the initial raw data available are common for all the countries and usually consist of a list of energy RD&D projects. Generally, the attributes available in this list are the title, an abstract, the name of the researchers and the funds allocated. These funds might be annualised in the case of multi-year projects.

Classifying the projects according to the IEA classification or any other technology-based classification can be challenging. Some projects might include multiple technologies, and it is not always possible to split the funding attributed to the project according to the actual funds going to each part of the project, especially for basic energy research and general-purpose technologies. The person classifying the project should try attributing the funds to the most detailed degree of classification to the best of their ability. In general terms, researchers have a better knowledge of the project subject, but the co-ordinating team is more familiar with the classification and the IEA manual and has a greater interest in ensuring the project is correctly classified.

Depending on who gets the responsibility of classifying the projects and aggregating the data, there are three main options to undertake the energy RD&D data collection: data extraction from a public database, an unstructured survey and a structured survey. The selection of one of these methodologies will depend

on the availability of data and the institution in charge of classifying the individual projects. The decision of who classify the projects is often a challenge when designing the process. To decide who is in charge of classifying each specific project, governments may consider assessing and defining the skills required to be part of the network and collaborate to compile the energy RD&D statistics. In fact, there can be a compromise on this set of ideal skills between mastering the IEA classification and statistical processes and having a thorough knowledge of the specific research projects. For this reason, methodologies to classify projects vary from a central unit in a ministry classifying the raw data project by project or using scripts, to researchers classifying their own projects. In fact, it may happen that along the process, different strategies are used in a single country. In Ireland, for example, the classification to the two-digit level is done by national research funders, and the co-ordinating team classifies the project to a more detailed degree to lower the burden on the national research funders. In Poland, the classification is done at an intermediary stage by the surveyed institutions.

In all cases, it is critical to associate the data collected with metadata to provide information about the data's structure, nature and context.

Data extraction from a public database

When there is a dataset available publicly, it might be efficient for the co-ordinating team to independently extract the raw data at the project level and classify the projects one by one. Depending on the size of the institution and the number of projects, this process can be automated by using a script that looks for keywords in the title and the abstract. This is done in Brazil, for example. Other countries, such as the Czech Republic (described in the next case study) and Hungary, use keywords to filter energy projects from the list of general RD&D projects. If the size of the sample is fewer than 100 projects, the benefit of the automatic classification might not justify the investment in the design and maintenance of the algorithms.

This option provides great independence for the co-ordinating team and minimises the burden on the contacts from the reporting institutions. The contacts will address doubts and provide additional information to understand any inconsistencies and breaks in the time series. In most cycles, they will not need to provide any information to the co-ordinating team.

Czech Republic case study: Using a public database to compile statistics back to 1996

The data collection in the Czech Republic is done by the Department of Strategy and International Cooperation in Energy in the Ministry of Industry and Trade of the Government of the Czech Republic. In the national RD&D landscape, there are four main actors: the Ministry of Education, Youth and Sports; the Ministry of Industry and Trade; the Czech Science Foundation and the Technology Agency of the Czech Republic. However, projects are supported mainly by funds managed by the Technology Agency of the Czech Republic through specific programmes. This agency maintains the public database STARFOS, with information on all the RD&D projects receiving public funds. Any performer receiving public funds is required to input information into this public database.

In 2018, the Czech Republic revised the energy RD&D data back to 1996. During this process, they mapped the energy RD&D landscape, developed a methodology and created a powerful network with the Technology Agency and the Research, Development and Innovation Council. The Czech Republic carries out an annual process to collect energy RD&D data and report it to the IEA. This annual cycle is aligned with the IEA's data collection cycle. As soon as the data are available, the Ministry of Industry and Trade starts the following process.

First, they download a list of projects from the STARFOS database, around 300 projects per year, using keywords to filter energy projects.

In this process, the Technology Agency of the Czech Republic, which has direct access to background data in the STARFOS database, collaborates with the ministry to provide the split between the eligible cost and the amount of public support. In addition to these two figures, the available information in the database used in the process is basic information about the institution performing the research, project solution time, programme under which the project is funded, public tender number, R&D categories field, etc. The Technology Agency is the main funding body and the owner of the most relevant funding programmes. However, some other sources of funding are not included in the data, which cover approximately 80% of the national public funding.

As a next step, the projects are classified according to the IEA categories. Initially, the projects are divided into two big categories according to the national classification: nuclear energy and non-nuclear energy. The co-ordinating team at the ministry classifies each project by reading their titles and abstracts. In this process, the ministry also receives the assistance of the Technology Agency to help classify certain projects.

The Czech Republic reports the public support figures to the IEA as the government RD&D budget, and the difference between the eligible cost and the public support as part of the private sector RD&D budget. Once the data are

compiled, they are validated by comparing the data of the year of study with those of the previous year in terms of order of magnitude. Additionally, the ministry performs predictions based on live projects that are also used to verify the completeness and accuracy of the data. Once the data are validated, the IEA questionnaire is completed and submitted.

The Ministry of Industry and Trade is currently assessing the possibility of asking the researchers to classify their projects according to the IEA classification and include this field in the public database. This would modify considerably the process of asking for public funds for research as it would require changing the structure of the STARFOS database. Transformation projects are proposed, assessed and performed in five-year national plans. The next programme in the Czech Republic is Data 2 between 2023 and 2028.

Source: Czech Ministry of Industry and Trade.

Unstructured survey

When the dataset exists but is not publicly available, and the classification of projects is intended to be centralised by the co-ordinating team, governments may consider collecting data using an unstructured survey. This strategy imposes a minimum burden on the data contacts as it concentrates the classification effort within the co-ordinating team. This way, the data contacts need not be familiar with the IEA classification, and they will limit their work to extracting the information from their systems and sharing it by email with the co-ordinating team. This is the case in the Netherlands, where the co-ordinating team classifies the projects one by one when assessing the application for public funding.

This approach is also interesting for large public databases with information on general RD&D projects (not exclusively for energy RD&D) where it might be difficult for the co-ordinating team to extract only the energy RD&D projects. For instance, in Estonia, the energy department in the Ministry of Economic Affairs and Communications requests from the Research Information Centre an extraction of the data from their database, filtering all energy-related projects. Afterwards, the co-ordinating team classifies the projects according to the IEA classification. However, there might not be a specific tag for energy in the existing database, which might require filtering energy and non-energy projects manually. In this case, it might be more efficient for the co-ordinating team to do the filtering themselves as they have a better knowledge of the criteria used.

In most cases, the unstructured survey will be an Excel file with one project in each row and with the following information: title, abstract, performing institution (sometimes the name of the project manager) and funds for the year of study, as well as any additional required information defined during step 1.

Structured survey

When the co-ordinating team is limited to co-ordination and reporting to the IEA or when the statistical and energy knowledge is concentrated in the reporting institutions, government may consider preparing a structured survey to collect the data. In most cases, the easiest way to collect the energy RD&D data is to directly use the IEA questionnaire. This way, the identification and classification of energy projects are done by the data contacts in the network of institutions. In Norway, for example, the Research and Technology Unit of the Climate, Industry and Technology Department in the Ministry of Petroleum and Energy sends the IEA questionnaire to seven funding institutions and state-owned enterprises, who fill in the energy RD&D data. Then, the co-ordinating team combines all the information in the form they submit to the IEA.

The main risk of this strategy is ensuring that all the reporting institutions have the right knowledge and skills to compute the statistics and fill in the IEA questionnaire, and that a homogeneous criterion is applied in this classification. The strategy reduces the effort required to collect the data, especially when there are few organisations to survey, and it almost eliminates the classification work for the co-ordinating team. However, it increases the requirements for robust data validation.

Tracking energy RD&D in the private sector

The business sector is a major contributor to energy innovation. For 2021, the IEA tracked almost USD 120 billion in corporate energy R&D spending, three times more than for governments. There are good reasons for estimating private sector contributions to energy R&D, including having a more comprehensive picture of R&D spending and differentiating between its roles. Public and private spending is generally not directly substitutable, with the private sector focusing more on incremental improvements and product development.

However, in most countries, information on private energy innovation is much less readily available and less reliable than that for the public sector. In addition, there is currently no guide to how to measure energy RD&D in the business sector that is equivalent to the IEA Guide to Reporting Energy RD&D Budget/Expenditure Statistics. To help governments understand the various options the IEA report Tracking Clean Energy Innovation in the Business Sector: An Overview, summarises the existing approaches used by governments and other analysts in this area. It provides examples from around the world of data sources – including financial filings, venture capital deals, patents, scientific publications, marketed

products and firm-level perceptions – and presents the advantages, disadvantages and trade-offs of each.

Among the options, surveys can be one of the most reliable and comprehensive means of gathering data on private R&D spending, and they can also include questions on other valuable energy innovation indicators. Encouragingly, a common international vocabulary and set of practices exist for measuring R&D consistently and comparably in the business sector through the OECD Frascati Manual, also used by UNESCO as its standard for measuring R&D. Most countries already have in place surveys about R&D activities in the business sector, usually following the Frascati Manual guidelines. The time needed to develop energy surveys can be reduced by "piggybacking" on the statistical architecture and legal framework of established business sector R&D surveys. For example, Austria, Canada and Italy have created dedicated sections on energy, integrated into mandatory broader R&D surveys. They ask for disaggregated data on different technologies, sometimes according to international energy technology classifications, such as those of the IEA. Other indicators, such as financial statements, can complement surveys by providing near-real-time data on R&D expenditure.

7 – Develop the validation process

Validating the collected data is essential for any statistical process. There are different methodologies to validate the data, from basic consistency checks to advanced algorithms that validate the classification of projects. The methodologies used will depend mainly on the decisions taken in the previous step and the secondary sources of data available.

Once the data are received it is important to ensure that they are complete and accurate. The process to validate the data will greatly depend on the strategy defined for the collection and classification. In any case, it is important to verify the split of energy RD&D funds by technology area. Additionally, the checks also depend on the secondary sources of data available. Hungary, for example, uses two secondary databases to complete and validate the data, the Hungarian Central Statistical Office and Eurostat databases.

When the raw data at the project level are available, a possible methodology to check the classification of projects is to run scripts that classify them according to keywords. This methodology will not give perfect results, but it may highlight some projects that need verification, especially when the funds for that project are high.

In some cases, it might be necessary to contact the performer to ensure that the project is correctly classified.

However, in some cases, the project-level data might not be available. In such cases, the only way to verify the classification is to look for breaks in the time series compared with previous years, as is done in France, for example. In some cases, these breaks may be a reflection of the true underlying data due to a new programme to accelerate the development of a specific technology or a cut in energy RD&D funds due to an economic crisis. In any case, the co-ordinating team may consider verifying these jumps with the reporting institutions.

To check the completeness of the data, it is important to go back to step 3 and make sure that the data were collected from all the institutions identified when mapping the energy RD&D landscape. Additionally, assessing the trend in the total national RD&D budget may show that some data are missing or that there might be some double-counting errors. For this total budget, there might be secondary sources to compare the data with.

Another good practice to identify data errors is to collect data from both funders and performers. If the two datasets are available, the sum of all the budgets of the funders should be similar to the sum of the money received by the performers. Of course, there will always be a statistical difference, but this may highlight big gaps in the coverage and double counting. This can be especially relevant for European countries trying to distinguish between EU funds (that should not be included in the national aggregates) and national funds.

In all these cases, it is important to engage with contacts in the reporting institutions or those institutions that maintain the public databases where the data are collected from. These institutions may need to bear in mind that some resources will be needed to collaborate in the validation process. The next case study summarises the entire Swiss process to collect, classify and validate energy RD&D data. Switzerland is an example of a country that has automated many tasks along the process and utilises both data from public sources and a structured survey.

Switzerland case study: Automating data collection, classification and validation

The Swiss process to collect, classify, validate and publish the data is divided into five steps done in an annual cycle:

- step 1: analysis of landscape

- step 2: federal and EU data management
- step 3: regional and institutional data management
- step 4: co-ordination and overhead costs
- step 5: publication.

The first step consists of a continuous process of overview and identification of key actors in the energy RD&D landscape. The output of this process is to connect with a contact person in each of the institutions and to make sure that all the relevant programmes are considered in the process. These contacts are key to the robustness of the process as they will assist in the classification of projects and provide additional data.

The second step is the biggest one, and it is carried out between March and May, when project information is available from public databases with federal or EU funding. The data availability is manually checked, and once this is done, the Swiss Federal Office of Energy downloads the data from the three public project databases: Swiss National Science Foundation, Aramis and CORDIS. There are around 3 000 new projects to be filtered every year, 10% being energy relevant. This is done automatically, using R code. These databases include either the real payments or the approved total contributions from the public funding bodies to the research organisations.

Once the data are downloaded, they are filtered based on specific criteria, such as keywords in the title and project description, the programme and the funding area. This results in the compilation of a list of energy projects. This is also done using R code. After the filtering process, there is a manual verification to reduce false positives and false negatives. Then, each of the projects is classified down to the most detailed level of the IEA and the Swiss classifications. This is the most time-consuming part of the process. Two people undertake a semi-automatic process to classify the type of research project and then a manual classification of the topic. Finally, the availability of annual payment data is assessed, and the budgetary stage is selected based on the following priority criteria, with currency conversion when needed:

1. effective annual payment
2. annual payments according to the budget
3. estimated annual amounts from the total budget.

Once all the data are selected and arranged, they are transformed into an Excel format to perform a final manual consistency check.

The third step is collection through surveys of non-federal and non-EU funding. This is done by collecting the information directly from the contacts, between June

and August, using surveys. Using R scripts, three files are created with a list of projects per research organisation:

1. Projects according to step 2 (with federal or EU funding for the year of interest).
2. Projects according to step 3 of the previous year that are still ongoing (with own or cantonal funds in the previous year). They are asked to complete the information on spending for the year of study.
3. A list with empty rows to indicate new projects or projects missed last year.

These questionnaires are sent by email to all the contact persons with a deadline to send them back after a few weeks. As soon as these files are received back, they are checked manually, looking at duplicates, the scope and classification according to Swiss and IEA guidelines and the project type, etc. Including federal funding, there are around 600 new projects every year to be classified. Finally, the consolidated list of projects is loaded into the system and transformed into an Excel comma-separated value format. A total of more than 2 000 projects and activities are included in the annual statistics.

The fourth step is the collection of the co-ordination and overhead costs. This can be done in parallel with step 3 as soon as the federal institutions, universities and universities of applied science report these costs to the Federal Statistical Office. For other funding agencies, such as the Swiss National Science Foundation, these data are extracted from their public annual reports. Then, co-ordination and overhead costs are proportionally allocated to the projects funded by each agency. In 2019, CHF 427 million was accounted for in the statistics, of which 53% corresponded to projects in the databases in step 2, 21% to questionnaires in step 3 and 26% to estimates of overhead costs in step 4.

The fifth step is publication and data dissemination. In November, the first draft version of the data is prepared. Publication is further explained in the data dissemination section. To prepare the submission for the IEA, the EU contributions are excluded.

Source: Swiss Federal Office of Energy.

Data management and technology

Apart from the organisational side of the energy RD&D data collection activity, there is an important technical side. Energy RD&D statistics are supported by technological pieces, such as databases, integrated national systems and data platforms. Even though most countries rely on Excel spreadsheets for the process described in this document, and the information is exchanged by email, there are already good examples of more complex data management tools in the international energy RD&D data, such as the STARFOS database in the Czech Republic, the Research Information Center in Estonia or the iPCTn platform in Portugal. In addition, it is possible that individual institutions that respond to the surveys for the co-ordinating teams rely on internal databases to compile their energy RD&D data.

8 – Select and create the information technology tools

All processes are sustained by technological pieces of hardware and software. Selecting the right systems is a challenge because energy RD&D data are usually too small a field to justify the complexity and economics of large-scale information technology (IT) projects. For this reason, it can be helpful to cluster the energy RD&D process with other similar processes when selecting the right IT tools, such as platforms for digital questionnaires, databases to store project-level data and advanced analytics to automate tasks.

In the last decades, data management capabilities have evolved at an unprecedented speed. Technological changes happen every few years, bringing new pieces of hardware, software and technological services constantly into the market and enabling new data management strategies. In addition to this environment of continuous transformation, the projects to build and update these systems are usually long, complex and resource-intensive and difficult to integrate into the IT systems of governments. They usually require specific professional skills to be successful. These characteristics might make it difficult for public institutions to actively launch large-scale IT transformation projects. Nonetheless, governments will require more and more data, and the number of data collection, validation and dissemination processes supported by modern tools will increase exponentially, bringing automation and creating more efficient processes.

It is important to acknowledge that it might be difficult for the energy RD&D data process described in this document to justify an IT transformation project. For this reason, governments may need to consider their entire data management requirements when defining their data strategies and launching and deploying new software and hardware. The main role of the co-ordinating team in this regard is to actively disseminate the work done with the energy RD&D data. This way, other ministries will be aware of the energy RD&D process, and it will be considered when defining data management strategies.

Additionally, the entire network can be proactive and continuously evaluate possibilities to adapt existing platforms to incorporate the energy RD&D data collection, validation and dissemination processes. An additional common requirement of all these technologies is cybersecurity. Small teams may develop departmental tools connected with data sources that do not comply with cybersecurity standards. These tools may seem to be effective and fast to implement, but they may leave the door open to cyberattacks.

The main technologies that can be used for the energy RD&D data process are digital questionnaires, project databases and scripts for project classification.

Digital questionnaires

Digital questionnaires are digital forms of the surveys used to collect data from respondents that can be completed and submitted online. These need to be integrated into platforms that can manage users to ensure that the questionnaires are completed only by valid respondents and connected to databases that store the answers. These platforms can be particularly useful when the number of questionnaires processed annually is high. If the process includes the private sector, and therefore thousands of actors are surveyed, digital questionnaires might become essential. This is the case for Portugal, which uses a data platform to collect and process more than 12 000 questionnaires every year.

Another driver in deploying a digital questionnaire is the capability to automatically process and validate the answers. These platforms can incorporate all the checks required to ensure that the data are correct and highlight all the inconsistencies instantly to the data submitter for them to correct. This way, the process becomes faster, and the exchange of communications needed to validate the data is reduced.

Project databases

Some countries have project databases to store information on all national RD&D. In some cases, these databases are limited to projects receiving public funds, but some countries like Estonia are trying to create research and innovation data hubs, including information on private research, active researchers and institutions

in the database. These databases usually have information including the project title, abstract, performing institution, researcher and topic according to national and international classification criteria. In fact, the main benefit of these platforms for the compilation of energy RD&D statistics is that the burden to classify a specific project is put on the researcher, who has the complete information and technical knowledge to classify the project correctly.

Scripts for project classification

When project databases exist, it is unlikely that the projects are classified according to the IEA classification. In these cases, the first step is to map the national classification to the IEA classification at the most disaggregated level possible. However, there might not be unique relations between classifications, and it might be difficult to do a complete mapping to the level of detail requested in the IEA questionnaire. In these cases, governments could consider developing scripts that go through the list of projects and classify them according to pre-defined keywords or researchers. These scripts are used by many countries, such as Brazil and Switzerland. In the coming years, it might be possible to use text analytics to improve the effectiveness of the scripts to classify projects, but a big list of projects would be needed to train the algorithm.

Estonia is an example of a country that has created a public database to manage all data on national RD&D. The institution managing the database collects the energy RD&D data using an unstructured survey, which are then sent to the co-ordinating team at the Estonian Ministry of Economic Affairs.

Estonia case study: The Research Information System

The Energy Department of the Estonian Ministry of Economic Affairs and Communications is the institution in charge of compiling the energy RD&D statistics and submitting them to the IEA. This ministry is in charge of designing and implementing national development plans. It does not carry out any data collection activities for energy RD&D because the data are already publicly available and can be consolidated from the existing database.

The Research Information System was established by the Estonian Ministry of Education and Research and is maintained and operated by the Estonian Research Council. Researchers are required to fill in the data when receiving public funds for their research. The system gathers information on research and development institutions, researchers, research projects and various results. It is

also an information channel for submitting and processing grant applications and for submitting and validating project reports.

In addition, the Research Information System is trying to broaden its scope and is intended to become a meeting point and central source of information for the RD&D landscape in Estonia. It is, thus, working to include more information about privately funded RD&D projects. Additionally, there are some small projects with public funds given to consultancies when no research centres are available that are currently not included in the database but could be in the future.

Source: Estonian Ministry of Economic Affairs and Communications.

Data dissemination

Once the data are processed, it is important to disseminate them effectively. As described in the purpose section, it is good practice to have a vision of what the final output of the process will be from the very beginning of the project, as this vision will guide the design of the entire collection and validation process. Data dissemination is probably the most important step of the roadmap, as the relevance of the compiled dataset will depend entirely on the documents and tables that are published, either for internal users or the public in general. To ensure that the objectives defined at the beginning of the process are met, it may be appropriate for all the publications to focus on identified data users. As a general rule, data should be easily accessible, including all the relevant documentation and metadata to understand it, and data users should be able to extract information from the data easily in order to inform policy decisions.

Additionally, disseminating the data is key to providing visibility of all the efforts made by the network. Sharing the data results with the responding institutions, as is being done in Canada by NRCan, will strengthen the engagement of the entire network and can create a forum to introduce new data cycles, explain changes from previous years and answer questions.

9 – Share the data

Sharing the compiled energy RD&D statistics is the final goal of the process. Selecting the right communication strategy and format for the data is a critical step. At this stage, it is important to go back to the objectives identified in the first step and to make sure that all of them have been fulfilled.

Data users can be divided into internal users (inside the ministries and governing bodies) and external users (the general public, academia and the private sector, etc.). The needs and motivations of these two types of users are very different, and the dissemination channels and strategies should, therefore, be defined with these different needs in mind.

Internal users use the energy RD&D data to assess policies, inform decisions and design energy RD&D funding programmes. They are usually one of the main sponsors of a project to set up the collection and validation systems described in this document, and they have clear requirements regarding data dissemination.

These data users are generally interested in higher-level aggregated data but can also use project-level data in policy evaluation. In many cases, because they are part of governmental institutions, they use similar IT systems to the ones used by the co-ordinating team, enabling the development of ad hoc dashboards integrated with internal databases. These dashboards can allow internal data users to filter the data, create graphs with time series and dive into the data. Nonetheless, these developments might be too complex, and in some cases, sharing the annual IEA questionnaire internally might be enough to provide all the information needed.

External users include academic researchers, journalists, some of the organisations that collaborated in the data collection process and private companies. The information required by these users might be at any level of detail, so it is more difficult to ensure that all their needs are considered and met. Many countries usually give access to their micro-data on the basis of project proposals for scientific purposes, but another good option is to apply an open access data strategy. Open access data means that governmental data will be available to anyone with the possibility of redistribution in any form without any copyright restriction. Governments increasingly have incentives to make as much data available as possible while minimising the processing necessary to manage confidentiality concerns. Switzerland is an example of this open data strategy. To accomplish this dissemination strategy, governments might consider using the statistical resources already available in most countries to enable anyone to filter and download any data required. These resources are generally managed by the national statistics office. Certain countries, such as Ireland and Brazil, have chosen to disseminate their data through databases, at the project level for Ireland and at the topic level for Brazil.

Additionally, a common need among all the users is to have available a detailed data dictionary and set of documents explaining the methodology, including all metadata available. The data dictionary is a document centralising all the information about the data, such as their definitions, relationships to other data, origin and format. The methodology document explains all the processes for collecting, classifying, validating and disseminating the data. In fact, it could have a very similar structure to this handbook but with country-specific information. Finally, the metadata is a document that provides information about the coverage, budgetary stages or information about jumps in the time series or similar anomalies that could be interpreted as errors by others. This information can also be included in the data dictionary. These documents will allow users to accurately extract information from the data.

10 – Communicate the findings

If the co-ordinating team is a group of experts on energy RD&D data, they can not only share the compiled statistics but also add an analysis of the trends in energy RD&D. Governments may consider writing a report and arranging a presentation or webinar to explain the key outcomes of the annual cycle.

In addition to the data, the co-ordinating team can also perform data analysis and publish the findings. These analyses can be shown in annual reports published online. This is the case in countries such as Austria, the Czech Republic, France and Germany who, at the end of the cycle, write reports showing the key trends deduced from the data and explaining the most relevant facts on energy RD&D. The structure of these reports is often similar regardless of the country. They show the key figures for the year of study, highlighting the main increases and decreases in energy RD&D budgets for specific technologies. The data are usually classified at the two-digit level, and in some countries, they also include the time series and the regional distribution of research funds. Dashboards such as the one developed by the United Kingdom are also a good way to disseminate the data.

There are some good practices to increase the value of these documents. For instance, it can be interesting to collaborate with internal users to include some of the conclusions of their policy analyses. This provides an additional layer of analysis to the data, showing the purpose behind the effort to collect the data. If this information is available, it can be positive to present it to the network that participated in the collection and classification processes, as it will prove that the effort carried out by the network has a great impact.

Another interesting way to complete the dissemination is by adding international comparisons. This is a potential way to publicise the work done by all the countries collaborating with the IEA in the compilation of comparable global energy RD&D statistics. In addition, it provides an international benchmark to assess which countries are making greater efforts in energy RD&D or how relevant global investments are in bringing specific technologies to the market.

Continuous improvement

At the end of every cycle, the entire process might be reviewed. To effectively review the process, the co-ordinating team might use the five phases described in this roadmap to ensure the completeness of the revision: purpose and objectives; institutional arrangement; collection, classification and validation; data management and technology; and data dissemination.

11 – Establish a learning and adaptation culture

The first item that the co-ordinating team could review is the purpose and objectives. In some cases, new policy priorities might have appeared along the cycle. When this is the case, it is important to ensure that the current process integrates these new policy priorities and that the compiled statistics have enough information to track the progress. Additionally, the participation of the country in international forums might inspire new motivations that would need to be incorporated into the process. For this reason, it is important to research continuously the broader energy and innovation landscape, nationally and internationally.

Regarding the institutional arrangement, the co-ordinating team might regularly screen the energy RD&D landscape to identify and add new contacts to the network. In many cases, some institutions in the network will face staff rotations or transformations in their internal processes and duties. It is important that the co-ordinating team assists them in this process, providing training when needed to ensure data continuity.

For data collection, classification and validation, it is important to identify and solve bottlenecks. The co-ordinating team should be critical of the methodology and continuously assess its efficiency and implement changes to automatise parts of the process. The end of the cycle is also a good moment to ensure that the network is effectively engaged and to identify and improve institutional relationships.

The developments in data management and technology include two potential different issues to screen. On the one hand, the co-ordinating team might assess whether there are any new technological developments in the market that could improve the current process. On the other hand, as mentioned in the section on data management and technology, it is key to be aware of the internal IT projects launched by the institutions of the co-ordinating team or the network. This way,

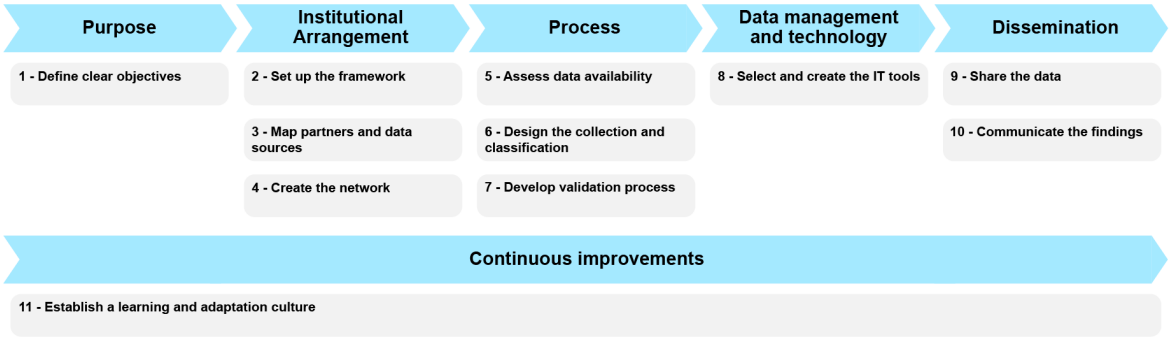
the co-ordinating team and the data contacts can assess the possibility of incorporating some of the needs of the energy RD&D data collection into these projects.

Finally, regarding data dissemination, the co-ordination team assess whether the outputs, such as publications and presentations, are sufficiently circulated and reach the right users. It is also important to take into account user feedback to improve analysis and reports, including in terms of relevancy to the current energy technology priorities.

Conclusion

As described in this document, the different methodologies followed by countries to compile energy RD&D statistics are grouped into six phases and 11 steps. These six phases are: purpose and objectives; institutional arrangement; collection, classification and validation; data management and technology; data dissemination; and continuous improvement. These phases can be followed in sequence for countries near the beginning of their journeys towards energy RD&D data collection but also independently for countries that are redesigning specific areas of the process. While the phases described in this report follow an order, they can be considered in parallel depending on the context of each country.

Simplified roadmap to collecting energy RD&D data



As mentioned earlier, the IEA describes here possible options for countries to follow during the design of their energy RD&D data collection systems. Each country's situation is different, and governments should see this report as a toolbox to adapt to their individual situations. This roadmap is an initial step that aims to be the basis for further exchanges between countries, and the IEA is happy to provide further support to any country that wants to improve or set up its data collection system.

Annex

Austria

Institutional arrangement	
Reporting institution	Austrian Energy Agency, contracted by the Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology
Role of reporting institution	Developing, supporting and implementing measures that aim at a sustainable energy supply and use
Funding responsibilities of the reporting institution	Not a funding institution
Way to formalise relationship between institutions	Contract between the ministry and the agency No legal framework with the surveyed institutions

Collection, classification and validation process	
Type of data collection	Structured survey Unstructured survey Public database Private database
Type of survey	Different from the IEA survey Project level
Survey frequency	Annual
Data extraction	Project data (contracts) from funding institutions
Data extraction frequency	Annual
Classification	IEA classification done by the co-ordinating team Four stages of RD&D: basic research, experimental research, technical development and first-of-its-kind demonstration
Data validation	Cross-check with project title or other project information for topics Time series assessment

Data management and technology	
Data platform	Internal Excel database with all projects
Advanced data analytics	No

Data dissemination	
Main data users	Ministries and federal authorities
Dissemination channel	Annual report in June Annual public presentation in June Dedicated website Specific queries
Main publication	Energy RD&D 2021 - Public Expenditures in Austria. Survey for the IEA

Purpose

Energy RD&D data have been collected in Austria since 1974 to inform the IEA, ministries and federal authorities. The main objective of these statistics is to be the quantitative basis for the design, tracking and evaluation of the RD&D funding programmes. They are also used as a quantitative basis to assess the alignment between public policies (for instance, to support electromobility or grid-scale storage) and the research projects carried out.

Institutional arrangement

The responsibility to collect and report energy RD&D data in Austria lies with the Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology. However, instead of dedicating internal resources to the collection and reporting process, the ministry has externalised this activity. The contract specifies the outputs and quality required and provides the awardee with the resources to undertake the tasks needed to collect the data, with the requirement to minimise the burden on respondents.

Currently, the Austrian Energy Agency is carrying out work to collect, process and validate the energy RD&D statistics. The Austrian Energy Agency is an energy research and policy organisation through which a group of institutions co-operate, such as the federal and provincial administrations and important corporations from a variety of economic sectors. The board of directors comprises the federal minister dealing with environmental affairs, the federal minister charged with energy affairs and the chairman of the provincial governors.

The Austrian Energy Agency has been doing this activity for the last 18 years. Each annual cycle, the Austrian Energy Agency dedicates around 0.3-0.4 FTEs to this process. The main effort is dedicated to data validation, analysis and dissemination as they are requested to prepare a 100-page report for the ministry and present it at different forums.

The data collection is done differently for each institution and includes structured surveys, unstructured Excel files, extractions from private databases and access

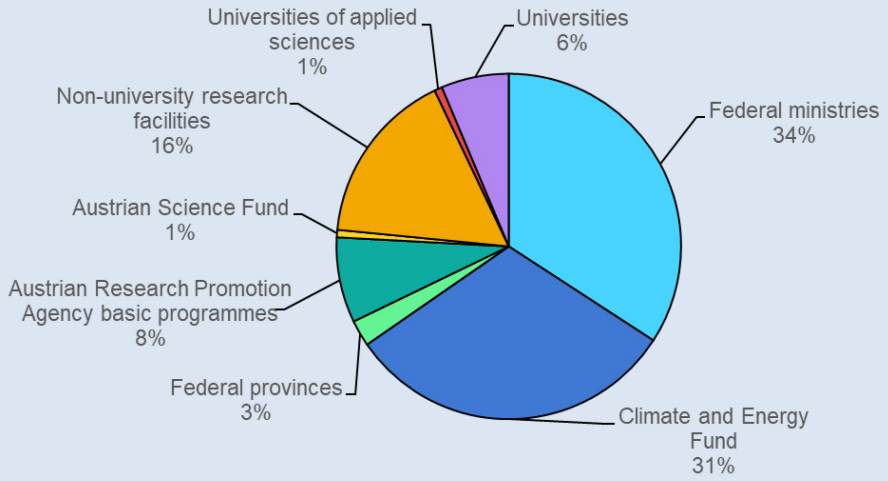
to public databases. This heterogeneity makes it difficult to develop a conventional legal framework to formalise the relationship between different institutions. However, the general interest in appearing in the national statistics, and the fact that the cycle has been repeated for many years, has resulted in a robust process with high coverage. Additionally, there is an important effort by the Austrian Energy Agency to perform a continuous screening of the institutional landscape to quickly identify new actors in the energy RD&D arena.

State-owned enterprises are not included in the public data, but they are included in the data of the private sector.

Funding institutions and major programmes

The main sources of funding for energy RD&D are the federal ministries and the Climate and Energy Fund. These funds are mainly transferred to the research institutions through the national funding agencies. In 2021, almost three-quarters of this expenditure was provided by governmental authorities (federal and regional funding organisations). The remaining part came from (publicly funded) research institutions and universities provided with equity capital.

Total energy RD&D expenditure by institution in Austria, 2021



Austria's national funding agencies assign a significant share of financial resources provided by federal budgets to energy RD&D. In 2021, EUR 163 million was contracted via these institutions.

Energy RD&D funding institutions and their funds in Austria in 2021

Funding institution	2021 funds
Austrian Research Promotion Agency	Contracted EUR 142 million, mostly from ministries and Climate and Energy Fund budgets but also including EUR 18 million from bottom-up programmes for companies
Kommunalkredit Public Consulting	Administered EUR 19 million for first-of-their-kind demonstration projects
Austrian Science Fund	Financed EUR 0.8 million in energy-related basic research
Austria Wirtschaftsservice	Provided EUR 1.6 million out of their seed financing programmes

Source: IEA Research Cooperation (2022), Energy RD&D Survey 2021 - Public Sector Expenditures in Austria. Survey for the IEA.

Collection, classification and validation process

The data collection process is very heterogeneous in Austria. The main principle of the Austrian Energy Agency is to reduce the burden on reporting bodies to a minimum. Therefore, a big part of the classification and validation tasks are undertaken by the agency itself. They collect the raw data at the project level using an optional Excel spreadsheet format, but not all the respondents provide the data with the same structure.

Additionally, in some cases, the reporting institutions make the data available to the Austrian Energy Agency directly from their systems: in a public database in the case of the Austrian Science Fund and from a private database in the case of the Austrian Research Promotion Agency. When the data are available, they are directly collected and processed by the Austrian Energy Agency without any interaction with the reporting institution unless there is a problem or an anomaly.

Projects are usually classified according to the IEA classification by the research institutions. They also classify each project into one of the four following RD&D stages: basic research, experimental research, technical development and first-of-its-kind demonstration. To avoid double counting on projects funded by different institutions, each respondent reports the amount funded by themself, not the total funding of the project, considering the contracts signed in the year of study. The projects are also classified according to other criteria that fall outside the scope of the IEA survey, such as gender balance. For example, projects are classified according to the gender of the project leader or the number of female experts working in a specific field.

Once the energy agency receives the data, they do some cross-checking with the project title and additional data to validate the classification and study the time series to assess breaks. If they identify an inconsistency, they solve it by reaching out to the contacts of the reporting institutions. In some cases, a project classification may need to be altered due to confidentiality issues. As a principle, it should not be possible to deduce from the statistics any specific project or institution information. Once everything is processed, all the validated project data are loaded onto an internal database (around 1 000 projects per year). All the tables, graphs and information published by the agency are extracted from this database.

Data management and technology

There is no specific data platform to deal with all the exchanges of information between the Austrian Energy Agency and the respondents. These interactions are different from one reporting institution to another and include the circulation of formatted Excel spreadsheets, general Excel spreadsheets, access to public databases and access to private databases. All the information is centralised in an advanced Excel database that is used to carry out the data validation. In general, there is a lot of manual work in this process.

Data dissemination

The key users of energy RD&D data in Austria are the ministries, federal authorities and programme designers. The organisations carrying out the projects are also interested in these data as they can obtain information about funding programmes and assess whether the funds in place are enough to advance the development of certain technologies at the required speed.

The main output is a 100-page report showing a review of energy RD&D in Austria, available online. Additionally, the Austrian Energy Agency prepares workshops to present the main conclusions of the report.

Brazil

Institutional arrangement	
Reporting institutions	Energy Research Office (EPE) Centre for Strategic Studies and Management (CGEE)
Role of reporting institutions	EPE: supporting the Brazilian Ministry of Mines and Energy's energy policies with studies and research on energy planning CGEE: supporting decision-making processes in science, technology and innovation
Funding responsibilities of the reporting institutions	Not main funders
Way to formalise relationship between institutions	No specific legal framework for energy RD&D data collection Collaborative framework with publicly available data

Collection, classification and validation process	
Type of data collection	Public database Raw project data sent by institutions
Data extraction	Project data (budgets) from funding institutions
Frequency of data extraction	Annual
Type of raw data	Projects
Classification	IEA classification done by the co-ordinating team
Data validation	Keywords Analysis by energy specialist

Data management and technology	
Data platform	Central platform hosted and managed by the EPE
Advanced data analytics	Classification based on R programme designed to identify keywords with continuous refining of the scripts

Data dissemination	
Main data users	Policy makers, academics, investors and civil society
Dissemination channel	Website
Main publication	Inova-e platform

Purpose

In 2018, Brazil launched an ambitious project to improve its processes for collecting and compiling energy RD&D data. The reasons to boost this effort were a need to guide public policy and to fill gaps in the compilation of these statistics.

In May 2018, during the preparation for the third Mission Innovation Ministerial, focused on enhancing data collection of public and publicly oriented investment in energy RD&D, Brazil identified a gap in having a robust, integrated, comprehensive and structured database with all the information required to produce statistics that could guide public policy.

In parallel, the United Nations ECLAC launched the Big Push for Sustainability in 2016. This was an approach to support countries in building more sustainable development styles. To accomplish this transition towards sustainability, RD&D in clean energy is vital. For this reason, the CGEE joined forces with ECLAC's Big Push for Sustainability in Brazil.

In this context, in 2019, ECLAC, the CGEE and the EPE created the Energy Big Push Brazil project. Once it was created, synergies were identified, and the IEA also joined the project within the scope of its Clean Energy Transitions Programme. The project was structured around four axes of activity, each with a specific objective:

- Axis 1 – Development of a process for collecting, structuring and managing data on public and private investments in energy RD&D.
- Axis 2 – Survey of technical, economic, social and environmental performance indicators associated with low-carbon energy solutions.
- Axis 3 – Identification of strategic guidelines and key policy instruments to accelerate investments in energy innovation.
- Axis 4 – Innovative and effective communication strategy of project results, targeted at decision makers.

The work on axis 1 had methodological support from the IEA from the beginning. The results of the first three axes were published in 2020 on the ECLAC website and were also disseminated at an event organised by the IEA with ECLAC, the EPE and the CGEE.

In 2020, when the first phase of the project ended, the Ministry of Mines and Energy instructed the EPE to build a platform on its website to make the results obtained so far available to a diverse audience and enable their annual update. Thus, with the technical and financial support of the United Kingdom's Prosperity Fund and the Brazilian Energy Programme, and under the co-ordination of the EPE, execution from the CGEE and technical support from Adam Smith International, the digital platform Inova-e was developed and launched in 2021.

Institutional arrangement

The EPE and CGEE oversee the energy RD&D data collection and compilation in Brazil. The EPE is responsible for reporting this information to the IEA. There is no specific legal framework for this data collection yet. However, the Lei de Acesso

a Informação ou Lei da Transparência [Law on Access to Information or Transparency] provides procedures in this regard to be followed by the union, states, federal districts and municipalities in order to guarantee access to information such as government expenditures. This excludes information for which secrecy is essential to the security of society and the state.

In some cases, data are collected from publicly available datasets. In other cases, collecting institutions request the project data from the data sources. There are no formal agreements with these institutions, and data sharing is based on a collaborative and voluntary framework, formalised by contacts at the director level. However, working groups have been established with the data providers and the IEA to enhance collaboration and to track that the development of the project is in line with the roadmap. Having this working group from the beginning of the process is essential for ensuring the involvement and engagement of the institutions and the working-level contacts. This has allowed collaboration to validate the classification of projects according to the IEA classification undertaken by the EPE every year. The resources carrying out this task are 2.5-3 FTEs. However, during the first two years, when all the processes were established and a data revision back to the year 2013 was completed, the number of people involved in the project amounted to 5-6 FTEs.

Funding institutions and major programmes

During the first two years of the project, once the data needs were identified, a significant effort was conducted to create a network of institutions. So far, eight institutions have been used as data sources in the process.

Energy RD&D funding institutions and performers in Brazil

Data source	Funding source	Performer
Funding Authority for Studies and Projects	National Science and Technology Development Fund Funding Authority for Studies and Projects	*Science and technology institution* *Private company*
National Council for Scientific and Technological Development	National Science and Technology Development Fund *Other*	*Science and technology institution*
Ministry of Science, Technology and Innovation	Federal Budget National Science and Technology Development Fund	National Nuclear Energy Commission *Science and technology institution*

Data source	Funding source	Performer
Brazilian Electricity Regulatory Agency	*Company*	*Company itself* *Science and technology institution* *Another company*
National Agency for Petroleum, Natural Gas and Biofuels	*Company*	*Company itself* *Science and technology institution* *Another company*
Siga-Brasil (for National Nuclear Energy Commission data)		
National Bank for Economic and Social Development	National Bank for Economic and Social Development	*Two companies* *Science and technology institution*
São Paulo State Research Foundation	São Paulo State Tax Revenue	*Science and technology institution*

Source: United Nations ECLAC (2020), Overview of Energy Innovation Investments in Brazil: Data for an Energy Big Push.

Collection, classification and validation process

The data collection system in Brazil is still very young, and while it became more mature with the Energy Big Push process, it is still in the process of being fully established. As of 2022, Brazil has run two cycles and expects to establish an annual cycle aligned with the IEA RD&D data collection timeline. As part of this process, Brazil has created a central database to contain all the information on RD&D and established a network of institutions as well as a governance model for the collection, classification and verification process. In parallel, it has compiled statistics back to 2013.

One of the main requirements when creating the process was to create a more automatised way of collecting and treating the data while also minimising the burden on the data providers, as well as benefitting from the experiences of other countries, international standards and collaboration.

The methodology to set up this process was a five-step cycle:

1. Identify information needs (based on the guiding questions).
2. Gather, extract, transform, clean and load the data.
3. Explore and analyse the data information.
4. Build visualisations and deliver information.

5. Consider feedback and lessons learnt.

The data sources are a combination of public databases and datasets prepared from data sources with raw project data. These different sources might have different formats, so the EPE and CGEE have to perform normalisation and classification work.

Data collection is done either automatically, when the data are publicly available and structured and can be accessed through an automatic query, or manually, by email, when the data are prepared in a file by the data source. In some cases, this file with raw project data may include projects unrelated to energy. The data sources are mainly funding agencies, so the data are project budgets and not actual spending. The essential data that are communicated are the data origin, the project title, the amount of funding, and the date and period of execution of the project. Although it is challenging, the CGEE and EPE are trying to implement in parallel a bottom-up approach for data verification.

The data are then transformed and cleaned to fit the data structure of the central database. The EPE runs a script to search for keywords in the title and description of each project in order to categorise it according to the IEA classification. In some cases, the original dataset contains only energy projects, whereas in other cases, there are projects from various different sectors (transport, construction, science, etc.) that do not relate to energy. The use of keywords also allows for filtering of the energy projects from non-energy projects.

There is a set of keywords for every two-digit IEA category. The output of the script is a new column in the database with the two-digit category for each project. As the development of this cleaning process is still at an early stage, it can lead to ambiguity, such as classifying some projects into two or more categories. The use of the algorithm for new data update cycles will allow the refinement of the keywords used and will reduce this type of ambiguity. The same methodology is applied to all the projects and there is no prioritisation based on the size of the project or other criteria.

Afterwards, this classification is validated by a technical energy analyst, whose focus is to disambiguate projects that have been allocated more than one category. Additionally, the analyst checks a sample of the rest of the projects to see if some might be missing. Once the data are cleaned, treated and validated, institutions are asked to check whether the validation is correct. Finally, all the data are consolidated before publication to run a final validation of the high-level results. There are roughly 16 000 projects per year, on average, on the platform.

Once the process is completely established, Brazil will focus on the following improvements to make the process more robust and efficient:

- increase process automation through extract, transform, load

- improve the algorithms to minimise the number of projects classified in more than one category as well as the need for manual validation
- improve classifications and keywords
- strengthen the governance of the process
- prioritise other types of indicators to publish on the platform.

Data management and technology

Data extraction from public databases is done automatically by scripts. Some of the data sources send files with datasets of raw data. All the projects are filtered and classified to the IEA classification two-digit level with a Boolean algorithm and keywords. Then, the cleaned data are published on the Inova-e platform.

The Inova-e platform is one of the longer-term outcomes of the Energy Big Push project. The development of the platform was funded by the Prosperity Fund of the United Kingdom under the Brazil Energy Programme. The Inova-e project aimed to create an open platform with data and analysis on energy RD&D investment, with the view to inform policy making and the country's energy innovation strategy. The EPE is the institution responsible for maintaining the platform, which hosts the data collected and analysed through the EBP.

Data use and dissemination

Consolidated data are made available to the public through the Inova-e platform. It is used by multiple users, from policy makers to research centres and the general public. In fact, since the creation of the database, project data have already been used to assist in public policy decision making in the energy RD&D area, such as in the following examples:

- CNPE Resolution No. 2/2021, which establishes guidelines on research, development and innovation in the energy sector in areas such as hydrogen, storage, digital transformation and biofuels, among others. The EPE provided technical support to the Ministry of Mines and Energy to prepare the resolution, based on information from the EBP and Inova-e.
- Improvement of the National Agency for Petroleum, Natural Gas and Biofuels Technical Regulation No. 3/2015 in order to strategically guide its investments in RD&I in 2021.
- Preparation by the EPE of a technical note, Bases for the Consolidation of the Brazilian Hydrogen Strategy, as an aid to the Ministry of Mines and Energy for the preparation of Resolution 6/2021. This note also uses information from the EBP and Inova-e as it pertains to hydrogen.
- The Energy Efficiency Atlas Brazil 2021 (a joint publication with the IEA) used data from Inova-e to report the status of investment in energy efficiency in Brazil.

- Representations of Brazil in international forums, such as Mission Innovation, including a workshop organised by the IEA, Working Together to Enhance Global RD&D Data Collection, and the preparation of a podcast reporting the Brazilian experience in this area, during the sixth Mission Innovation Ministerial in September 2021.

Canada

Institutional arrangement	
Reporting institution	Natural Resources Canada (NRCan)
Role of reporting institution	Developing policies and programmes that enhance the contribution of the natural resources sector to the economy Conducting innovative science in facilities across Canada to generate ideas and transfer technologies
Funding responsibilities of the reporting institution	One of the major spenders
Way to formalise relationship between institutions	No legal framework for the energy RD&D data collection but the commitment of senior officers

Collection, classification and validation process	
Type of data collection	Survey of institutions (federal departments/agencies, provincial and territorial governments)
Type of survey	Same survey as IEA with a different format
Survey frequency	Annual
Classification	IEA classification at the survey stage
Data validation	Collaboration effort with federal, provincial and territorial survey participants to ensure completeness and avoid double counting

Data management and technology	
Data platform	Exchange of Excel files by email Implementation of a data platform assessed and dismissed
Advanced data analytics	No

Data dissemination	
Main data users	Policy makers (e.g. support/renew/launch programmes as part of a decision-making tool)
Dissemination channel	Website
Main publication	Natural Resources Canada Energy Fact Book

Purpose

Canada collects energy RD&D data primarily to support the IEA in its work on energy innovation. Nationally, the data are used in various ways, such as to support the design of new programmes that include energy RD&D funding and to evaluate the performance of current programmes, for example. In addition, the

data are used to inform policy makers through internal and external reports produced by NRCan and other government organisations.

Institutional arrangement

Canada has a federal system of governance with one federal, ten provincial and three territorial governments. NRCan is the federal government department responsible for reporting energy RD&D data to the IEA. It also represents Canada at the international level to meet the country's global commitments related to the sustainable development of natural resources. NRCan has the mandate to develop policies and programmes that enhance the contribution of the natural resources sector to the economy and to conduct innovative science in facilities across Canada to generate ideas and transfer technologies.

This federal/provincial governance structure has a big influence on the institutional arrangement of the Canadian system to produce energy RD&D statistics as some of the energy-related jurisdictional responsibilities are divided between federal and provincial institutions and others are shared.

Share of responsibilities between federal and provincial institutions in Canada

Federal responsibilities	Shared	Provincial responsibilities
International energy	Environmental regulation of new energy projects (including indigenous consultation)	Regulation of natural resource development on provincial lands
Interprovincial energy	Scientific research and development	Land-use and project planning
Trade and investment	Offshore petroleum in Atlantic Accord Areas	Royalty design and collection
Nuclear energy and uranium	Infrastructure security and resiliency	Intra-provincial energy resource infrastructure, distribution and storage
Energy resources on federal Crown land, offshore and north of 60º latitude	Energy efficiency	Electricity generation
Regulations and standards relating to energy efficiency		

Source: Natural Resources Canada (2021), Canada: Energy RD&D Data Collection Process Knowledge Sharing.

One of the reasons for NRCan to co-ordinate this data collection effort across institutions is that it is also one of the main energy RD&D funders in Canada. Nonetheless, there are a considerable number of other federal departments and provincial and territorial governments that fund energy RD&D across the country. In total, there are approximately 30 federal departments and agencies (such as

Environment and Climate Change Canada; Innovation, Science and Economic Development Canada and NRCan itself) plus 13 provincial and territorial governments funding energy RD&D projects. In this context, NRCan interacts with all these federal, provincial and territorial institutions to collect and compile the energy RD&D data and submit them to the IEA.

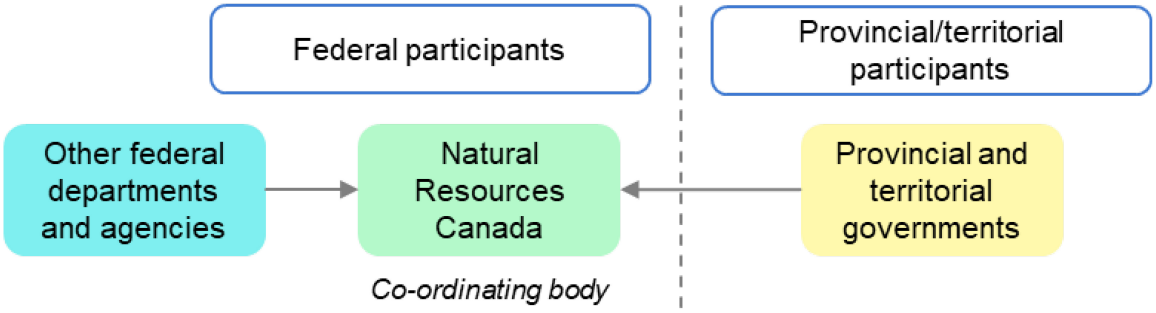
In the process of compiling statistics, they generate two different sets of data.

Federal data include energy RD&D projects funded by federal departments and agencies. NRCan co-ordinates the data collection and compilation efforts of around 30 departments and agencies. Generally, each federal participant collects and consolidates at the departmental or agency level. Consolidation efforts vary depending on how each department or agency is structured (e.g. one consolidated dataset versus three individual datasets for one department). Prior to consolidating all of the federal data, NRCan takes several steps to review, validate and verify the individual data submissions.

Provincial data include energy RD&D projects funded by provincial and territorial departments**.** Each provincial government has a similar structure to the federal government, with different ministries managing funding programmes. There is one department with a similar co-ordinating role as NRCan at a federal level in every provincial and territorial government. These co-ordinators collect and consolidate the data from all the ministries in the province or territory. They are the contact points for NRCan to collect the entire provincial or territorial dataset.

In summary, maintaining federal, provincial and territorial official and working-level contacts is important to ensure accurate and consistent datasets are produced annually.

Energy RD&D data collection flows between institutions in Canada



Regardless of the complexity and diversity of the federal, provincial and territorial participants, there is no obligation for the different institutions to collect and share the information with NRCan. However, the commitment as a country to collaborate

with the IEA and the good relationships between departments and institutions make the process very robust. To formalise this process, an official letter from the director general of NRCan is sent to the individual federal departments and agencies and to all provinces and territories. Apart from this formalisation of the process, NRCan makes a substantial effort every year to engage with all the participating institutions. For example, NRCan prepares guidance documents and conducts information sessions for the survey participants to help ensure accurate and consistent data are collected. In addition, NRCan also shares the data results in the form of a presentation with all the participants.

In all cases and regardless of the institution, the tasks for the energy RD&D data collection are done using internal resources covered by the budgets of each institution. There is no role 100% dedicated to these tasks, and, considering the number of institutions involved, it is difficult to estimate the FTE per year needed to carry out the data collection, processing and dissemination.

Funding institutions and major programmes

The Canadian energy RD&D data covers the following five main federal funders.

Energy RD&D major funding federal institutions and programmes in Canada

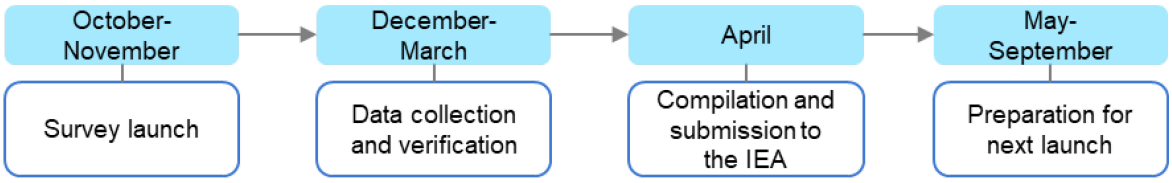
Funding institution	Major programmes
Natural Resources Canada	Program of Energy Research and Development Energy Innovation Program Impact Canada Initiative – Clean Technology Challenges Clean Growth Program Green Infrastructure – Smart Grid, Buildings, Electric Vehicles Infrastructure, Clean Energy for Rural and Remote Communities) Canadian Emissions Reduction Innovation Network Breakthrough Energy Solutions Canada
Atomic Energy of Canada Limited	Revitalisation of the Chalk River Laboratories Federal Nuclear Science and Technology Work Plan
Sustainable Development Technology Canada	Sustainable Development Tech Fund
National Research Council Canada	R&D programmes Industrial Research Assistance Program

Funding institution	Major programmes
Natural Sciences and Engineering Research Council of Canada	Discovery Research Research Training and Talent Development Research Partnership

Collection, classification and validation process

As described in the previous section, NRCan is the co-ordinator of the collection efforts of Canada's energy RD&D data, and it compiles and validates the data before filling and submitting the IEA questionnaire. It does this on an annual cycle using the IEA questionnaire as a survey for all the institutions. Each surveyed institution is responsible for classifying each project into the IEA categories. NRCan collects the templates filled with data and validates them, contacting the institutions when necessary to resolve any doubts or inconsistencies.

Timeline of the Canadian data collection process



Source: Natural Resources Canada (2021) Canada: Energy RD&D Data Collection Process Knowledge Sharing.

The data collection is done in two parallel steps, one for federal institutions and one for provinces and territories. NRCan launches the survey in October for the federal institutions and in November for provinces and territories. The survey is sent in an email from the director general's office to another senior officer of a similar level in the surveyed institution. Working-level contacts are also included in the communication. This communication consists of a formal letter asking for assistance to succeed on a new data cycle. In this email, the IEA survey template, with some re-formatting, is attached with some additional documentation to help guide the survey participants: a task letter, supplemental guidance and a frequently asked questions document.

The supplemental guidance is a short manual that is intended to help participants navigate through the full IEA RD&D Manual. NRCan also creates the frequently asked questions document to provide responses to questions that have come up in previous years of conducting the data collection efforts. The questions are either

broad in content or apply only to some participants. The frequently asked questions are updated each year as new questions arise.

Right after launching the survey, NRCan arranges several information sessions. For federal participants, there are two sessions, one for NRCan and one for other government departments. For provincial and territorial participants, there are two sessions, one in English and one in French. In these meetings, NRCan explains the process to the people who will prepare the data and complete the survey in each institution, highlighting the main topics discussed during the previous cycle and clearly describing what to do and when. NRCan finds these sessions very productive. In fact, many questions in the frequently asked questions document come from these meetings, especially as respondents can ask specific questions in one-to-one conversations with NRCan. Another key objective of the information sessions is to co-ordinate the reporting and avoid double counting among the federal, provincial and territorial levels.

Each participant is responsible for reporting the relevant expenditures for their institution. However, when there are transfers of funds between institutions, reporting funds can be tricky. In the case of federal participants, they follow rules to avoid or minimise double counting:

- Do not include funds that the institution transferred to other institutions, as those funds are to be reported by the recipient.
- Include funds received by the institution from other institutions.

Each department and agency can decide how to collect the data to adapt the process to the particularities of their department. NRCan provides guidance in terms of how best to collect the data, but then it is up to the institutions to follow these guidelines and adapt them to their specific needs. As NRCan has less visibility of the internal reality and processes of different provinces, it sticks to the co-ordinator role.

In addition to the efforts to co-ordinate and clarify the reporting at the beginning of the cycle, NRCan also carries out a validation process. It is an iterative process with each respondent during which they exchange information to clarify every detail and ensure data accuracy. Depending on the structure of a programme, capturing energy RD&D expenditures may be a challenging task. For some respondents, energy projects are relatively easy to report, while others have a hard time picking out energy projects in their vast array of supported sectors. For this reason, it is important to work closely with each department and agency to validate and verify what is within the scope of the IEA definitions and to provide assistance regarding the scope of data collection, types of expenditures and technology and category definitions. Furthermore, the validation and verification process can sometimes involve evaluating projects to ensure expenditures are within the scope of the IEA definitions.

The main validation checks are the following:

- comparing with the previous year's submission to identify trends and outliers
- comparing the previously budgeted expenditures against the actual expenditures for the same year
- validating budgeted or estimated amounts through budget or other announcements.

Once all the surveys are completed and verified with the respondents, all the templates are linked, and the results are consolidated. Finally, NRCan runs checks of the aggregated data to ensure completeness.

The entire process is subject to continuous improvement so, after the submission every year, the process is evaluated and adapted. For instance, the entire survey package (an official letter and various guidance documents) is revised and updated each year, and virtual meetings are held with some respondents to help prepare for the upcoming survey cycle. In conclusion, there are various communications taking place annually to help better Canada's reporting efforts.

Data management and technology

There is no central database across federal, provincial or territorial governments. For this reason, the exchange of information between different institutions is done by email using an Excel survey.

Data dissemination

One of the key actions identified to succeed every year in this process is sharing data results with all the respondents after consolidating the federal, provincial and territorial data. The results are shared in the form of a presentation, including the country ranking and the results by technology. Sharing the results provides an opportunity to strengthen links between institutions, remind respondents of the next year's survey cycle and address any questions or concerns that respondents may have. Additionally, some institutions use the results for their own prioritisation and benchmarking when designing energy RD&D programmes and other policy-related exercises.

The information is also used internally in NRCan for a breakdown of the spending. They use the data to make informed decisions when defining and launching new programmes and to prepare reports evaluating the performance of the spending or informing high-ranking officers. Additionally, the consolidated figures are published in the Energy Fact Book, which NRCan publishes every year on its website.

Czech Republic

Institutional arrangement	
Reporting institution	Department of Strategy and International Cooperation in Energy of the Ministry of Industry and Trade
Role of reporting institution	Responsible for the national industry policies, energy policies, trade policies, export promotion policies, integrated raw materials policies and the use of mineral resources
Funding responsibilities	No funding responsibilities
Way to formalise relationship between institutions	Legislation of Act No. 130/2002 Coll covers the requirement to submit information on research projects receiving public funding

Collection, classification and validation process	
Type of data collection	Public database
Data extraction	Project data
Frequency of data extraction	Annual
Classification	Classification done by the co-ordinating team using keywords
Data validation	Continuity of spending High-level figures

Data management and technology	
Data platform	STARFOS already offers a centralised database for RD&D projects.
Advanced data analytics	No

Data dissemination	
Main data users	Ministries and performers
Dissemination channel	Website
Main publication	Statistics on Research and Development Expenditure in the Field of Energy for the Purpose of International Energy Agency (IEA) Questionnaire Projects are also available in STARFOS

Purpose

The Czech Republic, as a member of the IEA, is required to report selected statistical data in the form of questionnaires, one of the questionnaires being

focused on energy RD&D. For the purpose of the preparation of statistical data for this questionnaire, analysis on RD&D expenditures has been carried out since 1996.

Institutional arrangement

Energy RD&D data are collected by the Department of Strategy and International Cooperation in Energy of the Ministry of Industry and Trade of the Czech Republic. In the national RD&D landscape, there are four main actors: the Ministry of Education, Youth and Sports; the Ministry of Industry and Trade; the Czech Science Foundation and the Technology Agency of the Czech Republic. However, projects are supported mainly by funds managed by the Technology Agency of the Czech Republic through specific programmes. This agency maintains a public database, STARFOS, with information on all the RD&D projects receiving public funds. Any performer receiving public funds is required to input some information into this public database.

For this reason, the Ministry of Industry and Trade and the Technology Agency of the Czech Republic actively collaborate on the energy RD&D data collection, validation and dissemination process. Since the information is publicly available, there is no specific legal basis for this collection. However, Act No. 130/2002 Coll and other secondary legislations formalise the data collection requirements on research projects when public finance is involved.

In 2018, when the Czech Republic carried out a project to compile the statistics back to 1996, there were two people in the ministry working on the project. For the annual revision, the number of FTEs in the ministry is considerably smaller. However, the effort to create and maintain the public databases STARFOS and ISVAV is supported by additional FTEs at the Technology Agency of the Czech Republic and the Research, Development and Innovation Council.

Collection, classification and validation process

In 2018, the Czech Republic revised the energy RD&D data back to 1996. During this process, they mapped the energy RD&D landscape, developed a methodology and created a powerful network with the Technology Agency and the Research, Development and Innovation Council. The Czech Republic carries out an annual process to collect energy RD&D data and report it to the IEA. This annual cycle is in fact aligned with the IEA data collection cycle. As soon as the data are available, the Ministry of Industry and Trade starts the following process.

First, they download a list of projects from the database STARFOS, around 300 projects per year, using keywords to filter energy projects.

Keywords used for filtering
Energy, nuclear, nuclear energy, non-nuclear energy, electricity, grids, heating, reactor, combustion, cogeneration, co-combustion, heat, natural gas, gas, gaseous, network, hydrogen, fuel, fuels, storage, distribution, transmission, electromobility, photovoltaics, bioenergy, biomass, biofuels, waste, smart, radioactive

In this process, the Technology Agency of the Czech Republic, which has direct access to background data in the STARFOS database, collaborates with the ministry to provide the split between the eligible cost and the amount of public support. In addition to these two figures, the available information in the database used in the process is basic information about the institution performing the research, the project solution time, the programme under which the project is funded, the public tender number and the R&D category field, etc. The Technology Agency is the main funding body and the owner of the most relevant funding programmes. However, some other sources of funding are not included in the data, which cover approximately 80% of the national public funding.

As a next step, the projects are classified according to the IEA categories. Initially, the projects are divided into two big categories according to the national classification: nuclear energy and non-nuclear energy. The co-ordinating team at the ministry classifies the projects one by one, reading their titles and abstracts. In this process, the ministry also receives assistance from the Technology Agency to help classify certain projects.

The Czech Republic reports to the IEA the public support figures as the government RD&D budget and the difference between the eligible cost and the public support as the private sector RD&D budget. Once the data are compiled, they are validated by comparing the data of the year of study with the previous year in terms of order of magnitude. Additionally, the ministry performs predictions based on live projects that are also used to verify the completeness and accuracy of the data. Once the data are validated, the IEA questionnaire is completed and submitted.

The Ministry of Industry and Trade is currently assessing the possibility of asking researchers to classify their projects according to the IEA classification and include this field in the public databases. This would considerably modify the process of asking for public funds for research, as it would require changing the structure of the STARFOS database. These types of transformation projects are proposed, assessed and performed in five-year national plans. The next programme in the Czech Republic is Data 2 between 2023 and 2028.

For now, the Czech Republic reports demonstration projects with R&D budgets, and RD&D by state-owned enterprises are not included.

Data management and technology

Information on most of the RD&D projects in the Czech Republic is publicly available in the STARFOS and ISVAV databases. This generates an efficient data collection methodology as these two databases centralise the information from many performers (research centres and universities, etc.).

STARFOS is a full-text search engine for projects and results in the field of research, experimental development and innovations that have been supported by public funds of the Czech Republic. The data source is the Information System of R&D operated by the Office of the Government of the Czech Republic. The data are updated every night.

Data dissemination

The data are disseminated at the end of the cycle. The project-level data are already available in the databases mentioned in the previous section. Additionally, the ministry disseminates the data reported to the IEA with a short analysis in a document on its website. Even though it is publicly available, the main users for the data are governing bodies (mainly the Ministry of Education, Youth and Sports, the Ministry of the Environment and the Ministry of Industry and Trade) and the statistics office.

Estonia

Institutional arrangement	
Reporting institution	Ministry of Economic Affairs and Communications
Role of reporting institution	Creating overall conditions for the growth of competitiveness of the Estonian economy
Funding responsibilities	Main funding institution
Way to formalise relationship between institutions	No need as the data are publicly available

Collection, classification and validation process	
Type of data collection	Public database
Data extraction	Project data filtered by energy-related keywords
Frequency of data extraction	Annual
Classification	IEA classification done project by project by the co-ordinating team
Data validation	Few projects so validation not indispensable

Data management and technology	
Data platform	Complete ETIS database Excel spreadsheet to classify the projects
Advanced data analytics	No

Data dissemination	
Main data users	Policy makers for more detailed data than the IEA classification
Dissemination channel	No specific data dissemination for energy RD&D data
Main publication	No specific publication for energy RD&D data

Purpose

Estonia, as a member of the IEA, is required to submit a range of energy-related statistics to the agency, including the questionnaire on energy RD&D data. In order to create separate national statistics on energy RD&D, further discussion on the creation of a related parameters database and its financing in the long term would be needed.

Institutional arrangement

The Energy Department of the Ministry of Economic Affairs and Communications is the institution in charge of compiling the energy RD&D statistics and submitting

them to the IEA. This ministry is in charge of designing and implementing national development plans. They do not carry out data collection activities for energy RD&D because the data are already publicly available, so they consolidate them from the existing database.

The Research Information System (ETIS) was established by the Estonian Ministry of Education and Research and is maintained and operated by the Estonian Research Council. The researchers are required to fill in the data when getting public funds for their research. ETIS gathers information on research and development institutions, researchers, research projects and various results. ETIS is also an information channel for submitting and processing grant applications and for submitting and validating project reports.

To work with a more detailed sample, the Ministry of Economic Affairs and Communications asks annually for a data extraction including only energy projects. There is no legal background making this communication compulsory, other than the mission of ETIS to disseminate public information on research activities in Estonia.

ETIS is trying to broaden the scope of the system and is intended to become a meeting point and central source of information for the RD&D landscape in Estonia. It is, thus, working to include more information on privately funded RD&D projects. Additionally, there are some small projects with public funds given to consultancies when no research centres are available that are currently not included in the database but should be in the future.

Funding institutions and major programmes

The Estonian energy RD&D data covers the following main funding institutions and programmes.

Energy RD&D funding institutions and major programmes in Estonia

Funding institution	Major programmes
Ministry of Economic Affairs and Communications	National Development Plan of the Energy Sector until 2030
Ministry of Education and Research Estonian Research Council	RITA – Support for sectoral R&D Mobilitas Pluss NUTIKAS – Applied research in smart specialisation growth areas TeamMe+

Collection, classification and validation process

Once a year, when the IEA sends the energy RD&D questionnaire, the Research Information Centre extracts data from ETIS filtering all the energy-related projects and sends them to the energy department in the Ministry of Economic Affairs and Communications. ETIS is a very detailed database, and the extraction includes large amounts of information for each project, such as the title and abstract, the classifications according to the Common European Research Classification Scheme and the Frascati Manual, and the funding institution and performer.

Researchers do not classify their projects according to the IEA classification, mainly because the database has a broader scope than energy. Once the Excel spreadsheet with the extraction is received, the ministry goes project by project, reading the titles and the abstracts to classify them. Once all the projects are classified, they input the data into the IEA questionnaire. This methodology is manageable because there are only 50-100 projects a year (65 in 2020) that fall in the scope of the IEA questionnaire. This work is carried out annually by one person and takes less than a week.

The database includes the money provided to the project each year and a forecast of the budgeted money for future years in multi-year projects. This way, it is possible to validate the extraction the following year by comparing it with the previous year's budget. In any case, considering the small sample of projects in the scope and the detailed description of each project in the database, the data quality is high and the Research Information Center hardly ever has to be consulted to discuss or solve any issues.

Currently, the ministry cannot differentiate accurately between demonstration projects and R&D. Unless clearly stated in the title or description, a project is not classified as a demonstration. Regarding state-owned enterprises, two main ones are identified because they appear as the financing institutions in the database. These are Eesti Energia and Elering.

The overall process is robust and simple due to the small number of projects covered per year and the good work to operate and maintain the public database of all the RD&D activity in the country.

Data management and technology

The source of the raw data is an online public database. Researchers need to input the information on their projects when they receive public funds, and this information is open to the public. The processing is done on an Excel spreadsheet using the results of a query to ETIS to extract only the energy-related projects. There is no analytical method or script to classify projects, and this is done manually.

As Estonia is a small country with a limited number of researchers in the energy field, an energy-only specific database would not be relevant. There are, however, areas for improvement in the existing system that could make it more relevant to the collection of energy RD&D data.

Data dissemination

Regarding data dissemination, Estonian institutions do not use the IEA classification, and they undertake the process only to fulfil international commitments. They usually need to do detailed analyses on specific RD&D topics to inform policy makers, and for this, they need to go back to the source and work with a more refined data extraction. Some of these analyses can be found on the website of the Ministry of Economic Affairs and Communications.

France

Institutional arrangement	
Reporting institution	Ministry for Ecological Transition Department of Data and Statistical Studies
Role of reporting institution	Responsible for preparing and implementing the government's policy in the fields of sustainable development, climate, energy transition and biodiversity
Funding responsibilities of the reporting institution	No funding responsibilities
Way to formalise relationship between institutions	No specific legal framework Good collaboration between public and semi-public institutions and the ministry

Collection, classification and validation process	
Type of data collection	Structured survey
Type of survey	IEA questionnaire
Survey frequency	Annual
Classification	IEA classification already in the survey
Data validation	Check for breaks in the time series at the aggregated and technological levels

Data management and technology	
Data platform	Exchange of Excel files by email
Advanced data analytics	No

Data dissemination	
Main data users	Government, public
Dissemination channel	Website
Main publication	Public Spending in Energy R&D in 2020 - Sharp Increase in Funding for New Technology

Purpose

France collects energy RD&D to assess innovation in the field of energy technology, in addition to the submission to the IEA. The data are used to inform policy makers and the public through reports produced by the Ministry of Ecological Transition.

Institutional arrangement

In France, the energy RD&D data collection is carried out annually by the Department of Data and Statistical Studies (SDES) of the Ministry of Ecological Transition. The ministry is responsible for implementing policies in the fields of sustainable development, climate, energy transition and biodiversity, and the SDES is responsible for the monitoring of data on housing, construction, transport, energy, environment and sustainable development. The ministry itself does not fund energy RD&D although this was the case in the past. The SDES collects data from around 13 institutions.

There is no specific legal framework for the energy RD&D data collection, but as all the surveyed institutions are public or semi-public, the collaboration between the ministry and the institutions is close, which makes it easier to collect the data. The SDES has good relationships with the surveyed institutions, which they consider critical. The institutions answer quickly and give explanations on changes or revisions in their data without being queried. There is a custom approach to each institution.

The data collection was previously managed by the Directorate General for Energy and Climate so there was already an existing system when the SDES inherited the process.

Funding institutions and major programmes

France has identified as the main funding institutions the following 13 public scientific and technical institutions, industrial and commercial institutions, public interest groups or public funding programmes.

Energy RD&D funding institutions and major programmes in France

Funding institution
Agency for Ecological Transition
National Agency for Radioactive Waste Management
National Research Agency
Public Investment Bank (BPI France)
French Geological Survey
National Centre for Scientific Research
Scientific and Technical Centre for Building
Alternative Energies and Atomic Energy Commission
French Institute of Petroleum and New Energies

Funding institution
Radioprotection and Nuclear Safety Institute
French Research Institute for Exploitation of the Sea
National Research Institute for Agriculture, Food and Environment
Gustave Eiffel University (formerly French Institute of Science and Technology for Transport, Development and Networks)
National Institute of Agricultural Research

Collection, classification and validation process

The SDES starts the process each year by sending an email in April to the institutions identified as active in public energy RD&D funding. This email includes the IEA questionnaire as well as the Energy RD&D Manual. The deadline for replying to the request is the end of June or beginning of July. It is sometimes required to send reminders, but there are usually no issues with institutions submitting data.

The process usually takes around a month and a half spread over several months. An estimated total of 0.2 FTEs is attributed to this activity.

Revisions to the data are quite rare, but they do happen on occasion. For example, there was a revision of the National Centre for Scientific Research data in order to better reflect its energy RD&D funding. It submitted a revision starting from the beginning of the 2010s, and the ministry estimated the revision for the previous period starting from 2002.

The validation process occurs first when receiving the data from an institution. The SDES compares the data with the previous year. If there are breaks in the time series, it asks the institution for more information. There is also some checking done to make sure an item has not been wrongly attributed to one technology. This can be tracked by looking at breaks in the time series for specific technologies.

One difficulty that institutions sometimes encounter is meeting the level of disaggregation required by the IEA questionnaire, as well as attributing the data to the right category. Some technologies, for example, do not fit well into the IEA classification and have to be put in the “unallocated” category. This is the case for certain technologies related to information and communication technology or energy efficiency, for example.

The final coverage at the national level is estimated to be quite complete. The SDES is not aware of any other relevant institutions that should be included. For the 2021 data, all of the organisations surveyed completed the questionnaire. The National Research Institute for Agriculture, Food and Environment did not respond from 2014 to 2021 (for data from 2013 to 2020). As the institute is under the Ministry of Agriculture and not the Ministry for Ecological Transition, the SDES has less leverage to obtain an answer. So, its data were estimated since 2014 (concerning data from 2013). However, this only represents about 0.3% of the total funding. The data at the regional level are currently not included. There is probably existing funding that is not covered because regions also have the mandate to fund R&D. In order to launch any new statistical survey, they would have to go through the National Council for Statistical Information to justify how useful the collection is.

The three state-owned enterprises, Réseau de Transport d'Électricité, Électricté de France and Orano, are currently not included because of secrecy. They cannot publish company data if it is for less than three companies or if one company amounts to more than 85% of the total. The addition of state-owned enterprise data is not planned in the short term.

Data management and technology

In France, the exchange of information between different institutions is done by email using the Excel survey.

Data dissemination

The SDES publishes a report, Les Dépenses Publiques de R&D en Énergie, every year to present the energy RD&D data. The Ministry of Ecological Transition uses the report published each year for policy making. It is also used by the media to report on the subject.

Hungary

Institutional arrangement	
Reporting institution	Ministry for Technology and Industry (TIM) State Secretariat for Energy and Climate Policy Department for Strategic Planning and Programming National Research, Development and Innovation Office (NRDIO)
Role of reporting institution	Ministry for Technology and Industry: Manages and implements domestic energy policies and provides data to the IEA NRDIO: Supports the scientific and innovation ecosystem and provides data to the Ministry for Technology and Industry
Funding responsibilities of the reporting institution	NRDIO is a major RD&D funder
Way to formalise relationship between institutions	Non-energy R&D data are typically collected and provided to the European Union and international organisations by the Hungarian Energy & Public Utility Regulatory Authority, regulated by Act No. LXXXVI of 2007 on Electric Energy. The national report on GHG Emissions and Climate Change is set in Govt. Decree No. 278 of 2014 (XI. 14).

Collection, classification and validation process	
Type of data collection	Public and private databases
Contacts	Data collected directly from performers
Classification	Internal classifications
Data validation	Data validated using data from the Hungarian Central Statistical Office

Data management and technology	
Data platform	NRDIO manages a central database and a platform to request RD&D funding
Advanced data analytics	Filtering by fields of science classification (tier 1-3)

Data dissemination	
Main data users	Policy makers
Dissemination channels	Events, newsletters

Data dissemination	
Main publications	National Energy Strategy 2030 National Energy and Climate Plan National Clean Development Strategy 2020-2050 Energy Research, Development and Innovation in Hungary

Purpose

The energy RD&D statistics are compiled in Hungary mainly to assist policy makers in advising the government. The National Research, Development and Innovation Office (NRDIO) performs ad hoc data extractions to inform the government on specific topics and technologies on demand. In addition, data are used to prepare reports on energy strategy.

Institutional arrangement

The institution responsible for the data collection and compilation is the NRDIO. The Department of Strategic Planning and Programming, under the State Secretariat for Circular Economic Development, Energy and Climate Policy in the Ministry of Innovation and Technology, co-ordinates the energy RD&D data and reports it to the IEA in the annual cycle.

Additionally, the Hungarian Energy and Public Utility Regulatory Authority and the Hungarian Central Statistical Office are also involved in energy data collection (non-RD&D) and RD&D data (not limited to energy). These institutions are currently working to align their internal databases with the NRDIO to facilitate the exchange of data and find synergies to track energy RD&D initiatives.

Funding institutions and major programmes

The National Research and Innovation fund, as an umbrella scheme managed by the NRDIO, does not set out programmes or sub-funds dedicated to energy. However, it is the managing body for the following programmes.

Energy RD&D funding institutions and performers in Hungary

Funding institution	Major programmes
NRDIO	National Research and Innovation fund (for general RD&D)
Funded by the Ministry for Innovation and Technology from Green Economy Financing Systems (managed by the NRDIO) in 2020	Implementation of Development Projects Improving the Stability and Resilience of Power Grids Through Innovation Implementation of Development Projects Aimed at the Conversion of Excess Carbon-Free Power to Gas (Hydrogen, Biomethane) with Innovative Technology Ensuring Energy Supply to Settlements Using Alternatives to Natural Gas Supply, Advanced Technologies and Resilience Services Pilot Project Promoting the Establishment and Operation of Energy Communities
Funded by the Ministry for Innovation and Technology from the Energy and Climate Policy Modernisation System (managed by the NRDIO) in 2021	The Implementation of Developments for the Recovery, Storage or Market-Based Use of Waste Heat Through Innovative Storage or Conversion Technologies The Implementation of Developments Promoting Innovative Electrochemical Storage of Surplus Carbon-Free Electricity

Collection, classification and validation process

There are multiple systems and processes in place depending on the funding agency and programme.

For the projects funded by the NRDI fund, applicants fill out standard forms with project-level data when they request funding. These data are stored in a database managed by the NRDIO. The projects are not energy exclusive, so data must be filtered to compile energy RD&D statistics. To filter and classify each project, the NACE Rev. 2 codes and keywords are used. Some other relevant fields of the databases used for their internal processes are:

- a concise, contextual summary of the achieved results based on the closing report by the project owner
- the most relevant business figures (such as net turnover, total balance sheet and value of offer) on the subcontractors involved in the implementation of the project.

Additionally, to validate and complete the project dataset, two other public databases are used to compile energy RD&D statistics: the Hungarian Central Statistical Office and Eurostat. In the case of statistical data, the NRDIO examines the data according to the classifications stipulated by the Hungarian Central Statistical Office. From Eurostat, projects can be filtered by scientific classification of the System of European Union Programmes, recorded by the staff of the organisations managing the funding requests, such as the NRDIO. These data extractions are done twice a year: in January and July.

Hungary exclusively uses granted payment figures to compile energy RD&D statistics. European Union-financed projects are exported from the e-CORDA database, supervised by the European Commission's Directorate General for Research and Innovation for internal use. However, such data are not included in the IEA questionnaire, in order to not have duplications with the data reported directly from the European Union to the IEA.

Data management and technology

The NRDIO extracts data from the databases mentioned in the previous section in Excel spreadsheets and performs the data analysis in Excel. The filtering and classification are conducted by fields of science (tiers 1-3).

Data dissemination

There are several national publications in Hungary using energy RD&D data, including the following:

- National Energy Strategy 2030
- National Energy and Climate Plan
- National Clean Development Strategy 2020-2050
- Energy Research, Development and Innovation in Hungary

Ireland

Institutional arrangement	
Reporting institution	Sustainable Energy Authority of Ireland (SEAI)
Role of reporting institution	National sustainable energy authority, an agency under the Department of the Environment, Climate and Communications of the Government of Ireland
Funding responsibilities of the reporting institution	Funder of RD&D projects contributing to the national transition to a clean and secure energy future
Way to formalise relationship between institutions	Informal agreement

Collection, classification and validation process	
Type of data collection	Survey of other institutions (nine including the SEAI) to collect project-level data via an Excel template
IEA survey?	No. Project-level data
Survey frequency	Annual
Classification	Projects classified by the SEAI according to IEA classification
Data validation	At the project level to avoid double counting

Data management and technology	
Data platform	National Energy Research Database, which includes information on RD&D projects receiving public funding
Advanced data analytics	No

Data dissemination	
Main data users	Research, policy, industry and other interested stakeholders, to find out more about ongoing research projects and to search for research partners or collaborators
Dissemination channel	Website
Main publications	Open database with project-level data National Energy Research Database

Purpose

Ireland, as a member of the IEA, is required to report statistical data on national energy RD&D investment and, for this purpose, analysis of expenditure on RD&D energy-related projects in Ireland is carried out. As part of this process, the SEAI has developed and maintains an online National Energy Research Database. This

database aims to be a meeting point and a central source of information for all energy RD&D projects in Ireland. This way, researchers and key stakeholders who work or are interested in energy RD&D, can identify relevant ongoing projects and seek potential partners.

Institutional arrangement

The institution responsible for the data collection and compilation is the SEAI. The SEAI is an agency under the Department of the Environment, Climate and Communications of the Government of Ireland. Its vision is to be a leading authority driving Ireland's sustainable energy transformation for the benefit of society.

One key focus area of the SEAI is the national co-ordination of energy research funding and support. The SEAI aims to improve the coherence of Irish energy research and development. It co-ordinates and funds a range of RD&D activities relating to the production, supply and use of energy. The primary SEAI funding programme to support energy research is the SEAI National Energy RD&D Funding Programme, which invests in innovative energy RD&D projects that contribute to Ireland's transition to a clean and secure energy future. Additionally, the SEAI also maintains the National Energy Research Database and is responsible for collecting national energy RD&D data and reporting it to the IEA, among other activities.

The SEAI collects data from the primary public RD&D funding organisations in Ireland (nine, including the SEAI). There is no specific legal framework formalising this data collection process, but an informal agreement and ongoing close collaboration efforts between the relevant public agencies support this process. These collaborations are reinforced by participation in different collaborative working groups, including the newly established National Energy Research Funders' Forum co-ordinated by SEAI, as well as the Climate Research Coordination Group, among others. The Climate Research Coordination Group includes key actors in Ireland's climate change-related research activities and issues an annual publication summarising these activities. Additionally, the SEAI co-funds a number of RD&D projects with these other institutions, further strengthening the collaboration.

Collection, classification and validation process

The SEAI implemented a new process to collect energy RD&D data in 2019, when they revised data back to 2016. Each year, the SEAI issues an Excel questionnaire template (different from the IEA questionnaire) to nine institutions (including the SEAI) to gather details on national energy RD&D investment. This questionnaire is at the project level, and the information gathered is used to input data into the

online National Energy Research Database. The main information gathered in this questionnaire includes the project title, the abstract, the start and end dates, the funding amount, the funding agency, the lead organisation and the lead researcher. The funding amount figure included is the maximum amount as agreed at the project award stage, however the actual project expenditure may differ. The project cost information collected includes direct costs only, excluding overheads. For multi-annual projects the total budget is divided by the number of years (for example, if a project started in May 2018 and ended in March 2020, the total budget is divided by three and allocated equally to the years 2018, 2019 and 2020).

The respondents complete the questionnaire with details of all active projects for the year of study and return it to the SEAI. To reduce the administrative burden on the respondents, they are only asked to classify each project according to the IEA classification to the two-digit level. Afterwards, the SEAI performs the detailed classification for each project with the collected information according to the IEA classification. The number of projects funded can vary from year to year depending upon various factors, including the response to each research call, the available budget and the number of research calls launched by each of the funding institutions. On average, around 80 energy-related RD&D projects have been funded annually since 2018, and in 2021, there were 224 active projects in Ireland. Of these, the SEAI typically funds 50 energy-related RD&D projects each year.

The SEAI then validates the data at the project level by checking for double reporting and double counting of the reported projects. Data are also validated by comparing the projects reported with those reported in previous years. If there are any doubts, the SEAI follows-up to clarify details with their contacts in the relevant funding institutions.

Once all the project data are validated, the SEAI aggregates and compiles the project-level data according to the IEA classification and returns the completed IEA energy RD&D questionnaire to the IEA.

The data collected are also used to feed into the National Energy Research Database subject to the relevant confidentiality conditions. This database contains details of projects funded by public bodies. The SEAI manages this database, which is hosted on the SEAI website, and is responsible for updating and maintaining it. The SEAI operates on a continuous improvement basis, and further developments to the database will take place in future, including, for example, broadening the database to include details of energy RD&D projects funded by EC research and innovation programmes.

Data management and technology

The National Energy Research Database is a central database for energy RD&D projects in Ireland funded by public organisations. It is an open database maintained by the SEAI. Data are collated using the Excel questionnaires that the SEAI sends by email to other national research funding bodies.

Data dissemination

Currently, the main outputs of the energy RD&D data collection process are updates to the National Energy Research Database and the IEA questionnaire.

The main users of the energy RD&D data in Ireland are researchers and other interested stakeholders in energy-related RD&D in Ireland, including, for example, research funders, government departments, companies and community groups. The database is also a good starting point to find partners for future research projects and to understand the current research areas. Additionally, the data are used by public bodies designing funding programmes to minimise duplication of research and to enhance the co-ordination of national research policies.

The SEAI also receives queries from policy makers and other stakeholders about energy RD&D activity in Ireland, and the database is a useful source of information to support these queries.

Lithuania

Institutional arrangement	
Reporting institution	Lithuanian Energy Agency, with oversight from the Ministry of Energy of the Republic of Lithuania
Role of reporting institution	Assessing the state of renewable energy and energy efficiency, and the progress towards the energy sector targets under the National Energy and Climate Plan (NECP)
Funding responsibilities	Not a funding institution
Way to formalise relationship between institutions	In the process of setting up a legal framework for energy RD&D data collection

Collection, classification and validation process	
Type of data collection	Voluntary survey
Type of survey	Same as the IEA survey
Survey frequency	Annual
Classification	IEA classification at the survey stage
Data validation	High-level assessment of the figures

Data management and technology	
Data platform	Exchange of Excel files by email
Advanced data analytics	No

Data dissemination	
Main data users	Policy makers Co-operative research programmes in the Baltic region
Dissemination channel	IEA publication
Main publication	Assessment of the need for an internal publication

Purpose

In 2020, Lithuania started to collect energy RD&D data. Before, the only data available were the general RD&D data produced by the national statistics office. However, these statistics were at a much higher level than the IEA classification, without a breakdown by technology. This effort to collect data that are more detailed was undertaken because of a combination of three main drivers.

First, the Lithuanian government pushed to have solid data to make informed policy decisions on energy research. This was the leading driver to launch the initiative to establish this data collection system.

Secondly, Lithuania is part of the Nordic-Baltic co-operation, which has a joint energy research funding programme. One of the aims of this programme, described by the Roadmap, is to identify, prioritise and suggest energy-related technologies to invest in in the short- and longer-term to reach the climate and energy objectives of the country. Energy RD&D data are a good indicator for tracking compliance with this roadmap.

Finally, one of the criteria to become a member of the IEA is to submit energy data, including energy RD&D data.

After one year and the effort of four people dedicated to this project, Lithuania managed to collect energy RD&D data with reasonable coverage and data quality.

Institutional arrangement

The Lithuanian Energy Agency is responsible for the collection, processing and submission of the energy RD&D data to the IEA, with oversight from the Ministry of Energy of the Republic of Lithuania. Lithuania is currently working on the introduction of a legal background that will define the specific responsibilities of each of the institutions and formalise the data collection to support the changes required to collect the data from each of the institutions.

When Lithuania ran the first data collection cycle in 2020, they identified 19 organisations involved in energy RD&D. As voluntary surveys are used to collect the data, it is key to identify the right contacts in each institution. Despite the success of the initial data cycles, the Ministry of Energy and the Lithuanian Energy Agency are still refining the identification of contacts. As a small and centralised country, it was easy to draw the high-level landscape of companies and institutions active in energy RD&D, but it is more challenging to ensure data availability.

Funding institutions and major programmes

The following list of institutions received the questionnaire in 2022. They include ministries, agencies, science and technology centres, state-owned energy enterprises, the Research Council of Lithuania, the Lithuanian Energy Institute, RTO Lithuania and universities.

Energy RD&D funding Institutions surveyed in Lithuania in 2022

Institution	Additional information
Centre for Physical Sciences and Technology	
Vilnius Gediminas Technical University	
AB Amber Grid	Lithuanian natural gas transmission system operator
LITGRID AB	Lithuanian electricity transmission system operator
Agency for Science, Innovation and Technology	
UAB Ignitis	Largest supplier of electricity and gas in Lithuania
Ministry of Transport and Communications	
Lithuanian Business Support Agency	
Ministry of the Economy and Innovation	
Ministry of Education, Science and Sport	
Ministry of Environment	
Research Council of Lithuania	
Kaunas University of Technology	
Vilnius University	
Klaipeda University	
Vytautas Magnus University	
Lithuanian Energy Institute	
RTO Lithuania Association	Non-university research and technology organisations
Energijos Skirstymo Operatorius AB	Lithuanian electricity and natural gas distributor
EPSO-G AB	State-owned group of energy transmission and exchange companies
Klaipėdos Nafta AB	Company operating oil and liquefied natural gas terminals in Lithuania

Collection, classification and validation process

As of 2022, Lithuania has run three data collection cycles: one in the fourth quarter of 2020, one in the first half of 2021 and the latest one at the beginning of 2022. The spring 2021 data collection was to align with the IEA annual data reporting cycle, and to kick off the regular process that would be repeated annually.

Data are collected through voluntary questionnaires sent by email directly to different institutions involved in energy RD&D. The questionnaire is not sent with any specific supporting documentation, apart from a link to the IEA RD&D Manual. If possible, the targeted contact is intended to be the person who has the technological knowledge to classify the different projects and to fill in the questionnaire.

The surveyed institutions are responsible for putting together all the funding they receive from public budgets to finance energy RD&D, with most institutions submitting for the year of study. As there is a data lag of a few months, the data for the previous year are available by the end of the second quarter of the current year. These institutions are also responsible for classifying the data according to the IEA classification, which can be challenging.

There is no normalised methodology for collecting data across institutions, so each of them has different data coverage and granularity. Out of the 19 questionnaires the Ministry of Energy of the Republic of Lithuania sent, they received ten responses in 2020, seven in 2021 and 15 in 2022. However, most of the energy RD&D funds are accounted for even if not all of the institutions submit data, because the main spenders report data with good quality and coverage.

The responses collected are very detailed with good data quality and well-accounted figures so, for now, there is no specific data validation apart from a high-level assessment of the figures. The main challenge encountered by the contacts is to correctly classify projects according to the IEA classification. Demonstration projects are separated from the other research states, but, according to the Lithuanian Energy Agency, these demonstration projects are underrepresented.

Once all the answers are received, they are aggregated in a questionnaire and submitted to the IEA.

Data management and technology

For now, no data management system has been implemented in Lithuania. Data are managed through questionnaires in Excel spreadsheets and information is exchanged by email. It may take some time to set up a data management platform and to efficiently connect it with other institutions. Additionally, the small number of institutions makes it feasible to manage this task by email, thus decreasing the urgency of having a data management system.

In many cases, some of the institutions are already publishing RD&D data but according to different criteria than the IEA standards, and these databases are already in place, so it would be challenging to create a separate system. In the shorter term, the co-ordinating team might make a recommendation to flag

projects that are within the scope of the IEA energy RD&D data collection at an early stage. This would make the overall process more efficient.

Data dissemination

There is no specific national energy RD&D data publication. Instead, the IEA publication is used to disseminate the data. Lithuania is assessing the internal interest in preparing a publication once the entire process is well established. Nonetheless, the data are widely used internally to inform policy decisions.

Netherlands

Institutional arrangement	
Reporting institution	Netherlands Enterprise Agency of the Ministry of Economic Affairs and Climate Policy
Role of reporting institution	Helping business owners run sustainable, agricultural, innovative or international enterprises
Funding responsibilities of the reporting institution	Most important funder of energy RD&D in the Netherlands
Way to formalise relationship between institutions	National obligation in the Dutch Climate Act

Collection, classification and validation process	
Type of data collection	Structured form at the project level filled in by companies Unstructured project list collected from the two other funding agencies
Frequency	Continuous for the company data Annual for the other funding agencies' data
Classification	IEA classification done by the co-ordinating team
Data validation	Comparison between the internal database and the overall programme budgets

Data management and technology	
Data platform	Automated form via a web-based portal In-house database for the projects Exchange of Excel files by email
Advanced data analytics	No

Data dissemination	
Main data users	Policy makers, academics and private companies
Dissemination channel	Website
Main publications	Annual publication Dashboard

Motivation

The energy RD&D statistics are compiled in the Netherlands mainly to assist policy makers and advise the government when designing programmes to support innovation. Additionally, the Netherlands Enterprise Agency also prepares public reports targeting private companies and academia, who benefit from networks analysis and the identification of sector clusters. The collection and classification processes are embedded into the funding request, so there is no separate data collection process in place.

Institutional arrangement

The institution responsible for the data collection and compilation is the Energy Innovation Team of the Netherlands Enterprise Agency. The agency is inside the Ministry of Economic Affairs and Climate Policy, and, together, they support entrepreneurship, improve collaborations and strengthen positions through funding and networks for private companies. The main responsibility of the Energy Innovation Team is to evaluate project proposals and manage funding programmes to allocate energy RD&D funds. They also undertake the process of reporting and monitoring energy RD&D. The Energy Innovation Team is comprised of around 70 people and there are 5-6 people working part-time monitoring energy innovation.

This agency is also one of the main funders of energy RD&D in the Netherlands. In addition, the Netherlands Organisation for Scientific Research and the Netherlands Organisation for Applied Scientific Research also manage significant public funding for energy RD&D. For this reason, the Netherlands Enterprise Agency works closely with them in a collaborative effort to have reliable energy RD&D data, as the agency is the central hub monitoring energy innovation. To guarantee data sharing and a collaborative framework, the agency has a data declaration agreement with these two institutions.

In addition, all the institutions receiving public funding are obliged to provide requested data by the Dutch Climate Act.

Collection, classification and validation process

There are multiple systems and processes in place depending on the institution receiving the public funds and the funding agency. The volume of energy RD&D projects receiving public funding in the Netherlands is around 200 projects per year, which allows centralised management of the reporting and classification at the project level.

Regarding projects delivered by private companies, the collection, classification and validation are done integrally by the Netherlands Enterprise Agency. When companies request a subsidy to perform energy RD&D, they submit the relevant information about the project through the Netherlands Enterprise Agency platform. This proposal includes a detailed budget for the project in a specific format, and the proposal is loaded into the agency's internal database. The Energy Innovation Team thoroughly assesses the proposal. If the project is accepted, the team categorises the project according to different classifications, including the IEA classification, and updates it in their database. The projects are classified almost immediately, although there might be a few weeks of delay from the acceptance to the classification.

For projects funded through one of the other funding agencies, the project-level data are shared by these agencies through spreadsheets once a year. These files do not have a standard format as they are linked to each agency's internal system in order to try to minimise the data collection burden. Additionally, the level of detail of the shared information is not uniform across projects. In these cases, the projects have already been classified according to internal classifications by the funding agencies. The Netherlands Enterprise Agency then uses a mapping matrix to convert these internal categories to the IEA categories and load the projects into their database.

Additionally, data are validated by comparing the budgets of the projects in their internal database with another database of the administration system that contains the information on subsidies. Once all the projects are loaded in the database and aligned with the annual IEA cycle, the agency aggregates the data, completes the questionnaire and sends it to the IEA. The figures reported in the questionnaire are the money that has been made available by the government in a certain year for a specific project. This does not mean that the money is spent that year (for multi-year projects, 100% of the budget is allocated to the first year).

Currently, the Netherlands Enterprise Agency is in the process of expanding the scope of the innovation monitored from just energy to all the fields related to climate. Even if this does not influence the reporting to the IEA, the agency will include more projects in the internal database, interacting with more funding agencies.

Data management and technology

The Netherlands Enterprise Agency manages an internal database with project-level data. The project proposals are collected from companies through a web portal that is linked to this database. Additionally, the Netherlands Enterprise Agency manages Excel spreadsheets to collect information from other funding agencies.

Data dissemination

Apart from submitting data to the IEA, the Netherlands Enterprise Agency uses energy RD&D data to conduct analysis for many different publications focused on specific technologies, clusters or areas. There is an annual publication on public spending in energy innovation. Additionally, in 2020, they prepared a Climate Policy Dashboard that includes many energy RD&D data, and they are currently preparing a more interactive dashboard on energy innovation to benefit from the continuous process of feeding their internal database.

Norway

Institutional arrangement	
Reporting institution	Ministry of Petroleum and Energy
Role of reporting institution	Responsible for the government's energy policies, including the management of Norway's energy resources
Funding responsibilities of the reporting institution	The ministry provides the overall budget, but the research is mainly funded by the Research Council
Way to formalise relationship between institutions	Informal agreement Reporting of energy RD&D data included in the institutions' annual assignment letters

Collection, classification and validation process	
Type of data collection	Survey to funding institutions
Type of survey	Same survey as the IEA
Survey frequency	Annual
Classification	IEA classification at the survey stage
Data validation	Coherency checks of the questionnaire Inconsistencies resolved in collaboration with the contacts

Data management and technology	
Data platform	Exchange of Excel files by email
Advanced data analytics	No

Data dissemination	
Main data users	Policy makers
Dissemination channel	None outside of the IEA submission
Main publication	Research council project databank

Motivation

The main motivation to undertake the energy RD&D data collection process in Norway is to report the data to the IEA. Norway is committed to providing consistent energy RD&D data in order to collaborate with IEA member countries to generate an international benchmark. In addition, the Ministry of Energy and Petroleum uses energy RD&D statistics to assess the performance of research programmes in place and to design new funding schemes. To inform these decisions, Norway uses the budget figures of the Research Council, the main funder of RD&D in Norway, instead of IEA statistics.

In addition to the Research Council, a part of the funds goes through other agencies and state-owned enterprises organised under different ministries and is not covered by the budget of the Research Council. Even if the Ministry of Energy and Petroleum does not have day-to-day knowledge of their activities, the ministry is aware of all the calls, programmes and budgets funding energy research in these agencies. The combination of all this information provides the Ministry of Energy and Petroleum with a strong basis to design policies without using the data submitted to the IEA.

The priorities for the energy sector are mainly defined through the XXI Platforms designed by the Ministry of Petroleum and Energy. The main platforms are OG21 (oil and gas) and Energi21 (energy), but there are others, such as digital and maritime platforms. All these platforms include experts from industry, public agencies and authorities, and academia.

Institutional arrangement

The team responsible for the data collection and compilation is the unit of Research and Technology of the Department of Climate, Industry and Technology, within the Ministry of Petroleum and Energy. The main responsibility of this unit is to design the policies to manage the public funding from the state budget to support RD&D in renewable energy, petroleum and carbon capture and storage.

Most of the budget supporting energy RD&D goes through the Research Council, the main institution managing RD&D in all sectors in Norway. It is also responsible for creating specific calls and programmes to distribute the funds and for executing the grants. The Research and Technology Unit of the ministry works closely with the Research Council, and they are in contact almost daily. For this reason, communications to perform the energy RD&D data collection are included in the general day-to-day work.

Apart from the Research Council, a small share of the budget goes through other agencies and state-owned enterprises that fund specific technologies, such as carbon capture and storage. Some of these other agencies are organised under other ministries and do not have such a close collaboration with the Ministry of Petroleum and Energy, so the co-ordinating team needs to request the data annually to compile the statistics.

There is no specific legal framework to collect the data, so the collaboration is based on an informal agreement. To formalise this collaboration process, when planning the annual activities of ministries and departments, the Ministry of Energy and Petroleum makes sure that the reporting of energy RD&D data is included in the assignment letter of the relevant institutions so the resources for this task are accounted for in their budgets.

Funding institutions and major programmes

The Norwegian energy RD&D data to the IEA covers seven funding institutions.

Energy RD&D funding institutions and major programmes in Norway

Funding institution	Ministry responsible for the institution	Major programmes
Research Council Norway	Ministry of Education and Research	ENERGIX PETROMAKS2 Demo 2000 CLIMIT Centres for Environment-friendly Energy Research PETROSENTER
Enova	Ministry of Climate and Environment	
Norwegian Water Resource and Energy Agency	Ministry of Petroleum and Energy	
Innovation Norway	Ministry of Trade, Industry and Fisheries	
Gassnova (state-owned enterprise)	Ministry of Petroleum and Energy	CLIMIT Demonstration Technology Centre Mongstad (considered government funding instead of state-owned enterprise)
Statnett (state-owned enterprise)	Ministry of Petroleum and Energy	
StatKraft (state-owned enterprise)	Ministry of Petroleum and Energy	

Collection, classification and validation process

Every year, when the request from the IEA arrives at the Ministry of Energy and Petroleum, they create seven copies of the IEA questionnaire and send them to the seven different funding institutions listed in the previous section. Each of these institutions compiles the data internally, fills in the questionnaire with the data and sends it back to the ministry. The institutions report the data slightly differently depending on the programmes and schemes they use to distribute the budgets. For instance, some of the agencies report 100% of the budget allocated to a project even if the project is multi-year, whereas other agencies report the actual money flowing each year from the funding agency to the research institution.

The person responsible for co-ordinating the work at the ministry checks the consistency of the data and addresses any inconsistencies by directly asking the contacts from the institutions by phone or allocating the data to the “unallocated”

section. The Ministry of Energy and Petroleum aggregates the seven questionnaires into one and sends it to the IEA. Some of the data collected in the questionnaire are also used for submissions to Mission Innovation and the European Commission.

These requests are aligned with the IEA's annual data cycle. The data collection process takes around two weeks per year and there is one person leading this task.

Data management and technology

There is no central database or platform in Norway. For this reason, the exchange of information between different institutions is done by email using the IEA questionnaire. Each of the institutions manages the project-specific data collection, so the ministry has no visibility of the process of each reporting institution to fill in the questionnaire.

Data dissemination

The questionnaire is only used to report to the IEA. On demand, the ministry will prepare a report on RD&D with a focus on specific technologies of interest. As a result, when Norway disseminates data on energy RD&D, it is usually focused on a specific sector or to answer a specific policy priority. For this reason, they undertake an ad hoc process to produce the statistics they use in the analysis.

There is annual reporting by the Research Council covering all the sectors of the Norwegian RD&D with higher-level data since 2004. Additionally, the Research Council has a project databank with data and statistics on all the projects they fund, with information such as the topic, the priority area, the region in Norway and the allocated budget.

Poland

Institutional arrangement	
Reporting institutions	Ministry of Climate and Environment – reporting to the IEA Ministry of Science and Higher Education – R&D data collection
Role of reporting institutions	Responsible for the implementation of environmental protection and climate policies Responsible for the implementation of state policy in the area of science and higher education
Funding responsibilities of the reporting institution	Funder and supervisor of main funding agencies
Way to formalise relationship between institutions	Informal agreements Existing specific legal framework for statistics, but energy RD&D is out of the scope

Collection, classification and validation process	
Type of data collection	Structured survey
Type of survey	IEA questionnaire
Survey frequency	Annual
Classification	IEA classification done by the surveyed institutions
Data validation	Basic data checks

Data management and technology	
Data platform	No central platform
Advanced data analytics	No

Data dissemination	
Main data users	Mainly for IEA reporting Also used by the Ministry of Science and Higher Education to build the national policy and to write strategy documents
Dissemination channel	Not published
Main publication	Not published

Purpose

The main goal of the energy RD&D data collection process is to report the data to the IEA. However, the collected data provides valuable knowledge for the Ministry of Science and Higher Education. Based on the data, they can identify the main topics where Polish institutions are more active in RD&D. This facilitates building Polish national policy and compiling strategy documents.

Institutional arrangement

The responsibility to report data to the IEA in Poland lies with the Ministry Climate and Environment. Although they are responsible for submitting the energy RD&D questionnaire, it is the Ministry of Science and Higher Education that collects the data (including R&D but excluding demonstration, other institutions are responsible for demonstration project funding, e.g. the National Fund for Environment Protection, supervised by the Ministry for Climate and Environment), more specifically the people working on energy in the science department. In recent years, the Ministry of Science and Higher Education has submitted the questionnaire directly to the IEA, as requested by the Ministry of Climate and Environment. These two ministries collaborate actively in this process.

The ministry requests the data on energy R&D projects from two main funding agencies: the National Centre for Research and Development (agency funding applied research supervised by the Ministry of Science) and the National Centre of Science (basic research supervised by the Ministry of Science).

There is no specific legal framework for the energy RD&D data collection. The main legal framework covers the general RD&D data collection carried out by Statistics Poland. In this data collection, energy is just one of the 13 objectives, so the level of detail is much lower than in the IEA's energy RD&D questionnaire.

Even though there is a strong collaboration between ministries and Statistics Poland, the energy RD&D data collected by the Ministry of Science and Higher Education does not match with the higher-level statistics compiled by the statistics office. The ministry collects these data in an informal process at the request of and for the IEA.

Funding institutions and major programmes

The scope of the Polish energy RD&D data collection is limited to the following funding agencies.

Energy RD&D funding institutions and major programmes in Poland

Funding institution	Responsibilities
Ministry of Science and Higher Education National Centre for Research and Development	Applied research supervised by the Ministry of Science
National Centre of Science	Basic research supervised by the Ministry of Science
Ministry of Climate and Environment	
National Fund for Environment Protection and Water Management	Demonstration and investment projects

Collection, classification and validation process

Every year, aligned with the IEA timeline, the Ministry of Climate and Environment asks the Ministry of Science and Higher Education to send the IEA questionnaire to the two funding agencies: the National Centre for Research and Development and the National Centre of Science. This process is done exclusively to report to the IEA. There are other RD&D data collection processes in parallel, but none of them is exclusive to the energy field.

To complete the IEA questionnaire, the Ministry of Science and Higher Education sends the IEA questionnaire to the two main funding agencies. The two agencies report funds based on obligations, so the actual money provided to R&D projects in the year of study according to the contracts signed. Data are classified according to the IEA classification and reported in the IEA questionnaire. This is done by the funding agencies, who go through their project database and classify each individual project based on the keywords in the titles and abstracts. The coverage of the Polish data collection is partial as only these two funding agencies and the Ministry of Science and Higher Education itself are included in the process. Other funding agencies supervised by other ministries are not included, and those are mainly funding demonstration projects.

In general, Poland reports the data at the two-digit level. Demonstration projects and state-owned enterprises are not included in the coverage. A big part of the data validation is done by the funding agencies.

Data management and technology

The process is supported by the IEA questionnaire in Excel files and emails. The funding agencies have internal databases of all the projects they fund, which are the main data source they use to fill in the IEA questionnaire.

Data dissemination

The process is done exclusively for the IEA, which collects the questionnaire from IEA members, and the data are not published in any national report. In some cases, the data are used by policy makers to design programmes and policies.

Portugal

Institutional arrangement	
Reporting institutions	Directorate General for Energy and Geology (DGEG) Data collection by the Directorate General for Education and Science Statistics (DGEEC), under the Ministry for Education and the Ministry for Science, Technology and Higher Education
Role of reporting institutions	DGEG: Designing, implementing and evaluating policies on energy and geological resources DGEEC: Guaranteeing the production and statistical analysis of education and science
Funding responsibilities	Not funding institutions
Way to formalise relationship between institutions	Obligation under Law No. 22/2008, which makes reporting data to statistics authorities mandatory Relationship between the DGEG and DGEEC based on informal agreements of collaboration

Collection, classification and validation process	
Type of data collection	Structured survey to performers
Type of survey	General survey for RD&D. Not exclusive to energy
Survey frequency	Annual
Classification	Only classified to the one-digit level of the IEA classification by respondents of the survey
Data validation	Good data quality estimated based on a high response rate

Data management and technology	
Data platform	Data collection platform to manage the surveys (iPCTn)
Advanced data analytics	No

Data dissemination	
Main data users	Ministries
Dissemination channel	DGEEC website
Main publication	No publication

Purpose

The RD&D data collection in Portugal provides the quantitative basis to assess the evolution of the national science and technology system. Portugal uses surveys to identify the volume of resources devoted to RD&D in public and private

institutions across the country. In addition, as a member, Portugal is committed to submitting energy RD&D data to the IEA.

Institutional arrangement

The institution responsible for reporting energy RD&D data to the IEA is the DGEG. However, the reported data are based on the data collection carried out by the DGEEC under the Ministry for Education and the Ministry for Science, Technology and Higher Education.

Data are captured by two annual surveys: the Survey of the National Scientific and Technological Potential (IPCTN) for government, state-owned enterprises and private non-profit institutions, and the IPCTN for the private sector. Law No. 22/2008 is the legal framework that supports this data collection. This law makes it compulsory for public and private institutions to report to an official body collecting statistics.

The main RD&D funder in Portugal is the Foundation of Science and Technology, the Portuguese public agency that supports science, technology and innovation in all scientific domains, under the responsibility of the Ministry for Science, Technology and Higher Education. Most funds are allocated on a competitive basis.

Collection, classification and validation process

Portugal has collected RD&D data from both public and private organisations through the IPCTN since the 1960s. This was a biannual survey until the 2008 year of study, after which it became annual.

It follows the internationally established guidelines by the OECD with four institutional sectors: business and enterprise, government, higher education and private non-profit.

Every year, in March, the Institutions Directory, which includes the institutions that receive the request to answer the IPCTN on an annual basis, is updated. Portugal uses information from the previous inquiries and consults various institutional sources, such as:

- websites of universities, colleges, polytechnic institutes, higher schools and research centres
- Tax Incentive System for Business R&D
- Foundation for Science and Technology, a public agency funding RD&D projects
- a list of companies with RD&D and innovation projects financed under Portugal 2020, which includes general and regional operational programmes

- companies participating in projects within the European Union (Framework Programmes for R&D and H2020)
- companies with investment in RD&D or in declared development in the various items of simplified business information
- companies with primary or secondary economic activities classified in division 72 of CAE-Rev. 3 (scientific research and development activities)
- companies located in technology parks or RD&D incubator technology centres and other institutions that interface with companies, among others.

After this, the platform for the survey (IPCTN) is opened, and companies and public institutions are required to provide their RD&D data. This platform includes a digital version of the questionnaires. There are two different questionnaires, one for private companies and another for public institutions. This survey is completed by both funding agencies and performers.

In 2019, globally, 12 049 potential RD&D executing entities were surveyed, of which 10 518 answered, representing a response rate of 87%. Among the respondents, 4 707 were entities that carried out RD&D.

Summary of 2019 respondents by organisation type

Organisation	Surveyed	Answers	Response rate	Active in RD&D
Companies	10 540	9 112	86.0%	3 761
State entities	816	721	88.0%	310
Higher education units	623	620	99.5%	599
Private non-profit institutions	701	65	93.0%	37

The energy RD&D data are sorted on the basis of replies to question 5 (energy) of the survey. In this question, the nomenclature of socio-economic objectives is based on the Nomenclature for the Analysis and Comparison of Scientific Programmes and Budgets. Starting from the 2019 survey, the IPCTN questionnaire form disaggregated the energy objective in order to comply with the one-digit level of the IEA questionnaire.

The platform is open until December. Then, the collected data are processed through the platform. Once the DGEG receives the request from the IEA to answer the questionnaire, consolidated energy RD&D data for government and private sector are collected from the DGEEC.

Data management and technology

Due to the large number of respondents for the RD&D survey, Portugal maintains a platform where respondents can submit the data. The platform contains digital questionnaires, and the user management allows only the entities in the Institutions Directory to input the data. The platform is managed by the DGEEC, which processes the answers to compile the RD&D statistics.

Data dissemination

Data are exclusively disseminated by the DGEEC on its website, and there is no specific publication for energy RD&D. In fact, the DGEG does not publish any RD&D data. Nonetheless, the energy RD&D data are used internally to evaluate the progress of the National Plan for Energy and Climate Change.

Spain

Institutional arrangement	
Reporting institutions	Ministry for the Ecological Transition and the Demographic Challenge (MITECO) – reporting to the IEA Ministry of Science and Innovation – data collection
Role of reporting institutions	MITECO: Responsible for developing policies for the fight against climate change, prevention of pollution and protection of the environment and energy Ministry of Science and Innovation: Responsible for developing and implementing policies on scientific research, technological development and innovation
Funding responsibilities of the reporting institutions	No direct funding, only through funding agencies
Way to formalise relationship between institutions	Informal agreements General legal framework that allows the public administration to collect the data needed to compile the statistics

Collection, classification and validation process	
Type of data collection	Survey
Type of survey	Yes
Survey frequency	Annual, aligned with the IEA cycle
Classification	IEA classification done by the surveyed institutions
Data validation	Basic data consistency checks

Data management and technology	
Data platform	No
Advanced data analytics	No

Data dissemination	
Main data users	Process designed to report to the IEA
Dissemination channel	Not published
Main publication	Not published

Purpose

The purpose of collecting energy RD&D data in Spain is mainly for submission to the IEA and the European Commission and to respect its engagements as a member.

Institutional arrangement

The responsibility to report data to the IEA in Spain lies with MITECO. For this reason, they are also responsible for submitting the energy RD&D questionnaire. However, it is the Ministry of Science and Innovation who collects the data. They compile the data and send them to MITECO, who submits them to the IEA. These two ministries collaborate actively across this process.

To complete the IEA questionnaire, the Ministry of Science and Innovation requests the energy RD&D project data from the two central funding agencies: the State Research Agency and the Centre for the Development of Industrial Technology. The coverage of the Spanish data collection is partial as only these two funding agencies are included in the process. Other smaller funding agencies, university funds and funding institutions from the autonomous communities are not included.

There is no specific legal framework for the energy RD&D data collection. However, there is a general legal framework that allows the public administration to collect the data needed to compile the statistics and makes it compulsory for the respondent to provide the data, including private sector. However, RD&D data are out of the scope of the regulation of energy statistics in Europe and Spain. This legal framework would be a powerful tool for member states to strengthen the process.

Even though there is strong collaboration between the ministries and the National Statistics Institute, the energy RD&D data collected by the Ministry of Science and Innovation are not shared with them. However, this interaction between the ministries and the statistics office is currently growing.

Funding institutions and major programmes

The scope of the Spanish energy RD&D data collection is limited to the two following funding agencies.

Funding institution	Major programmes
State Research Agency	National Plan for Scientific and Technical Research and Innovation 2021-2023 There is a specific strategy workstream: climate, energy and mobility.
Centre for the Development of Industrial Technology	Offers different types of aid (reimbursable aid, partially reimbursable aid and subsidies), which are part of the National Plan for Scientific and Technical Research and Innovation 2021-2023.

Ministry for the Ecological Transition and the Demographic Challenge (MITECO) Institute for Diversification and Saving of Energy	In the framework of the Resilience and Recovery Plan, several components dedicated to the energy sector (components 7, 8, 9 and 10) contain RD&D programmes to promote the use of new technologies. The PERTE ERHA, a public-private partnership programme in the framework of the Resilience and Recovery Plan, contains several lines of support related to the RD&D phase of development of energy technologies, such as energy storage, hydrogen and offshore wind.

Collection, classification and validation process

Every year, aligned with the IEA deadlines, MITECO asks the Ministry of Science and Innovation to send the IEA questionnaire to the two funding agencies: AEI and CDTI. This process is done exclusively to report to the IEA. There are other RD&D data collection processes in parallel, but none of them is exclusive to the energy field. There are internal discussions to harmonise this process with the general RD&D data collection process.

The two agencies report the actual money provided to RD&D projects in the year of study according to the contracts signed. Data are classified according to the IEA classification and reported in the IEA questionnaire. The ministries do not have a lot of visibility of the internal processes of the funding agencies. The coverage includes only the money flows from these two funding agencies to research institutions, and the funds provided by the research institutions themselves or other funding agencies are not covered.

In general terms, Spain reports the data at the two-digit level. In some cases, a part of the collected data may have a bigger granularity (to the two-digit level), but the data are aggregated to the highest level of the two funding agencies to provide uniformity of the dataset. Demonstration projects are not reported separately, and state-owned enterprises are not included in the coverage.

A significant part of the data validation is done by the funding agencies, and despite the problems with the coverage, the collected data has good quality. Sometimes, the Ministry of Science and Innovation performs in-depth analyses of specific programmes and funding activities. These opportunities are used to further validate the dataset by the ministry and to collect metadata.

Even though it may not happen in the short term, Spain is planning to improve this data collection. Promoted by the European Union and Eurostat, Spain is

participating in a working group to define a process to collect energy RD&D in Europe. Spain will need to adapt and transform its current process to meet the objective and to report the progress of the National Energy and Climate Plan. It will be key to have a common taxonomy between the European Union and the IEA to minimise the burden of this process.

Data management and technology

The process is supported by the IEA questionnaire in Excel files and emails.

Data dissemination

The process is exclusively done for the IEA and the European Commission, which collects the IEA questionnaire from IEA members. For this reason, the data are not published in any national report. In some particular cases, there are internal users, but this is not common.

Switzerland

Institutional arrangement	
Reporting institution	Swiss Federal Office of Energy, Energy Research and Cleantech, in the Department of the Environment, Transport, Energy and Communications
Role of reporting institution	Energy ministry responsible for all the aspects of energy policy, including energy research policy
Funding responsibilities	One of the main funding institutions in the energy domain, covering the innovation chain between fundamental research and product-related development
Way to formalise relationship between institutions	Parts of the data collection covered by article 53 of the Federal Act on the Promotion of Research and Innovation

Collection, classification and validation process	
Type of data collection	Public databases Survey
Type of survey	Survey of all relevant research organisations requesting a list of in-house projects with no European Union or federal funding
Survey frequency	Annual
Data extraction	Projects including European Union or federal funding Co-ordination and overhead costs
Frequency of data extraction	Annual
Classification	IEA classification done by the co-ordinating team Swiss internal classification also used
Data validation	Continuity of spending Close collaboration with funding and research institutions to ensure data quality Top-down check

Data management and technology	
Data platform	Internal offline database fed by pre-processed data from three public databases and surveys
Advanced data analytics	Many automatic processes with R scripts to download and filter the data

Data dissemination	
Main data users	Energy Research Commission, internal users, international reporting and universities, media, public and the parliament
Dissemination channel	Website

Data dissemination	
Main publications	Raw data at the topic level Swiss Energy Research Statistics

Purpose

Switzerland has been collecting data related to energy RD&D data since before the IEA started collecting these data from its member countries. The main objective of this collection is to use them as the quantitative basis for the design of Swiss energy research policies (also used by the Research and Innovation Ministry). It is also the quantitative basis for the evaluation of Swiss research programmes and project funding and is used to answer questions from parliament and the public.

For these reasons, Switzerland tries to have a complete view of national energy RD&D funds, including the co-ordination and overhead costs. It tracks the money flows, identifying the funders and the spenders while classifying projects per topic and project type.

Institutional arrangement

The data collection is done by the Energy Research and Cleantech team of the Swiss Federal Office of Energy, which is responsible for the national and international co-ordination of energy research in Switzerland. This office is inside the Department of the Environment, Transport, Energy and Communications, a ministry of the federal government of Switzerland. Additionally, there are different cantonal funding bodies that report the data from an annual survey. Even though the Swiss Federal Office of Energy is one of the main funders of the country, a considerable effort is carried out to collect data from other spending institutions and funding bodies.

Thus, the co-ordinating team continuously screens energy RD&D activities in Switzerland to make sure that they identify the key actors and gather relevant information about them, such as the field of research they are active in and the main researchers and project managers in all universities, universities of applied sciences, research centres and the private sector.

The same is done for the main funding institutions and programmes. The Swiss Federal Office of Energy identifies contacts in all the active institutions.

There is no specific legislation regulating the responsibilities of each member of the network, but parts of the data collection by the Swiss Federal Office of Energy are based on article 53 of Federal Act on the Promotion of Research and Innovation. Additionally, the researchers receiving any federal public funding are obliged to agree that the main information of the project is visible in a public

database, making the process very efficient. As these data are the quantitative basis for the evaluation of research programmes, all the members of the network have the common interest to have as good data quality as possible.

Due to the efficiency of the process, the Swiss process requires limited personnel resources (0.1-0.2 FTE) and has very limited external dependency, relying as much as possible on publicly available data.

Funding institutions and major programmes

The Swiss energy RD&D data submitted to the IEA cover the following main funding institutions and programmes.

Energy RD&D funding institutions and major programmes in Switzerland

Funding institution	Major programmes
ETH Domain	Basic financing and internal competitive programmes of the federal technical universities and research organisations (Swiss Federal Institute of Technology in Zürich, Swiss Federal Institute of Technology Lausanne, Paul Scherrer Institute, Swiss Federal Laboratories for Material Science and Technology, Swiss Federal Institute of Aquatic Science and Technology, Swiss Federal Institute for Forest, Snow and Landscape Research)
Swiss National Science Foundation	Open project funding (fundamental research) National Research Programmes National Centres of Competence in Research European Cooperation in Science and Technology
Swiss Innovation Agency	Open project funding (applied research and development) BRIDGE Flagship Initiative EUREKA/Eurostars
Swiss Federal Office of Energy	SWiss Energy research for the Energy Transition Energy Research Programmes Pilot and Demonstration Programme
Swiss Federal Nuclear Safety Inspectorate	Nuclear Safety Research Programme Radioactive Waste Research Programme

Funding institution	Major programmes
State Secretariat for Education Research and Innovation	Replacement measures Horizon 2020 Replacement measures Horizon Europe Euratom
Cantons	Basic financing of cantonal universities and universities of applied sciences

Collection, classification and validation process

The Swiss process to collect, classify, validate and publish the data is divided into five steps and done in an annual cycle:

- step 1: analysis of the landscape
- step 2: federal and EU data management
- step 3: regional and institutional data management
- step 4: co-ordination and overhead costs
- step 5: publication.

The first step consists of a continuous process of overview and identification of key actors in the energy RD&D landscape. The output of this process is to connect with a contact person in each of these institutions and to make sure that all the relevant programmes are considered in the process. These contacts are key to the robustness of the process as they will assist in the classification of projects and provide additional data.

The second step is the biggest one and is carried out between March and May, when project information is available in public databases with federal or EU funding. Data availability is manually checked, and once this is done, the Swiss Federal Office of Energy downloads the data from three public project databases: Swiss National Science Foundation, Aramis and CORDIS. There are around 3 000 new projects to be filtered every year, 10% being energy relevant. This is done automatically, using R code. These databases include either the real payments or the approved total contributions from public funding bodies to research organisations.

Once the data are downloaded, they are filtered based on different criteria, such as the keywords in the title and project description, the programme and the funding area. This results in the compilation of a list of energy projects. This is also done using R code. After the filtering process, there is a manual verification to reduce false positives and false negatives. Then, each of the projects is classified down to the most detailed level of the IEA and the Swiss classifications. This is the most time-consuming part of the process. Two people undertake a semi-automatic process to classify the type of research project and then a manual classification of

the topic. Finally, the availability of annual payment data is assessed, and the budgetary stage is selected based on the following priority criteria, converting the currency when needed:

1. effective annual payment
2. annual payments according to the budget
3. estimated annual amounts from the total budget.

Once all the data are selected and arranged, they are transformed into an Excel format to perform a final manual consistency check.

The third step is the collection through surveys of non-federal and non-EU funding. This is done by collecting the information directly from the contacts with surveys between June and August. Using R scripts, three files are created with a list of projects per research organisation:

1. Projects according to step 2 (with federal or EU funding for the year of interest). This is mainly for their information.
2. Projects according to step 3 of the previous year that are still ongoing (with own or cantonal funds in the previous year). They are asked to complete the spending for the year of study.
3. A list with empty rows to indicate new projects or projects missed last year.

These questionnaires are sent by email to all the contact persons with a deadline to send them back within a few weeks. As soon as these files are received back, they are checked manually looking at the duplicates, the scope and classification according to the Swiss and IEA guidelines, and the project type, etc. Including federal funding, there are around 600 new projects every year to be classified. Finally, the consolidated list of projects is loaded into the system and transformed into an Excel comma-separated value format. A total of more than 2 000 projects and activities are included in the annual statistics.

The fourth step is the collection of the co-ordination and overhead costs. This can be done in parallel with step 3 as soon as the federal institutions, the universities and the universities of applied science report these costs to the Federal Statistical Office. For other funding agencies, such as the Swiss National Science Foundation, these data are extracted from their public annual reports. Then, co-ordination and overhead costs are proportionally allocated to the projects funded by each agency. In 2019, CHF 427 million were accounted for in the statistics, of which 53% corresponded to projects in the databases in step 2, 21% to the questionnaires in step 3 and 26% to the estimates of overhead costs in step 4.

The fifth step is publication and data dissemination. In November, the first draft version of the data is prepared. Publication is further explained in the data dissemination section. To prepare the submission for the IEA, the EU contributions are excluded.

Data management and technology

The energy RD&D statistics in Switzerland are conditioned by two main premises: limited personnel resources and minimum dependency on third parties. For these reasons, the process is well-engineered, and the data extractions from public databases are automated. There is no central database or platform, but R scripts are used to do the queries on external databases, the filtering and the export into the Excel format.

Data dissemination

Once a year, the data are published on the Swiss Federal Office of Energy website in the publication Swiss Energy Research Statistics. Data are published according to both IEA and Swiss classifications in an Excel spreadsheet. Data are arranged in different tables according to:

- Research organisation.
- Funding source.
- Type of research.
- Swiss classification system.
- IEA classification system.

Switzerland has started publishing the raw data at the topic level as part of the open government data initiative that was started two years ago. Additionally, the energy RD&D data are also disseminated in a summary and in specialised articles for different technologies.

United Kingdom

Institutional arrangement	
Reporting institution	Department for Business, Energy and Industrial Strategy
Role of reporting institution	Government department
Funding responsibilities of the reporting institution	Major funder of energy innovation
Way to formalise relationship between institutions	Informal agreement

Collection, classification and validation process	
Type of data collection	Survey to other institutions
Type of survey	Same survey as IEA
Survey frequency	Annual
Classification	IEA classification
Data validation	Coherence check of the questionnaire and alignment with the previous year's reporting. Inconsistencies are solved in collaboration with the contacts

Data management and technology	
Data platform	Excel
Advanced data analytics	No

Data dissemination	
Main data users	Policy makers
Dissemination channel	Website
Main publication	There is no UK document exclusively on energy RD&D data, but the data are used in many publications

Purpose

The Department for Business, Energy and Industrial Strategy co-ordinates the United Kingdom's (UK) energy RD&D data collection across all relevant departments and bodies and provides this to the IEA as well as a more detailed split between departments to the government's Net Zero Innovation Board. The Net Zero Innovation Board provides strategic oversight of the government funding of net zero innovation programmes.

Institutional arrangement

The institution responsible for the data collection and compilation in the United Kingdom is the Department for Business, Energy and Industrial Strategy, which lead the country's analysis of energy innovation and co-ordinates the collection of energy RD&D data across the public sector.

There is no specific piece of regulation governing this activity, but it is managed through informal agreements with different departments and public sector bodies, each of which names a contact to provide the data to the co-ordinating team.

Collection, classification and validation process

Every year, the Department for Business, Energy and Industrial Strategy contacts all public RD&D funding bodies across the United Kingdom to prepare them for data collection. The department distributes the IEA questionnaire to all the organisations active in RD&D and asks them to complete it for spending during the United Kingdom's financial year (from 6 April to 5 April of the following year).

When inconsistencies are found in data returns, teams across the government are consulted to ensure the figures are being correctly reported. Guidance on classification methodology is aligned across the government, however there is a degree of interpretation, especially for organisations running innovation programmes that have a wide scope.

The UK government's financial year finishes in April, and their data update is usually available around August.

Data management and technology

There is no central database or platform in the United Kingdom. For this reason, the exchange of information between different institutions is done by email using the Excel template of the IEA, when possible, or other Excel files. The project-specific information is managed by each of the bodies and organisations, so the Department for Business, Energy and Industrial Strategy does not have visibility of the processes of each institution in the network for filling in the questionnaire.

Data dissemination

The questionnaire is used to report to the IEA and to support the UK government's analysis on energy innovation. There is no specific publication of the data, but they are used as an evidence source in various UK strategy documents.

Abbreviations and acronyms

DGEG	Directorate General for Energy and Geology
ECLAC	Economic Commission for Latin America and the Caribbean
FTE	Full-time equivalents
IEA	International Energy Agency
IT	Information technology
NRDIO	National Research, Development and Innovation Office
R&D	Research and experimental development
RD&D	Research, development and demonstration
SEAI	Sustainable Energy Authority of Ireland
SET	Strategic Energy Technology
SETIS	Strategic Energy Technology Plan Information System

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