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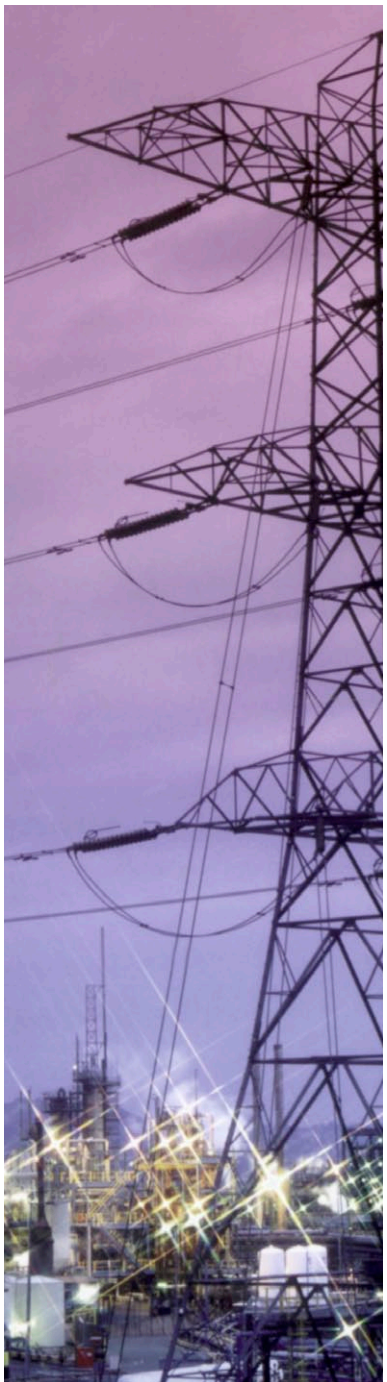
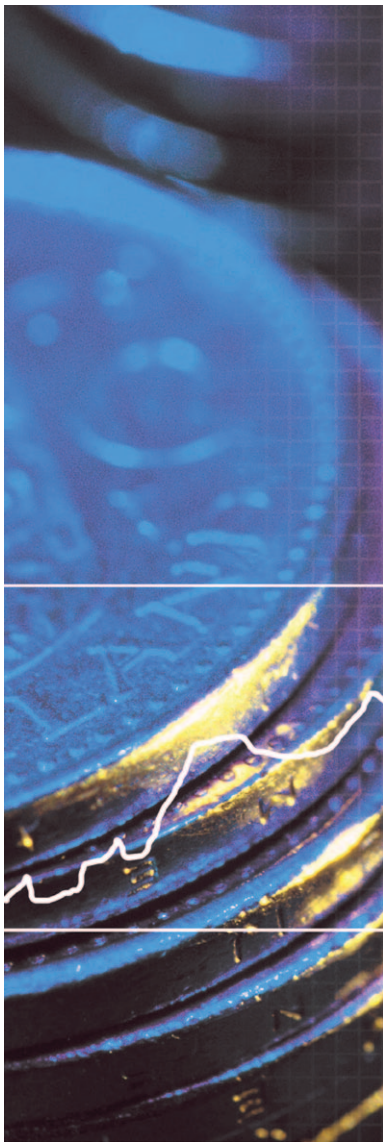
IEA Guide to Reporting Energy RD&D Budget/ Expenditure Statistics





International Energy Agency

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 28 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

IEA member countries:

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Japan
Korea (Republic of)
Luxembourg
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

The European Commission also participates in the work of the IEA.

International Energy Agency

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FOREWORD

As part of an ongoing effort to improve the reporting of energy research, development and demonstration (RD&D) budgets, and to leverage the high-level policy attention to these data provided by various fora, in 2010 the IEA undertook an evaluation of its categories for reporting public sector RD&D spending. The goal was to ensure that the categories accurately reflect the evolving portfolio of energy research that is underway, while at the same time balancing this with a framework that allowed reporting by countries that did not currently have budgets at a detailed level. Over several months, the IEA consulted both with member countries and with IEA experts to determine the level of detail that should be requested. As a consequence of these consultations, the IEA has updated the RD&D questionnaire to ensure better coverage of some of the fast-growing sectors while at the same time enabling countries with less detail to continue reporting their budget information.

In parallel, the IEA undertook the development of this manual to help countries provide good quality and harmonised information on RD&D budgets. The first part of the manual is based heavily on the 2002 edition of the *Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development*, published by the OECD. This part of the manual briefly describes some basic concepts relating to R&D statistics and how they relate to the energy RD&D statistics collected by the IEA. It also gives tips on how to fill in the IEA questionnaire. The second part of the manual gives precise definitions for each of the items requested in the questionnaire.

The consultation with member countries and the draft manual culminated in a workshop on 25-26 May 2011 entitled "Improving decision making on energy research, development & demonstration investment through enhanced data and analysis". Discussion during the workshop was animated, and the IEA is pleased to report that participants in the meeting actively contributed to improving both the questionnaire and the manual. The IEA is confident that these two elements will help to improve the collection and reporting of energy RD&D in the future, both in terms of coverage and accuracy.

The *IEA Guide to Reporting Energy RD&D Budget/Expenditure Statistics* is published under my authority as Executive Director of the IEA.

Nobuo Tanaka

Executive Director
International Energy Agency

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The IEA would like to thank and acknowledge the dedication and professionalism of the participants from the member countries who contributed substantively to both the questionnaire design and the technical definitions for the manual. Laura Diaz Anadon, Charles Jones and Ruud Kempener, from Harvard University, also provided many helpful comments.

This manual would not have been possible without the many IEA and OECD colleagues who gave their contributions, comments and suggestions: Robert Arnot, Milou Beerepoot, Adam Brown, Keith Burnard, Douglas Cooke, Anne-Sophie Corbeau, Davide D'Ambrosio, Zuzana Dobrotkova, Anselm Eisentraut, David Elzinga, Carlos Fernandez Alvarez, Paolo Frankl, Lew Fulton, Fernando Galindo-Rueda, Steve Heinen, Shinichiro Kadono, Tom Kerr, Seul-Ki Kim, Juho Lipponen, Vladimir Lopez-Bassols, Samantha Olz, Cedric Philibert, Carrie Pottinger, Yamina Saheb, Robert Schnapp, Cecilia Tam, Michael Taylor, Peter Taylor, Paul Tepes and Michael Waldron. Desktop publishing was carried out by Sharon Burghgraeve and Corinne Hayworth.

PART 1

FUNDAMENTALS

I • INTRODUCTION

I.1 Background

The International Energy Agency (IEA) acts as energy policy advisor for the governments of its 28 member countries and beyond to promote reliable, affordable and clean energy for the world's consumers.

As such, one of its priorities is to collect data on research, development and demonstration (RD&D) spending in the field of energy. The IEA has been collecting data on government funding of RD&D activities across countries since 1974. 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 quality of IEA statistics and recommendations is directly dependent on the quality of the information delivered by national data collectors in countries. Since the IEA questionnaire uses very precise and technical terms, the availability of guidelines to help national data collectors in their task should greatly enhance the quality of the information on RD&D that is collected.

I.2 Concept of the manual

This manual was written by the IEA for experts who collect and issue national RD&D data and submit responses to IEA RD&D surveys; it is mainly intended as a reference document.

The aim of the manual is not to provide statistics from previous surveys. Therefore, no key global figures or country figures are included in this document.

The manual is divided into two parts:

Part 1 - Fundamentals: this part of the manual defines how the questionnaire is structured and presents guidelines on which types of budgets/expenditures should be included by national data collectors in the IEA RD&D questionnaire. It covers all energy-related activities.

Part 2 - Definition of terms: this part of the manual gives precise definitions of all energy-related items that correspond to a specific row in the IEA questionnaire. The questionnaire is split into seven main groups: energy efficiency, fossil fuels, renewable energy sources, nuclear fission and fusion, hydrogen and fuel cells, other power and storage technologies and other cross-cutting technologies or research.

The IEA RD&D guidelines are largely inspired by the 2002 edition of the OECD *Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development*. The *Frascati Manual*, first published in 1962, is the key reference book on the subject of research and experimental development (R&D) measurement, and it is cited when appropriate. The *Frascati Manual* can be downloaded for free from *http://www.oecdbookshop.org*.

The *IEA Guide to Reporting RD&D Budget/Expenditure Statistics* is published in electronic version and is available on the Internet at *http://www.iea.org*.

II • SCOPE OF THE MANUAL

II.1 What is "Energy RD&D"?

General concepts related to R&D (Frascati Manual)

"**R&D** comprises creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications." *(Frascati Manual, 63)*

R&D covers three activities:

Basic research: the experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. *(Frascati Manual, 240)*

Applied research: the original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective. *(Frascati Manual, 245)*

Experimental development: the systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed. *(Frascati Manual, 249)*

R&D excludes:

Demonstration: the design, construction, and operation of a prototype of a technology at or near commercial scale with the purpose of providing technical, economic and environmental information to industrialists, financiers, regulators and policy makers.

Deployment: the selection and use of a commercially available technology-based product or service in normal operations by businesses, individuals or government agencies with the aim of accelerating the diffusion and adoption of technologies or practices. [1]

Other exclusions

R&D must be distinguished from a wide range of related activities with a scientific and technological basis; therefore, R&D efforts *exclude* projects from the following areas:

"Education and training (partially excluded)" relates to all education and training of personnel in universities and special institutions of higher and post-secondary education and should be excluded. However, research by students at the PhD level carried out at universities should be counted, whenever possible. *(Frascati Manual, 68)*

"Administration and other supporting activities" related to the raising, management and distribution of R&D funds to performers by ministries, research agencies, foundations or charities should be excluded. Indirect supporting activities such as repair, maintenance and security activities within R&D centres should also be excluded. *(Frascati Manual, 81-83)*

1. Government activities intended to accelerate the diffusion into the marketplace of technologies or practices, whose adoption would advance attainment of public policy goals, are considered deployment, and are not R&D. Examples include outreach, technical assistance, energy audits, efficiency labelling, consumer guides, information dissemination, voluntary programs, market development, pre-production planning, and work to get a production or control system working smoothly. These activities are often complementary parts of a technology R&D program, but their costs should not be counted as R&D.

"Other related scientific and technological data (partially excluded)" relates to the following activities and should be excluded except when conducted solely or primarily for the purpose of supporting an R&D project:

- Scientific and technical information services,
- General purpose data collection,
- Testing, standardisation and feasibility studies,
- Patent and licence work,
- Policy-related studies,
- Routine software development.

(Frascati Manual, 69-77)

"Other industrial activities" related to innovation, production and related technical activities should be excluded. This covers activities from the acquisition of technology (embodied and disembodied), tooling up and industrial engineering, industrial design to industrial preproduction and production as well as allied activities such as market research. *(Frascati Manual, 78-79)*

Specificities of energy RD&D

Energy RD&D reported under this manual should include the research, development, and demonstration as defined above when the work applies to technologies that are used to extract, convert, generate, transport, distribute, control, and use energy. Energy in this context should include the entire chain from primary forms found in nature, through secondary forms more convenient for transport and storage, through to end uses such as heat, light, motive force, and other energy services.

The IEA concept of Energy RD&D differs from the Frascati concept of R&D, in that: (i) it focuses on energy-related programmes only; (ii) it includes "demonstration projects"; and (iii) it includes state-owned companies.

The IEA has decided to include demonstration projects when collecting R&D budget data because quite often this is an important part of the development of new technologies. The project's outcome may be uncertain and there is an element of risk that is often too large for the private sector to assume alone.

Coverage

Energy **RD&D** covers research, development and demonstration related to the production, storage, transportation, distribution and rational use of all forms of energy.

Energy RD&D covers:

- Basic research when it is clearly oriented towards the development of energy-related technologies,
- Applied research,
- Experimental development,
- Demonstration.(shown separately)

For the purposes of energy RD&D, state-owned companies should be considered as public bodies, but shown separately.

*Deployment should be **excluded** from RD&D.*

The IEA's RD&D data comprise all programmes that focus on: (i) sourcing energy; (ii) transporting energy; (iii) using energy; and (iv) enhancing energy efficiency.

This includes all RD&D programmes that concern one of the following seven main branches of energy-related developments, as collected by the IEA, which are: (i) energy efficiency; (ii) fossil fuels (oil, gas and coal); (iii) renewables; (iv) nuclear fission and fusion; (v) hydrogen and fuel cells; (vi) other power and storage techniques; and (vii) other cross-cutting technologies or research.

The energy RD&D data collected by the IEA should not be confused with the data on government budget appropriations or outlays on R&D (GBAORD[2]) collected by the OECD Directorate for Science, Technology and Industry for the socio-economic objective "Production, distribution and rational utilisation of energy", as defined in the *Frascati Manual*, which is a somewhat narrower concept. *(Frascati Manual, 503-515)*

II.2 What are public RD&D budgets/expenditures[3]?

RD&D performer-based expenditures *vs.* budget data sources

Government energy technology RD&D budgets are submitted on an annual questionnaire every year to the IEA Secretariat by national administrations. This focus on budgets reflects user interest in the extent of government effort in support of energy technologies development. This concept and its practical implementation through data collection need some clarification.

Firstly, it is important to draw a clear distinction between this concept of budget effort and measures of RD&D activity in the economy. Estimates of RD&D can be reported: (i) from a performer perspective as expenditures; or (ii) from a funder perspective as budgets.

RD&D intramural expenditures can be calculated based on surveys of the units that carry out RD&D in order to identify the amount effectively spent on RD&D. The sources of the data are the **performers**, i.e. the entities undertaking the RD&D activity across all sectors, both in the public and private sectors. The analogue to this concept in the *Frascati Manual* for R&D is the gross expenditure in R&D (GERD), hence the sum of the RD&D spending in a national territory could be known as "gross domestic expenditure on RD&D", part of which is funded by government (government-financed GERD). This information can be also collected from the performers, as in the case of GERD.

Unfortunately, even with statistical sources in place, a measure of government-financed GERD data would not become available until between one and two years after the RD&D has been carried out. Furthermore, the RD&D-performing units responding to the surveys are sometimes unable to report on where their particular grant or contract fits in the government's overall energy policy. An alternative way of measuring government support for RD&D has been developed using data from budgets and related administrative sources.

RD&D budgets are calculated by identifying all the budget items involving RD&D and measuring or estimating their RD&D content in terms of **funding**. These estimates may be less accurate than performance-based data but as they are derived from the budget, they can be linked to policy through classification by "objectives" or "goals". In the context of the *Frascati Manual* on R&D, budget-based data are referred to as "government budget appropriations or outlays for RD&D" (GBAORD).

Budget figures are often appropriated over longer periods than one year. They also can be revised from year to year based on new budget allocations.

2. See Section II.2 "Budgets vs. expenditures" for an explanation of GBAORD.
3. In this section, the discussion is referring to RD&D. The IEA has adapted the original *Frascati Manual* definitions to also include demonstration.

Estimated budgets and actual expenditures by governments often differ because projected amounts of RD&D at the appropriations stage are different than what is actually measured by the performers. It may also be due to an imprecision in the budget appropriations that does not allow for separate identification of appropriations that are specifically targeted to RD&D.

Coverage

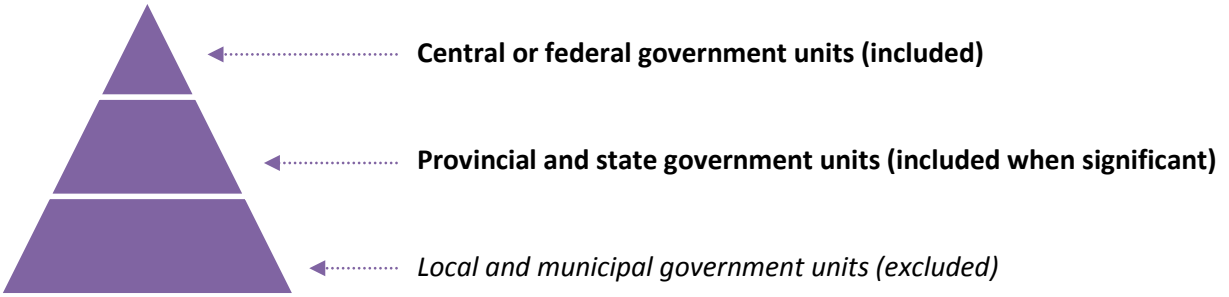
Energy RD&D budgets collected by the IEA should be reported on a GBAORD basis based on information coming from the funders.

What is public?

Overall, public RD&D collected by the IEA designates government budgets for energy RD&D, regardless of who the performer is.

Who funds?

The IEA scope includes RD&D funded by public bodies either at central or federal level, or at a country's first administrative subdivision level.



Identification of all public bodies involved in energy-related RD&D

Public RD&D data collected by the IEA designate government budgets/expenditures for energy RD&D, regardless of who the performer is.

Therefore, by identifying all government bodies involved in financing energy-related RD&D, the national data collector will make sure all concerned entities are covered.

Coverage

Government establishments:

- All bodies, departments and establishments of government – central, state or provincial – that engage in a range of energy-related activities. The legislature, the executive, departments, establishments and other bodies of government should be included, irrespective of their treatment in government accounts. *(Frascati Manual, 185)*
- All non-market non-profit institutions (NPIs) controlled and financed by government are included in the government sector.

Examples of government establishments are:

- Ministries or cabinet-level departments
- Regional councils
- Independent public agencies
- Government-funded research organisations
- Public higher-education establishments

To be exhaustive, the list of government establishments should include not only entities that dedicate their resources entirely to energy-related RD&D, but also entities that fund energy-related RD&D programs even though their main focus is on other activities.

Similarly, national entities funding specific non-national programs related to energy RD&D are included.

In normal R&D statistics, public enterprises are not considered as government establishments, as they are treated as part of the business enterprise sector. However, for the purposes of energy-related RD&D, state-owned enterprises should be treated as public bodies. The RD&D by these enterprises is quite large for certain sectors. In many, but not all instances, some of the funding comes from public tax money. If the RD&D spending from these enterprises were excluded, the usefulness of the RD&D energy budgets would be considerably diminished. Care should be taken to avoid double counting of any RD&D that may already figure in the government RD&D budgets.

If the spending occurs at the deployment stage, which is often the case for state-owned enterprises, then these amounts should not be included.

Who performs?

The IEA scope includes publicly financed energy RD&D performed in any establishment or organisation, at home or abroad, such as: (i) public establishments; (ii) any of the other three domestic sectors (business enterprise, private non-profit, higher education); as well as (iii) abroad programs.

Direct expenditures by IEA member countries in energy-related projects undertaken ***with*** the European Commission (EC) or other countries (bilaterally or multilaterally) should be included in national energy RD&D data. However, countries' contributions ***to*** the EC energy RD&D budget should not be included in national data.

Similarly, only contributions to international RD&D programmes or organisations solely or mainly concerned with energy RD&D should be included, for example contributions to:

- IAEA (International Atomic Energy Agency)
- ITER (International Thermonuclear Experimental Reactor)
- CERN (European Organisation for Nuclear Research)

The IEA RD&D data also take into account the public part of the RD&D financing of public-private partnerships (PPPs).

What is excluded?

- Contributions of each of the IEA-EU countries *to* the EC Energy RD&D budget (information on the EC energy RD&D budgets should be supplied directly by the EC),
- RD&D expenses of semi-public or private bodies,
- Privately funded spending from public bodies (RD&D expenses of public institutions financed by non-governmental sources, such as private companies are therefore excluded),
- Private contributions to PPPs,
- RD&D funding from local public bodies, NGOs and charities.

II.3 Main differences between GBAORD and GERD data

Users of the GBAORD often discover and have difficulty in understanding differences between the sums reported as total GBAORD and government-financed GERD and between GBAORD for a given objective and total RD&D expenditure on the same objectives. The variations in the sums reported spring from differences in the specifications of the data. *(Frascati Manual 520-526)*

General differences

In principle, both series should be established on the basis of the same definition of R&D, should cover R&D in both natural sciences and engineering and in social sciences and humanities and include both current and capital expenditures.

They differ in two main respects. First, government-financed GERD and GERD objectives data are based on reports by R&D performers, whereas GBAORD is based on reports by funders. Second, the GERD-based series cover only R&D performed on national territory, whereas GBAORD also includes payments to foreign performers, including international organisations.

Differences may also occur because the periods covered are different (calendar or fiscal years), because the money is finally spent by the performer in a later year than the one in which it was committed by the funder, and because the performer may have a different and more accurate idea of the R&D content of the project concerned.

GBAORD and government-financed GERD

In addition to the general differences, government-financed GERD should include R&D financed by central (or federal), provincial (or state) and local government, whereas GBAORD excludes local government and sometimes also provincial government.

GBAORD and GERD by socio-economic objectives

GBAORD covers only R&D financed by government (including abroad), whereas GERD covers all sources of funds on national territory.

The performer's appreciation of the objectives of the project concerned may differ significantly from that of the funder, notably for R&D funded from block grants such as public general university funds (GUF), which should be distributed by objective in the GERD approach.

III • Measurement of RD&D

This section of the Guidelines lays out some of the concepts covered in the *Frascati Manual* and specifies whether they should be included or excluded from the RD&D data. For more information on these concepts the paragraph reference in the *Frascati Manual* has been provided.

III.1 What is included in RD&D?

Costs and capital expenditures

Current costs include labour costs as well as non-capital purchases of materials, supplies and equipment to support RD&D performed by the statistical unit in a given period. Also, indirectly paid current costs are included, for example: (i) rents for research facilities; and (ii) social security costs and pensions for RD&D personnel. *(Frascati Manual, 361, 364)*

Capital expenditures are composed of expenditures on land and buildings, instruments and equipment as well as computer software. Capital expenditures are the expenditures on major fixed assets used in RD&D programs of statistical units. *(Frascati Manual, 374)*

Note: The boundary between "major" fixed assets and other fixed assets varies slightly among countries according to their taxation practices and among different firms and organisations in the same country according to their accounting practices. These differences are rarely significant, and it is neither necessary nor practical to insist on any rigid standard. (Frascati Manual, 384)

Coverage

Energy RD&D budgets collected by the IEA include both current costs, composed of labour costs and other current costs, and capital expenditures.

*The value-added tax (VAT) is **excluded**. (Frascati Manual, 371)*

Depreciation of fixed assets

Capital expenditures should be reported in full for the period when they took place and should not be registered as an element of depreciation. *(Frascati Manual, 374)*

As a consequence, all depreciation provisions for building, plant and equipment, whether real or imputed, should be excluded from the measurement of RD&D. *(Frascati Manual, 375)*

III.2 What is not considered as RD&D?

A lot of care must be taken to exclude activities which, though they are undoubtedly a part of the innovation process, rarely involve any RD&D. The following paragraphs aim at taking a closer look at the cut-off line between the energy RD&D data as requested by the IEA and data that are not included.

Scientific and technological activities

Scientific and technological activities (STA) comprise systematic activities which are closely concerned with the generation, advancement, dissemination and application of scientific and technological knowledge in all fields of science and technology.

As mentioned in section II.1, RD&D must be distinguished from a wide range of activities. The cut-off point between RD&D and non-RD&D data for each STA is detailed below.

The following activities are excluded from the IEA's energy RD&D data: STA of libraries and museums, translating and editing of scientific & technological (S&T) literature, surveying and prospecting, data collection on socio-economic phenomena, testing, standardisation and quality control, client counselling and advisory services. *(Frascati Manual, 19)*

Scientific and technical information services

The specialised activities of collecting, coding, recording, classifying, disseminating, translating, analysing and evaluating, all conducted by scientific and technical personnel, bibliographic services, patent services, scientific and technical information, extension and advisory services and scientific conferences are to be excluded, except when conducted solely or primarily for the purpose of RD&D support. For example, the preparation of the original report of RD&D findings should be included in RD&D. *(Frascati Manual, 70)*

General purpose data collection

General purpose data collection is undertaken generally by government agencies to record natural, biological or social phenomena that are of general public interest or that only the government has the resources to record. Examples are routine topographical mapping; routine geological, hydrological, oceanographic and meteorological surveying. Such data are excluded, except when the purpose of the research is solely or primarily to improve an energy RD&D process. Market surveys should also be excluded. *(Frascati Manual, 71)*

Testing and standardisation

Testing and standardisation items such as the maintenance of national standards, the calibration of secondary standards and routine testing and analysis of materials, components, products, processes, soils, atmosphere, etc. should be excluded from the IEA's RD&D data. *(Frascati Manual, 72)*

Feasibility studies

Investigation of proposed engineering projects, using existing techniques to provide additional information before deciding on implementation, is not RD&D. In the social sciences, feasibility studies are investigations of the socio-economic characteristics and implications of specific situations (*e.g.* a study of the viability of a petrochemical complex in a certain region). However, feasibility studies on research projects are part of RD&D. *(Frascati Manual, 73)*

Patent and licence work

Patent work connected directly with RD&D projects is included in the IEA's RD&D data. However, all other administrative and legal work connected with patents and licenses are excluded. Patent and licensing activities by public bodies are excluded. *(Frascati Manual, 19, 75)*

Policy-related studies

Policy-related studies cover a range of activities, such as the analysis and assessment of the existing programs, policies and operations of government departments and other institutions; the work of units concerned with the continuing analysis and monitoring of external phenomena; and the work of legislative commissions of inquiry concerned with general government or departmental policy or operations. Such studies are excluded. *(Frascati Manual, 76)*

Routine software development

Software-related activities of a routine nature are not considered to be RD&D. Such activities include work on system-specific or program-specific advances which were publicly available prior to the commencement of the work. Technical problems that have been overcome in previous projects on

the same operating systems and computer architecture are also excluded. Similarly, routine computer maintenance is excluded from RD&D. *(Frascati Manual, 77)*

RD&D and technological innovations

RD&D needs to be distinguished from the related activities required to realise an innovation, such as routine tests and public inspection control.

The greatest source of error in measuring RD&D is the difficulty of locating the cut-off point between experimental development and the related activities required to realise an innovation. The primary objective of RD&D is to make further technical improvements on the product or process. On the other hand, if the product, process or approach is substantially set and the primary objective is to develop markets, to do pre-production planning or to get a production or control system working smoothly, then the work is no longer RD&D. *(Frascati Manual, 21, 110)*

RD&D in software, social sciences and service activities

The tools developed for identifying RD&D in traditional fields and industries are not always easy to apply to new areas. This section deals with the problems of identifying RD&D in software development, in the social sciences and humanities and in service activities.

Software activities

For a software development to be classified as RD&D, its completion must be dependent on a scientific and/or technological advance, and the aim of the project must be the systematic resolution of a scientific and/or a technological uncertainty. *(Frascati Manual, 135)*

Should be included in RD&D, when (and only when) they are specifically related to energy:

- RD&D producing new theorems and algorithms in the field of theoretical computer science,
- Development of information technology at the level of operating systems, programming languages, data management, communications software and software development tools,
- Development of Internet technology,
- Research into methods of designing, developing, deploying or maintaining software,
- Software development that produces advances in generic approaches for capturing, transmitting, storing, retrieving, manipulating or displaying information,
- Experimental development aimed at filling technology knowledge gaps as necessary to develop a software programme or system,
- RD&D on software tools or technologies in specialised areas of computing.

Should be excluded from RD&D:

- Business application software and information system development using known methods and existing software tools,
- Support for existing systems, adaptation of existing software, preparation of user documents,
- Converting and/or translating computer languages,
- Adding user functionality to application programs,
- Debugging of systems.

Social sciences and humanities activities

An appreciable element of novelty or a resolution of scientific/technological uncertainty is again a useful criterion for defining the boundary between RD&D and related (routine) scientific activities. Related activities of a routine nature can only be included in RD&D if they are undertaken as an integral part of a specific research project or undertaken for the benefit of a specific research project.

Therefore, projects of a routine nature, in which social scientists bring established methodologies, principles and models of the social sciences to bear on a particular problem, cannot be classified as research.

The following are examples of work which might fall into this routine category are generally not RD&D: commentary on the probable economic effects of a change in the tax structure, using existing economic data, etc. *(Frascati Manual, 143-144)*

Service activities

Defining the boundaries of RD&D in service activities is challenging, for two main reasons: first, it is difficult to identify projects involving RD&D; and, second, the line between RD&D and other innovative activities which are not RD&D is a tenuous one. *(Frascati Manual, 145)*

The following are among the criteria that can help to identify the presence of RD&D in service activities:

- Links with public research laboratories,
- The involvement of staff with PhDs, or PhD students,
- The publication of research findings in scientific journals, organisation of scientific conferences or involvement in scientific reviews,
- The construction of prototypes or pilot plants.

RD&D administration and other supporting activities

The RD&D funding activities of policy agencies, such as ministries of science and technology or research councils, do not constitute RD&D. *(Frascati Manual, 26)*

Post-payment

Funds received for RD&D performed during earlier periods should be excluded from the sources of funds reported for the specific period. *(Frascati Manual, 390)*

IV • TIPS TO FILLING IN THE QUESTIONNAIRE

The IEA asks that respondents complete the tables provided without making any alterations, as these are used directly for computer processing.

IV.1 Structure of the questionnaire

Levels of information

The questionnaire comprises seven groups of energy-related RD&D topics:

- Energy efficiency
- Fossil fuels: oil, gas and coal
- Renewable energy sources
- Nuclear fission and fusion
- Hydrogen and fuels cells
- Other power and storage technologies
- Other cross-cutting technologies or research

For each of those groups, national data collectors should proceed as follows:

(i) Group-level data correspond to the total budgets/expenditures allocated to corresponding activities.

(ii) Data at the 2-digit level corresponds to a first breakdown of group-level data: the sum of all 2-digit level budgets/expenditures should match group-level budgets/expenditures. Every effort should be made to have complete information that adds up at this level.

(iii) Similarly, data at the 3-digit level provide a breakdown of the 2-digit level categories and data at the 4-digit level provide a breakdown of the 3-digit level. The 3-digit and 4-digit levels will be more difficult to complete.

At each of the 2-digit, 3-digit and 4-digit levels, a category for unallocated budgets/expenditures has been provided. This category should be used in the event that budgets/expenditures cannot be allocated to one specific area at that level, and where it is not possible to estimate the split between two or more of the sub-categories.

Memo items

The IEA RD&D questionnaire also requests data for new themes where RD&D is conducted across different technological groups. Those new themes are essential to the future of energy-related activities. Therefore, acquiring accurate data that are consistent among countries is essential to having a global and comprehensive view of these new technologies.

Memo items (currently limited to: (i) smart grids; (ii) electric vehicles; and (iii) energy storage) are calculated by adding budgets/expenditures already allocated to other categories, according to the table that can be found at the bottom of the questionnaire.

When parts of rows are required for the calculation of a memo item, the national data collector should allocate the most relevant figure, and avoid leaving a blank cell. Furthermore, it is possible that a country knows its spending figure on the new technology but does not know its breakdown between the IEA's current categorisation. In this case the memo item total should be reported on its own, without any breakdown.

Optional categories and the use of "Unallocated"

The categories at the 3-digit and 4-digit level are optional and the unallocated categories may be used. However, as mentioned above, every effort should be made to avoid using the unallocated rows and to divide budgets/expenditures into "normal" categories whenever possible.

R&D column

The R&D column contains budgets/expenditures on research and development. In previous questionnaires, this data was not collected separately but also included demonstration.

Demonstration column

Demonstration data should not be included in general figures of R&D data, but entered in the separate column entitled "Demonstration". Although not usual, if demonstration data on budgets/expenditures are confidential, then demonstration can be added to the R&D column and not shown separately. However, this should be noted in the metadata. If accurate demonstration data cannot be found, then please consult the instructions below in "Treatment of missing information".

RD&D for state-owned companies

The R&D and demonstration data for state-owned companies should be given separately in the appropriate table. If, however, RD&D budgets/expenditures data for the state-owned companies are confidential, then the amounts may be reported with the rest of the RD&D data and this should be noted in the metadata. If, for whatever reason, state-owned companies are not included, then this should also be noted in the metadata.

IV.2 Reporting issues

This section of the Manual attempts to respond to some frequently asked questions concerning the questionnaire.

Currency

RD&D figures should be entered in nominal million national currency units only.

For publication, the IEA Secretariat will convert the national currency units to USD (using exchange rates), to USD (using purchasing power parities) and to Euros (using exchange rates).

Fiscal year vs. calendar year

If the country does not report RD&D budgets/expenditures on a calendar year basis, then the fiscal year should be clearly indicated in the specified row.

Multi-annual projects

When reporting RD&D budgets, the *Frascati Manual* stipulates that multi-annual projects budgeted in only one year or over several years should be allocated to the data of the year(s) in which they are budgeted, not in the years of performance. Multi-annual programmes that are authorised at some

stage but budgeted over several years should be allocated to the years in which they are budgeted, not the year of authorisation. *(Frascati Manual, 495)*

When reporting multi-year budgets, the budget profile (if available) should be used to distribute the funds over the years of the multi-annual project. If no budget profile is available, then the funds should be allocated equally over the years.

Metadata

Metadata should be added to the submission of data when it is believed that the information provided will help the reader to better understand limitations to the data (for example, where the category of data requested is not fully congruent with the data provided or where some significant change in the statistics could benefit from explanation). These metadata can be added to the "comments" tab in the questionnaire, provided in a text file or included in the email when the questionnaire is transmitted.

Treatment of missing information

If some information is missing when completing the questionnaire, please specify which of the following categories of non-response is most accurate:

- Budgets/expenditures are nil, i.e. no activity ("--")
- Data are not available at this time ("n.a.")

Budgetary stage and actualisation of anterior data

Although details of the budgetary procedure vary from country to country, seven broad stages can be identified:

i) Forecasts (estimates of funding before beginning of budget discussion).
ii) Budget forecasts (preliminary figures as requested by ministries, especially for inter-ministerial discussions).
iii) Budget proposal (figures presented to the parliament for the coming year).
iv) Initial budget appropriations (figures as voted by the parliament for the coming year, including changes introduced in the parliamentary debate).
v) Final budget appropriations (figures as voted by the parliament for the coming year, including additional votes during the year).
vi) Obligations (money actually committed during the year).
vii) Actual outlays (money paid out during the year).

Stages i)-iv) describe the government's intentions. The data for budgetary year y should be available as soon as possible after the end of year y – 1. It is suggested that the preliminary GBAORD data should be based on the first budget agreed between the government and the parliament, or stage iv). Some countries might even base their preliminary figures on stage iii). During the budgetary year, supplementary budgets may be voted, including increases, cuts and reallocations of R&D funding. These are reflected in stage v). Data should be available as soon as possible after the end of the budgetary year. It is suggested that the final GBAORD data should be based on final budget appropriations. Some countries may have to base their final figures on stages vi) or vii).
(Frascati Manual, 478-479)

PART 2

DEFINITION OF TERMS

Group 1 • Energy Efficiency

Energy efficiency: Energy efficiency gathers efforts made along the production, transformation and consumption chain of all products either to deliver more services for the same energy input, or the same services for less energy input.

11 Industry

111 Industrial techniques and processes

Definition

Industrial techniques refer to procedures used to accomplish a specific activity or task within industry. Assembling a car in the automotive industry is a technique (or a series of techniques).

Industrial processes refer to a specific step, or to a series of mechanical or chemical operations, which modify, to whatever extent, the original products. Examples of processes are combustion, electrolysis, fermentation, phase changing, welding and many more.

RD&D activities focus: (i) on the improvement of the energy efficiency of industrial processes (e.g. thanks to insulation, recycling, continuous operations, etc.); and (ii) on the development of innovative and more efficient techniques or processes (e.g. process intensification, diversification, etc.).

Also including:

- Combustion, when industry-specific

Excluding:

- Waste heat recovery *Ref. 141*
- Supporting measuring, monitoring and verifying technologies related to energy efficiency *Ref. 145*
- Non industry-specific oil and gas combustion (e.g. steam generation) *Ref. 214*
- Coal combustion *Ref. 222*
- Biofuels *Ref. 34*
- Energy storage *Ref. 63*

112 Industrial equipment and systems

Definition

Industrial equipment refers to devices which are used to achieve a task in industry, but which, although they may be single-use, are not consumed in the process. Boilers, burners, mixers, motors and robots are examples of industrial equipment.

Industrial systems refer to a set of interacting equipment which contribute to the accomplishment of a specific industrial task.

RD&D activities focus on designing and engineering equipment and systems enabling the implementation of energy-efficient processes. Applied research on materials with enhanced heat transfer properties, on premium efficiency electric motors and on advanced control/command is part of this effort.

Also including:

- Energy efficiency systems that integrate waste management

Excluding:

- Waste heat recovery *Ref. 141*
- Supporting measuring, monitoring and verifying technologies related to energy efficiency *Ref. 145*
- Equipment and systems for energy storage *Ref. 63*

113 Other industry

Definition

Other industry refers to energy-efficiency activities in industry not elsewhere specified.

Life cycle analyses are included here.

119 Unallocated industry

Definition

Unallocated industry refers to energy-efficiency activities in industry that cannot be allocated to one specific area of category 11 and where it is not possible to estimate the split between two or more of the sub-categories.

12 Residential and commercial buildings, appliances and equipment

121 Building design and envelope

Definition

Building design and envelope refer to techniques, processes, equipment and systems to better ensure the energy efficiency of constructions through their design and the choice of their envelope materials and technologies.

RD&D activities focus on: (i) developing low energy housing design, allowing for optimal heat, air and moisture flows in buildings; and (ii) optimising building envelope technologies, namely through new insulation and building materials.

Building design and envelope RD&D includes walls, windows, roofs and foundations based on a holistic (systemic) approach that ensures that all elements (energy supply and demand, natural resources, environment, envelope, equipment, operations, and appliances) of the building design work together as a whole.

Also including:

- Cold roofs and pavements
- Thermal performance of buildings
- Efficiency performance qualification for buildings

Excluding:

▪ Solar heating and cooling	*Ref. 311*
▪ Solar architecture	*Ref. 311*
▪ Solar photovoltaics	*Ref. 312*
▪ Indoor air quality	*Out of scope*

1211 Building envelope technologies

This row refers to technologies which relate to the structure, assembly, protection, or thermal efficiency of the building envelope, including windows.

1212 Building design

This row refers to the architectural and engineering activities to the design of energy-efficient buildings.

1219 Unallocated building design and envelope

This row refers to activities in building design and envelope that cannot be allocated to one specific area of category 121 and where it is not possible to estimate the split between two or more of the sub-categories.

122 Building operations and efficient building equipment

Definition

Building operations and efficient building equipment refer to techniques, processes, equipment and systems to meet energy needs within a building, with the highest possible energy efficiency.

RD&D activities focus on: (i) energy management systems within buildings (e.g. smart meters), allowing for an optimised use of energy sources; (ii) advanced lighting technologies (e.g. solid-state lighting, such as LEDs or OLEDs); (iii) efficient equipment generating space heating and/or cooling or ventilation within buildings (energy storage excluded); and (iv) efficient equipment and ancillary devices (e.g. motor drives) allowing for a cut in the energy consumption of buildings.

Also including:

- Efficient internet and communication technologies (ICT)
- Advanced energy metering infrastructure dedicated to residential and commercial buildings
- Refrigeration technologies
- Light-emitting diodes (LED) for buildings

Excluding:

▪ LEDs used in transport	*Ref. 133*
▪ Waste heat recovery	*Ref.141*
▪ Heat pumps	*Ref. 144*
▪ Solar heating and cooling	*Ref. 311*
▪ Solar photovoltaics	*Ref. 312*
▪ Thermal storage	*Ref. 632*
▪ Indoor air quality	*Out of scope*
▪ Water and waste water management, not related to energy efficiency	*Out of scope*

1221 Building energy management systems (including smart meters) and efficient internet and communication technologies

This row refers to devices, systems and software that measure and/or control the energy consumption inside a building, and allow for its optimisation. Includes smart meters and efficient internet and communication technologies for building energy management systems.

1222 Lighting technologies and control systems

This row refers to all RD&D aspects related to producing light, manufacturing bulbs or lamps to be used inside buildings, and monitoring their use. Includes LEDs for buildings.

1223 Heating, cooling and ventilation technologies

This row refers to all RD&D aspects related to generating space heating or cooling, ventilation and refrigeration inside residential and commercial buildings.

1224 Other building operations and efficient building equipment

This row includes RD&D fields not cited elsewhere in category 122, such as energy efficiency improvement of elevator/lift motors.

1229 Unallocated building operations and efficient building equipment

This row refers to activities in building operations and efficient building equipment that cannot be allocated to one specific area of category 122 and where it is not possible to estimate the split between two or more of the sub-categories.

123 Appliances and other residential/commercial

Definition

Appliances and other residential/commercial refer to techniques, processes, equipment and systems pertaining to energy-efficient home or commercial appliances and to items not covered elsewhere.

RD&D activities focus on: (i) optimising energy consumption of appliances, such as highly energy-efficient refrigerators, clothes washers and dryers, water heaters and other appliances; and (ii) developing long-lasting and reliable portable batteries with residential and/or commercial end-use, such as cell phone or laptop batteries.

Also including:

- Enhanced appliance controls

1231 Appliances

This row refers to electrical and/or mechanical machines, which accomplish some household, office or commercial function.

1232 Batteries for portable devices

This row refers to mobile electrical storage items with residential or commercial end-use.

1233 Other residential/commercial

This row refers to other items pertaining to residential/commercial buildings.

1239 Unallocated appliances and other residential/commercial

This row refers to activities in appliances and other residential/commercial that cannot be allocated to one specific area of category 123 and where it is not possible to estimate the split between two or more of the sub-categories.

129 Unallocated residential and commercial buildings, appliances and equipment

Definition

Unallocated residential and commercial buildings, appliances and equipment refers to other energy-efficiency activities that cannot be allocated to one specific area of category 12 and where it is not possible to estimate the split between two or more of the sub-categories.

13 Transport

131 On-road vehicles

Definition

On-road vehicles refer to techniques, processes, equipment and systems related to the manufacture and/or the use of vehicles allowed to circulate on roads, *e.g.* cars, light trucks, heavy trucks, buses, motorcycles and scooters.

RD&D activities focus on:

(i) The design of energy-efficient vehicles (e.g. aerodynamics),
(ii) The development of new materials and assembling techniques allowing for better energy performances (e.g. light alloys, composite materials, etc.) and better reusability/recyclability,
(iii) The development or the optimisation of power trains, including engines, power electronics and systems, vehicle batteries and storage technologies, waste heat recovery
(iv) The design and development of electric vehicle infrastructure, such as smart chargers, metering and invoicing devices, etc.

Also including:

- Use of alternative fuels (liquid, gaseous)
- Fuel additives
- Engine-fuel optimisation
- Hydrogen tanks to be mounted on-board on-road vehicles
- Life cycle analyses related to on-road vehicles

Excluding:

▪ Public transport systems	*Ref. 142*
▪ Biofuels	*Ref. 34*
▪ Hydrogen refuelling stations and dispensers	*Ref. 514*
▪ Fuel cells	*Ref. 522*
▪ Noise reduction, safety improvement, comfort (not related to energy)	*Out of scope*

1311 Vehicle batteries/storage technologies

This row refers to electrical and hydrogen storage technologies whether used for providing start-up power, for economising fossil fuel at low speed or for providing ancillary power (air conditioning, etc.).

1312 Advanced power electronics, motors and EV/HEV/FCV systems

This row refers to power electronics aimed at commanding and controlling power transmitted to train from electric (EV), hybrid electric (HEV) or fuel cycle (FCV) engine systems.

1313 Advanced combustion engines

This row refers to combustion engines with enhanced capabilities (e.g. diesel engines, stirling motors).

1314 Electric vehicle infrastructure (including smart chargers and grid communications)

This row refers to all means connecting electrically chargeable vehicles to the electricity grid. This includes smart meters, smart chargers and grid communication devices.

1315 Use of fuels for on-road vehicles (excluding hydrogen)

This row refers to fossil hydrocarbons and to additives thereof, used to fuel on-road vehicles.

1316 Materials for on-road vehicles

This row refers to materials and assembly techniques used in the manufacture of vehicle parts, with a view to enhancing the energy performance of the vehicles and/or their recyclability.

1317 Other on-road transport

This row refers to other items pertaining to efficiency improvement in on-road transport, and includes: (i) heating, ventilation and air conditioning; and (ii) waste heat recovery applied to on-road vehicles.

1319 Unallocated on-road vehicles

This row refers to items pertaining to on-road vehicles that cannot be allocated to one specific area of category 131 and where it is not possible to estimate the split between two or more of the sub-categories.

132 Off-road transport and transport systems

Definition

Off-road transport and transport systems refer to techniques, processes, equipment and systems related to the manufacture and/or the use of vehicles that do not travel roads, such as trains, planes, and ships.

RD&D activities focus on:

(i) The design of energy-efficient transport systems (e.g. aerodynamics),
(ii) The development of new materials and assembling techniques allowing for better energy performances (e.g. light alloys, composite materials, etc.)
(iii) The development or the optimisation of energy-efficient motorisations, of power electronics and systems, of on-board energy storage devices and of energy management systems, including for air conditioning.

Also including:

- Use of alternative fuels (liquid or gaseous)
- Fuel additives
- Hydrogen tanks to be mounted on-board off-road vehicles
- Transport system optimisation
- Metro, tramways, etc.

Excluding:

- Public transport systems *Ref. 142*
- Transport means for oil and gas (pipelines etc.) *Ref. 212*
- Hydrogen refuelling stations and dispensers *Ref. 514*
- Fuel cells *Ref. 522*

133 Other transport

Definition

Other transport refers to techniques, processes, equipment and systems pertaining to transport systems not elsewhere specified, such as construction vehicles (e.g. cranes, bulldozers, etc.), tractors, forklifts, golf carts, mowers, wheelchairs, etc.

RD&D activities focus on the development or the optimisation of energy-efficient motorisations, of power electronics, of on-board energy storage devices and of specific energy management systems.

Also including:

- Vehicle and transport system simulation and testing
- Hydrogen tanks to be mounted on-board vehicles assigned to row 133
- LEDs used in vehicles

Excluding:

- Hydrogen refuelling stations and dispensers *Ref. 514*
- Fuel cells *Ref. 522*

139 Unallocated transport

Definition

Unallocated transport refers to techniques, processes, equipment and systems pertaining to transport systems that cannot be allocated to one specific area of category 13 and where it is not possible to estimate the split between two or more of the sub-categories.

14 Other energy efficiency

141 Waste heat recovery and utilisation

Definition

Waste heat recovery and utilisation refer to techniques, processes, equipment and systems to: (i) recover all or part of the excess heat generated by industrial, residential, commercial or community applications; and (ii) convert such heat either into power or into thermal energy at a different temperature (higher or lower).

RD&D activities focus on: (i) mapping heat sources; (ii) developing or optimising low temperature thermo-dynamic cycles; and (iii) developing new techniques and the related materials and equipment to convert heat into power.

Also including:

- Thermo-acoustics
- Thermo-electricity
- Organic rankine cycles

Excluding:

▪ Process optimisation	*Ref. 111*
▪ Waste heat recovery devices to be mounted on-board vehicles	*Ref. 13*
▪ Heat pumps	*Ref. 144*
▪ Energy storage	*Ref. 63*
▪ Resource assessment of thermo-electric materials	*Out of scope*

142 Communities

Definition

Communities refer to techniques, processes, equipment and systems developed with a view to improving the energy efficiency of communal services.

RD&D activities focus on: (i) community design to improve energy efficiency; and (ii) improving and optimising the energy efficiency of collective installations, such as public transport systems, street lighting, etc.

Also including:

- District heating and cooling
- Traffic management systems

Excluding:

▪ Treatment of municipal waste	*Ref. 34*
▪ Production of biogases and/or landfill gas	*Ref. 343*

143 Agriculture and forestry

Definition

Agriculture and forestry refer to the techniques, processes, equipment and systems to reduce the energy consumption in forestry and agriculture.

RD&D activities focus on the reduction of energy consumption in the agricultural sector as well as in forestry, such as: (i) research on agricultural and forestry practices; and (ii) development of energy efficient equipment and processes.

Excluding:

- Biofuels *Ref. 34*
- Improvement of energy crops *Ref. 345*

144 Heat pumps and chillers

Definition

Heat pumps and chillers (scroll, screw, reciprocating and centrifugal) refer to the techniques, processes, equipment and systems for the provision of space cooling and/or heating and hot water. This category includes those technologies capable of providing both heating and cooling (including simultaneously).

Equipment includes those using vapour compression, absorption, Stirling and Vuilleumier cycles, single-phase cycles (e.g. with air, CO_2 or noble gases), solid-vapour sorption systems, hybrid systems (notably combining the vapour compression and absorption cycle) and electromagnetic and acoustic processes.

Systems may be designed to utilise all heat sources (e.g. ambient air, exhaust air, ground, rock, ground water, lake water, sea water, river water, waste water and effluent, waste heat) and all distribution systems (air and water).

Also including:

- Dessicant de-humidifcation systems in conjunction with heat pumps and chillers

Excluding:

- Simple cycle air-conditioning only units or room air conditioners units (window, split, mini, packaged) *Ref. 1223*

145 Other energy efficiency

Definition

Other energy efficiency refers to techniques, processes, equipment and systems to optimise the management of energy not covered elsewhere.

RD&D activities focus on sensors, meters and IT systems aimed at predicting, measuring, comparing and displaying energy consumption data.

Other energy efficiency includes RD&D activities aiming at reducing the energy consumption in the construction sector (*e.g.* cutback bitumen).

Also including:

- Supporting measuring, monitoring and verifying technologies related to energy efficiency in industry

149 Unallocated other energy efficiency

Definition

Unallocated other energy efficiency refers to techniques, processes, equipment and systems to optimise the management of energy that cannot be allocated to one specific area of category 14 and where it is not possible to estimate the split between two or more of the sub-categories.

19 Unallocated energy efficiency

Definition

Unallocated energy efficiency refers to techniques, processes, equipment and systems to optimise the management of energy that cannot be allocated to one specific area of group 1 and where it is not possible to estimate the split between two or more of the sub-categories.

Group 2 • FOSSIL FUELS: OIL, GAS AND COAL

21 Oil and gas

Oil: Liquid hydrocarbon of fossil origins comprising: (i) crude oil; (ii) liquids extracted from natural gas (NGL); (iii) fully or partly processed products from the refining of crude oil; and (iv) functionally similar liquid hydrocarbons and organic chemicals from vegetal or animal origins.

Gas: Gas refers to natural gas, which is a mixture of gaseous hydrocarbons, primarily methane, but generally also including ethane, propane and higher hydrocarbons in much smaller amounts and some non-combustible gases such as nitrogen and carbon dioxide.

211 Enhanced oil and gas production

Definition

Enhanced oil and/or gas production refer to techniques, processes, equipment and systems designed to increase the amount of oil and/or gas extracted by conventional means from underground oil and/or gas reservoirs or fields.

Enhanced oil and gas production is sometimes referred to as secondary and tertiary recovery of oil and gas.

RD&D activities focus on the injection of numerous gases, chemicals or micro-organisms, and on thermal recovery.

Also including:

- Hydro-fracturing techniques
- Water and waste water treatment specific to enhanced oil and gas production
- Reservoir engineering

Excluding:

- Non-conventional oil and gas production *Ref. 213*
- Development of advanced exploration methods *Ref. 216*
- Deep-drilling equipment and techniques *Ref. 216*
- Supporting measuring, monitoring and verifying technologies *Ref. 216*

212 Refining, transport and storage of oil and gas

Definition

Refining, transport and storage of oil refer to techniques, processes, equipment and systems applied to the transport of crude oil from its point of production to oil refineries, to the crude oil transformation chain inside refineries, and to storage of refined oil products and their transport to their points of use.

Refining, transport and storage of gas refer to techniques, processes, equipment and systems applied to each and every step from gas production to delivery of natural gas at point of use.

RD&D refining activities include refinery efficiency improvement, optimisation of the mix of refined products, mitigation of the environmental impact of refineries and of refined products.

RD&D transport activities focus: (i) on the transportation of LNG (liquefied natural gas); and (ii) on the transportation of liquid and gaseous hydrocarbons, pipeline network system evaluation, and research on sub-marine pipelines (shallow and deep sea).

RD&D storage activities focus on the storage of liquid or gaseous hydrocarbons, including sub-marine large scale storage units.

Also including:

- Optimisation of natural gas liquefaction and vaporisation units
- Safety aspects of LNG storage and transport
- Strategic storage of liquid and gaseous hydrocarbons
- Gasification of naphtha and feedstocks
- Natural gas transportation in the form of compact hydrate structures

Excluding:

- Supporting measuring, monitoring and verifying technologies *Ref. 216*
- Hydrogen production *Ref. 511*
- Hydrogen storage *Ref. 512*

213 Non-conventional oil and gas production

Non-conventional oils: Oils obtained by non-conventional production techniques, that is oils which are extracted from reservoirs containing extra heavy oils or oil sands which need heating or treatment *in situ* before they can be brought to the surface for refining/processing. They also include the oils extracted from oil sands, extra heavy oils, coal and oil shale which are at, or can be brought to, the surface without treatment and require processing after mining (*ex situ* processing).

Non-conventional gases: Non-conventional gases, often referred to as unconventional gases, comprise: (i) natural gas with low permeability either contained in oil rock (tight gas) or in shale rock (shale gas); (ii) methane-rich gas stored within coal structures (coal-bed methane); and (iii) natural gas hydrates.

Definition

Non conventional oil and gas production refers to techniques, processes, equipment and systems either to directly extract non-conventional oils or gases out of the ground, or to extract oil- or gas-rich materials out of the ground and to process them *ex-situ* to recover hydrocarbons.

RD&D activities focus on advanced drilling technologies and hydraulic fracturing, on thermal or gas injections, on *in situ* emulsification or heating, on depressurisation to recover gas from hydrates, and on retorting technologies for *ex situ* processing of shale oils.

Also including:

- Deep-water extraction of non-conventional oil and gas
- In-situ processes for shale gas
- Production of oil from tar sands

Excluding:

- Supporting measuring, monitoring and verifying technologies *Ref. 216*
- CO_2 capture and separation *Ref. 231*
- Hydrogen production *Ref. 511*

214 Oil and gas combustion

Definition

Oil and gas combustion refers to techniques, processes, equipment and systems to burn oil or gas in order to generate power or supply energy to non-specific applications, such as steam generation.

NOTE: RD&D related to specific combustion processes, e.g. glass melting, metals refining, cement kilns, etc. or to energy efficiency in industry are included in Group I, category 11.

RD&D activities focus: (i) on equipment such as turbines (e.g. micro turbines, multi-fuel gas turbines, combustion turbines) and turbo engines; (ii) combustion cycles whether conventional or combined; and (iii) on ways to limit the environmental impact of the combustion flue gases.

Also including:

- Flue gas cleanup, excluding CO_2 removal

Excluding:

- Reduction of energy consumption in industrial processes *Ref. 111*
- Development or improvement of burners and furnaces *Ref. 112*
- Supporting measuring, monitoring and verifying technologies *Ref. 216*
- CO_2 capture and separation *Ref. 231*

215 Oil and gas conversion

Definition

Oil and gas conversion refers to techniques, processes, equipment and systems to transform oil or gas into chemicals or synthetic fuels, the latter being hydrocarbons whose physical properties (e.g. liquid at ambient temperature) make possible their transport to be ultimately used as fuels.

RD&D activities focus on gas-to-liquid (GTL) technologies and on Fischer-Tropsch synthesis based on petroleum or gas products.

Also including:

- Methane partial oxidation to methanol
- Methane conversion to benzene

Excluding:

- Reduction of energy consumption in industrial processes *Ref. 111*
- Measuring, monitoring and verifying technologies *Ref. 216*
- CO_2 separation and capture *Ref. 231*
- Steam methane reforming (SMR) or other techniques for the production of hydrogen *Ref. 511*

216 Other oil and gas

Definition

Other oil and gas refers to techniques, processes, equipment and systems involving oil or gas that are not covered elsewhere.

RD&D activities focus on advanced exploration methods (geophysical, geochemical, seismic, and magnetic) for on-shore and off-shore prospecting, and on measuring, monitoring and verifying technologies in the field of oil and gas.

Also including:

- Environmental, safety and health aspects of oil and gas, both on-shore and off-shore, including off-shore structures
- On-shore/off-shore deep drilling equipment and techniques for conventional oil and gas

Excluding:

- Deep-water extraction of non-conventional oil and gas *Ref. 213*

219 Unallocated oil and gas

Definition

Unallocated oil and gas refers to techniques, processes, equipment and systems involving oil and gas that cannot be allocated to one specific area of category 21 and where it is not possible to estimate the split between two or more of the sub-categories.

22 Coal

Coal comprises solid fossil fuels consisting of carbonised vegetal matter and products derived from them including liquids and gases.

NB: For the purposes of this questionnaire, peat is included in 224 although it is not considered as coal in the Standard International Energy Product Classification (SIEC).

221 Coal production, preparation and transport

Definition

Coal production, preparation and transport refer to techniques, processes, equipment and systems applied to each and every step from coal mining to delivery at point of use, including the production of secondary coal products.

RD&D activities focus on mining (surface and underground mining, etc.), on mechanical preparation of coal (e.g. removal of non-combustible material, crushing, dewatering, etc.), the production of secondary coal product and on its transport.

Also including:

- Methane extraction from virgin seams, working and abandoned mines
- Removal of inorganic sulphur
- Coking, blending and briquetting of coal

Excluding:

- Coal transformation into syngas, organic gases or liquids *Ref. 223*
- Geological surveys and deposit evaluation techniques *Ref. 224*
- Environmental, safety and health aspects *Ref. 224*

222 Coal combustion (including IGCC)

Definition

Coal combustion refers to techniques, processes, equipment and systems to burn coal in order to generate electrical power or to supply energy to an industrial process, such as the production of cement.

RD&D activities focus on boilers (incl. conventional utility boiler, fluidised bed combustion, etc.), combustion efficiency measurement systems and flue gas clean-up.

Coal combustion includes RD&D on IGCC (Integrated Gasification Combined Cycle) units.

Also including:

- Coal handling and treatment at the 'plant'
- Coal co-firing with biomass
- Re-powering, retrofitting, life extensions and upgrading of coal power plants
- Pre and post-combustion removal of sulphur and nitrogen species
- Readying of combustion technologies to incorporate CO_2 capture and storage

Excluding:

▪ Energy efficiency improvements in industrial processes	*Ref. 111*
▪ Environmental, safety and health aspects of coal	*Ref. 224*
▪ Supporting, measuring, monitoring and verifying technologies in coal	*Ref. 224*
▪ CO_2 removal from flue gas	*Ref. 231*
▪ All other CO_2 capture and storage processes	*Ref. 231*
▪ Hydrogen production from IGCC	*Ref. 511*

223 Coal conversion (excluding IGCC)

Definition

Coal conversion refers to techniques, processes, equipment and systems to transform coal into syngas, organic gases or liquids.

RD&D activities focus on coal gasification (except for IGCC), resulting in the production of syngas, methane or other organic gases and on coal liquefaction, whether direct or preceded by a gasification step.

Also including:

- Coal underground in-situ gasification
- Hydrogenation of coal
- Fischer-Tropsch syntheses based on coal

Excluding:

▪ Fischer-Tropsch synthesis based on oil and gas	*Ref. 215*
▪ Techniques, equipment, systems and processes related to coal combustion	*Ref. 222*
▪ IGCC	*Ref. 222*
▪ Environmental, safety and health aspects	*Ref. 224*
▪ Supporting, measuring, monitoring, and verifying technologies in coal	*Ref. 224*

224 Other coal

Definition

Other coal refers to coal-associated techniques, processes, equipment and systems not elsewhere classified.

RD&D activities focus on environmental, safety and health aspects of coal, and also on supporting, measuring, monitoring and verifying technologies in coal.

By convention, *other coal* includes RD&D related to peat production, preparation, conversion and combustion not related to energy efficiency.

Also including:

- Geological survey and deposit evaluation techniques
- Management of ashes and coal wastes

Excluding:

- Energy efficiency related to peat consumption in industrial processes *Ref. 111*
- Coal combustion efficiency measurement systems *Ref. 222*

229 Unallocated coal

Definition

Unallocated coal refers to coal-associated techniques, processes, equipment and systems that cannot be allocated to one specific area of category 22 and where it is not possible to estimate the split between two or more of the sub-categories.

23 CO_2 capture and storage

231 CO_2 capture/separation

Definition

CO_2 capture/separation refers to techniques, processes, equipment and systems to produce a concentrated stream of CO_2 from large point sources (e.g. fossil fuel power plants or industrial sources) to be transported for use (e.g. enhanced oil recovery) or storage.

RD&D activities focus on all different separation techniques, namely: adsorption, absorption, permeation across membranes, condensation.

CO_2 capture/separation occurs at different steps of a power plant, including upstream (pre-combustion) and downstream (post-combustion), and is applicable to both new and retrofitted plants.

Also including:

- Cryogenic separation
- CO_2 capture/separation downstream in: large oxygen combustion, H_2/syngas production units and oil sands conversion facilities
- Chemical looping

Excluding:

- Techniques, processes, equipment and systems related to oil and gas combustion *Ref. 214*
- Techniques, processes, equipment and systems related to coal combustion *Ref. 222*
- Integrated gasification combined cycle (IGCC) units *Ref. 222*

232 CO_2 transport

Definition

CO_2 transport refers to techniques, processes, equipment and systems to convey CO_2 from the place it has been captured to the place it will be stored or utilised.

RD&D activities focus on all different transport techniques, regardless of the CO_2 physical state (gas, liquid), namely: pipelines and tankers.

Also including:

- CO_2 pipeline technologies
- Design of temporary or buffer storage
- Infrastructure for offshore CO_2 transport systems

233 CO_2 storage

Definition

CO_2 storage refers to techniques, processes, equipment and systems to inject CO_2 into underground reservoirs for permanent deposit.

RD&D activities focus on geology, storage mechanisms (i.e. physical or mineral trapping, solubility, etc.), monitoring, measurement, verification and risk management.

CO_2 storage may occur in existing oil and gas fields, depleted oil and gas reservoirs, deep saline aquifers as well as unminable coal-beds.

Also including:

- Mineralisation (CO_2 conversion into mineral carbonates)
- Monitoring and verification of stored CO_2 (including integrity, health and safety)
- Distribution of CO_2 underground
- Health and safety issues linked to CO_2 storage
- Natural analogues of CO_2 storage

Excluding:

- Technical services aimed at locating and identifying suitable reservoirs *out of scope*
- Legal aspects pertaining to CO_2 storage *out of scope*

239 Unallocated CO_2 capture and storage

Definition

Unallocated CO_2 capture and storage refers to techniques, processes, equipment and systems that cannot be allocated to one specific area of category 23 and where it is not possible to estimate the split between two or more of the sub-categories.

29 Unallocated fossil fuels

Definition

Unallocated fossil fuels refers to techniques, processes, equipment and systems related to fossil fuels that cannot be allocated to one specific area of group 2 and where it is not possible to estimate the split between two or more of the sub-categories.

Group 3 • RENEWABLE ENERGY SOURCES

Fuels and energy obtained: (i) directly from solar radiation; (ii) indirectly from its effects on the biosphere and the life within it; (iii) from geothermal energy; and (iv) from gravitational forces.

31 Solar energy

311 Solar heating and cooling

Definition

Solar heating and cooling refer to techniques, processes, equipment and systems to generate thermal energy from solar radiation at temperatures below circa 250°C, mainly with a view to heating/cooling water or air.

RD&D activities focus on technology improvements, including the development of high efficiency solar collectors and of solar cooling technologies (e.g. absorption refrigeration cycles, desiccant cycles) and on intelligent control systems of the energy flows.

Solar heating and cooling include solar drying (e.g. of agricultural products) and solar low-temperature process heating.

Also including:

- Low-temperature process heat
- Water heating
- Swimming pool heating
- Active and passive solar heating and cooling
- Daylighting
- Solar-assisted ventilation
- Solar architecture
- Solar drying

Excluding:

▪ Building design and envelope	*Ref. 121*
▪ Solar photovoltaic technology	*Ref. 312*
▪ Solar high-temperature applications	*Ref. 313*
▪ Concentrating solar power (CSP)	*Ref. 312 and 313*
▪ Thermal storage technologies	*Ref. 632*

312 Solar photovoltaics

Definition

Solar photovoltaics refer to techniques, processes, equipment and systems to produce electricity by the direct conversion of solar radiation in semiconductor devices (solar cells).

RD&D activities focus on improving the efficiency and the manufacture of photovoltaic (PV) equipment and systems. This includes the development of solar cells no longer based on multi – or single - crystalline silicon.

Solar photovoltaics also include RD&D focusing on polymer solar cells, including organic cells, and on systems based upon them.

Also including:

- Concentrating PV systems
- PV modules, including building-integrated PV modules
- PV inverters
- Polymer solar cells, including organic cells
- Dye sensitised cells, thermo-PV cells, quantum dots and wells
- Resource assessment for solar PV

Excluding:

- Building design and envelope *Ref. 121*
- Solar heating and cooling *Ref. 311*
- Concentrating solar thermal *Ref. 313*
- Power storage technologies *Ref. 631*

313 Solar thermal power and high-temperature applications

Definition

Solar thermal power and high temperature applications refer to techniques, processes, equipment and systems to generate high temperature (i.e. above circa 250°C) heat from solar radiation captured by concentrating solar thermal systems.

RD&D activities focus on the design, construction and testing of solar thermal-power plants. It also includes the development of concentrating collectors, and research towards solar-high-temperature applications for process heat and manufacturing hydrogen and a variety of solar fuels, including solar-enhanced biofuels.

Also including:

- Solar chemistry based on photochemical processes (e.g. for water detoxification)
- Resource assessment for solar thermal power

Excluding:

- Solar heating and cooling *Ref. 311*
- Solar photovoltaic technology *Ref. 312*
- High-temperature hydrogen production *Ref. 511*
- Power storage technologies *Ref. 631*
- Thermal storage technologies *Ref. 632*

319 Unallocated solar energy

Definition

Unallocated solar energy refers to techniques, processes, equipment and systems related to solar energy that cannot be allocated to one specific area of category 31 and where it is not possible to estimate the split between two or more of the sub-categories.

32 Wind energy

321 Onshore wind technologies

Definition

Onshore wind technologies refer to techniques, processes and equipment to produce electricity from onshore devices driven by wind.

RD&D activities focus on enhancing the performance and the reliability of the equipment (e.g. turbines and components).

Also including:

- Large-scale technologies
- Low wind speed technologies
- Distributed wind technology

Excluding:

- Wind energy systems *Ref. 323*
- Wind resource and site characterisation *Ref. 323*
- Electrical storage *Ref. 631*

322 Offshore wind technologies (excluding low wind speed)

Definition

Offshore wind technologies refer to techniques, processes and equipment to produce electricity from offshore devices driven by wind.

RD&D activities focus on the performance and the reliability of offshore wind technologies.

Also including:

- New materials for sea salt exposure
- Foundation and platform technologies to support offshore wind turbines

Excluding:

- Low wind speed technologies *Ref. 321*
- Wind energy systems *Ref. 323*
- Wind resource and site characterisation *Ref. 323*
- Electrical linkage of offshore sites to land *Ref. 622*

323 Wind energy systems and other technologies

Definition

Wind energy systems and other technologies refer to techniques, processes, equipment and systems not covered elsewhere.

Also including:

- Resource assessment
- Software development for better wind forecasting
- “Off-ground”, high altitude wind technologies (flying turbines, kites, etc.)

Excluding:

- Wind energy/hdrogen integration *Ref. 511*
- Grid integration *Ref. 6221*
- Load management *Ref. 6221*

329 Unallocated wind energy

Definition

Unallocated wind energy refers to techniques, processes, equipment and systems related to wind energy that cannot be allocated to one specific area of category 32 and where it is not possible to estimate the split between two or more of the sub-categories.

33 Ocean energy

331 Tidal energy

Definition

Tidal energy refers to techniques, processes, equipment and systems to generate power from tidal currents or from the differences of water level caused by tides.

RD&D activities focus on the design of tidal power units (e.g. dynamic tidal power), and on the technological development in turbine technology.

Also including:

- Tidal lagoons

Excluding:

- Ocean current power *Ref. 334*
- Siting for tidal energy *Ref. 334*
- Supporting measuring, monitoring and verifying technologies in tidal energy *Ref. 37*

332 Wave energy

Definition

Wave energy refers to techniques, processes, equipment and systems to generate power from the motion of waves.

RD&D activities focus on equipment design and optimisation.

Also including:

- Equipment resistance over time

Excluding:

- Ocean current power *Ref. 334*
- Siting for wave energy *Ref. 334*
- Supporting measuring, monitoring and verifying technologies in wave energy *Ref. 37*
- Energy transfer from offshore unit to land *Ref. 622*

333 Salinity gradient power

Definition

Salinity gradient power, also called osmotic power, refers to techniques, processes, equipment and systems to generate power from salinity differences between sea and fresh water.

RD&D activities focus on large-scale design and early industrialisation of units based upon technologies including osmosis and reversed electrodialysis.

Excluding:

- Siting for salinity gradient power *Ref. 334*
- Supporting measuring, monitoring and verifying technologies in ocean energy *Ref. 37*

334 Other ocean energy

Definition

Other ocean energy refers to techniques, processes, equipment and systems: (i) to generate power from devices which exploit sources of ocean energy not elsewhere specified; and (ii) siting studies for all ocean energy activities.

Examples of ocean energy sources are: ocean current power (e.g. non-tidal power) and ocean thermal power (e.g. temperature differences in seas).

RD&D activities focus on equipment design for small- and large-scale units, research on geography and related sciences, and the resistance of materials over time.

Also including:

- Resource assessment (i.e. energy production of an ocean energy unit)
- Effect on marine life of ocean energy

Excluding:

- All activities linked to algae harvesting or use *Ref. 341*
- Supporting measuring, monitoring and verifying technologies in ocean energy *Ref. 37*
- Grid integration *Ref. 6221*
- Load management *Ref. 6221*

339 Unallocated ocean energy

Definition

Unallocated ocean energy refers to techniques, processes, equipment and systems related to ocean energy that cannot be allocated to one specific area of category 33 and where it is not possible to estimate the split between two or more of the sub-categories.

34 Biofuels (including liquid biofuels, solid biofuels and biogases)

Liquid, solid or gaseous fuels derived directly or indirectly from biomass. Biomass is material obtained from living or recently living organisms. It excludes fossilised or partly fossilised material.

341 Production of liquid biofuels

Conventional liquid biofuel technologies

These liquid biofuels are commonly referred to as "first-generation" and include sugar- and starch-based ethanol, oil-crop based biodiesel and straight vegetable oil (SVO), as well as biogas derived through anaerobic digestion. Typical feedstocks used in these mature processes include sugarcane and sugar beet, starch bearing grains like corn and wheat, oil crops like rape (canola), soybean and oil palm, and in some cases animal fats and used cooking oils.

Advanced liquid biofuel technologies

These liquid biofuels are commonly referred to as "second-", or "third-generation biofuels". More specifically, this category includes emerging biofuel technologies such as hydrotreated vegetable oil (HVO), which is based on animal fat and plant oil, as well as all those based on lignocellulosic biomass, such as cellulosic-ethanol, biomass-to-liquids (BtL)-diesel and bio-synthetic gas (bio-SG), amongst others. The category also includes novel biofuel technologies such as algae-based fuels as well as the conversion of sugar into diesel-type biofuels, using biological or chemical catalysts.

Definition

The production of liquid biofuels refers to the techniques, processes, equipment and systems to obtain liquids derived from biomass and used as fuels.

Liquid biofuels comprise biogasoline, biodiesels, bio jet kerosene and other liquid biofuels.

RD&D activities focus on improving the performance of the existing generation units and on developing routes for the production of advanced and novel liquid biofuels. They also focus on mitigating the environmental impact of producing biofuels.

Also including:

- Liquids derived from biomass and used as blending components in fossil fuels
- Biomass-to-liquid (BTL) technologies

Excluding:

- Applications of liquid biofuels for heat and electricity *Ref. 344*
- Improvement of energy crops *Ref. 345*
- Genetically modifying microalgae *Ref. 345*
- Research on liquid biofuel production potential and associated land-use effects *Ref. 345*
- Supporting measuring, monitoring and verifying technologies for liquid biofuels *Ref. 37*

3411 Gasoline substitutes (including ethanol)

3412 Diesel, kerosene and jet fuel substitutes

3413 Algal biofuels

This row refers to liquid biofuels produced from (or by) algae.

3414 Other liquid fuel substitutes

This row refers to any RD&D activity related to the production of liquid biofuels and not classified in categories 3411 to 3413.

3419 Unallocated production of liquid biofuels

This row refers to activities relating to the production of liquid biofuels that cannot be allocated to one specific area of category 341 and where it is not possible to estimate the split between two or more of the sub-categories.

342 Production of solid biofuels

Definition

The production of solid biofuels refers to techniques, processes, equipment and systems to obtain solids fuels derived from biomass.

Solid biofuels comprise - but are not limited to - wood (under pellet, chip or any other form), bagasse and other vegetal waste, animal waste. and the renewable fractions of both municipal and industrial waste that can be used as a solid fuel, including dried sludge from waste water treatment plants.

RD&D activities focus on ways to increase the density and the caloric value of solid biofuels, and on ways to separate the biofuels from non-flammable or toxic residues also contained in the biomass.

Excluding:

- Applications of solid biofuels for heat and electricity *Ref. 344*
- Research on solid biofuel production potential and associated land-use effects *Ref.345*
- Supporting measuring, monitoring, and verifying technologies for solid biofuels *Ref.37*

343 Production of biogases

Definition

The production of biogases refers to techniques, processes, equipment and systems to obtain gases arising from the anaeorobic fermentation of biomass and the gasification of solid biomass, including biomass in waste.

RD&D activities are focused on improving the performance, the reliability and the competitiveness of the production processes, and on upgrading the biogases generated by separating the flammable fraction (mainly methane) from associated inert gases (mainly CO_2) and by eliminating toxic or corrosive impurities.

Also including:

- Anaerobic digestion of biomass
- Landfill gas
- Purification of biogases

Excluding:

- Applications of biogases for heat and electricity *Ref. 344*
- Research on biogas production potential and associated land-use effects *Ref. 345*
- Supporting measuring, monitoring, and verifying technologies for biogases *Ref. 37*

3431 Thermochemical

This row refers to biogases produced via thermal processes, such as gasification or pyrolysis. Includes syngas produced from biomass resources.

3432 Biochemical (including anaerobic digestion)

This row refers to biogases produced via biochemical processes, including anaerobic digestion.

3433 Other biogases

This row refers to any RD&D activity related to the production of biogases and not classified in categories 3431 or 3432.

3439 Unallocated production of biogases

This row refers to activities relating to the production of biogases that cannot be allocated to one specific area of category 343 and where it is not possible to estimate the split between two or more of the sub-categories.

344 Application for heat and electricity

Definition

Application for heat and electricity refers to techniques, processes, equipment and systems to generate heat, electricity or both simultaneously from biofuels.

RD&D activities focus on: (i) improving the performance, the reliability and the environmental footprint of the boilers generating heat from biofuels; and (ii) designing appropriate thermodynamic and mechanical systems to efficiently produce electricity from biofuels.

Also including:

- Bio-heat and bio-electricity, excluding multi-firing with fossil fuels
- Combined heat and power (CHP), excluding multi-firing with fossil fuels
- Combined cooling, heat and power (CCHP), excluding multi-firing with fossil fuels
- Flue gas purification, when specific to the combustion of biofuels

Excluding:

- District heating and cooling *Ref. 142*
- Multi-firing with oil and gas *Ref. 214*
- Multi-firing with coal *Ref. 222*
- Purification of biogases *Ref. 343*
- Supporting measuring, monitoring, and verifying technologies *Ref. 37*

345 Other biofuels

Definition

Other biofuels refers to techniques, processes, equipment and systems related to biofuels and not elsewhere specified, including genetically modifying the biofuel feedstocks.

RD&D activities focus on: (i) assessing biofuel production potential and associated land-use effects; and (ii) genetics and biology to develop new crop varieties or modify certain characteristics of existing varieties.

Also including:

- Improvement of energy crops
- Preparation and use of urban, industrial and agricultural wastes not covered elsewhere

Excluding:

- Reduction of energy consumption in the agricultural sector *Ref. 143*
- Supporting measuring, monitoring, and verifying technologies *Ref. 37*

349 Unallocated biofuels

Definition

Unallocated biofuels refers to techniques, processes, equipment and systems related to biofuels that cannot be allocated to one specific area of category 34 and where it is not possible to estimate the split between two or more of the sub-categories.

35 Geothermal energy

Heat extracted from the earth. The sources of the heat are radioactive decay in the crust and mantle and heat from the core of the earth. Heat form shallow geothermal sources will include heat gained by the earth from direct sunlight and rain. The heat is usually extracted from the earth in the form of heated water or steam.

351 Geothermal energy from hydrothermal resources

Definition

Geothermal energy from hydrothermal resources refers to techniques, processes, equipment and systems to generate power and heat from the earth's hot water.

Also including:

- Dry steam, flash steam and binary cycle power plants

Excluding:

- Enhanced geothermal systems *Ref. 352*
- Siting of hydrothermal plants *Ref. 354*

352 Geothermal energy from hot dry rock (HDR) resources

Definition

Geothermal energy from hot dry rock resources refers to techniques, processes, equipment and systems to capture the thermal energy contained in hot dry rock (HDR) situated within drilling reach below the earth's surface.

RD&D activities focus on techniques such as hydro-fracturing and other hydraulic simulation, and developments in equipment to maximise energy outputs.

Excluding:

- Geosciences pertaining to geothermal systems *Ref. 353*
- Siting of geothermal systems *Ref. 354*

353 Advanced drilling and exploration

Definition

Advanced drilling and exploration refer to techniques, processes, equipment and systems to design energy efficient drilling and exploration technologies aimed at recovering thermal heat from underground.

RD&D activities focus on drilling practices for both direct use (low temperature) and electrical generation (high temperature) wells.

Excluding:

- Advanced drilling technologies for non-conventional oil and gas *Ref. 213*
- Siting of geothermal systems *Ref. 354*

354 Other geothermal energy (including low-temperature resources)

Definition

Other geothermal energy refers to techniques, processes, equipment and systems not covered elsewhere.

RD&D activities focus on: (i) equipment design and optimisation; and (ii) environmental studies.

Other geothermal energy includes collecting, treating and piping hot water for direct-use (for greenhouses, aquaculture or community usage).

Also including:

- Resource assessment
- Mitigation of environmental risks associated with geothermal energy

Excluding:

- Efficient building equipment *Ref. 122*
- District heating and cooling *Ref. 142*
- Energy efficiency in agriculture and forestry *Ref. 143*
- Heat pumps *Ref. 144*
- Geosciences pertaining to geothermal systems *Ref. 353*
- Thermal energy storage *Ref. 632*

359 Unallocated geothermal energy

Definition

Unallocated geothermal energy refers to techniques, processes, equipment and systems related to geothermal energy that cannot be allocated to one specific area of category 35 and where it is not possible to estimate the split between two or more of the sub-categories.

36 Hydroelectricity

361 Large hydroelectricity (capacity of 10 MW and above)

Definition

Large hydroelectricity refers to techniques, processes, equipment and systems to produce electricity from devices driven by flowing or falling fresh water, whenever the capacity of such systems is 10 MW and above.

RD&D activities focus on improving the efficiency, reliability and longevity of equipment through computational fluid dynamics design, advanced manufacturing processes and new materials. They are also directed into IT systems, *i.e.* automation, remote control and diagnosis.

Also including:

- Siting for large hydroelectricity plants
- Study of local climatic conditions and ecosystems disruption

Excluding:

- Mechanical energy storage (hydro pumped storage) *Ref. 6313*

362 Small hydroelectricity (capacity of less than 10 MW)

Definition

Small hydroelectricity refers to techniques, processes, equipment and systems to produce electricity from run-of-river devices whose capacity is less than 10 MW.

RD&D activities focus on hydro-mechanical engineering, civil engineering and electrical engineering. Efforts are also being addressed to optimise generation as part of integrated water management systems.

Also including:

- Siting for small hydroelectricity plants
- Research on fish friendliness

369 Unallocated hydroelectricity

Definition

Unallocated hydroelectricity refers to techniques, processes, equipment and systems related to hydroelectricity that cannot be allocated to one specific area of category 36 and where it is not possible to estimate the split between two or more of the sub-categories.

37 Other renewable energy sources

Definition

Other renewable energy sources refer to techniques, processes, equipment and systems not covered elsewhere in the renewable energy source group.

By convention, *other renewable energy sources* include all supporting measuring, monitoring and verifying technologies in renewable energies.

Also including:

- Renewable energy potentials and distributed renewables not covered elsewhere.

39 Unallocated renewable energy sources

Definition

Unallocated renewable energy sources refers to techniques, processes, equipment and systems related to renewable energy sources that cannot be allocated to one specific area of group 3 and where it is not possible to estimate the split between two or more of the sub-categories.

Group 4 • NUCLEAR FISSION AND FUSION

41 Nuclear fission

Nuclear fission is the basic heat-producing process in a nuclear power plant. A heavy atomic nucleus (most often uranium 235) absorbs a neutron, causing it to split into smaller nuclei, releasing further neutrons and heat energy. If, on average, one of these neutrons goes on to cause a further fission, a stable nuclear chain reaction is established. The heat is removed from the nuclear fuel by a coolant and used to produce steam that drives a turbine-generator.

411 Light water reactors (LWRs)

Definition

Light water reactors refer to techniques, processes, equipment and systems to generate electricity in fission nuclear reactors that use ordinary water as both a coolant and neutron moderator.

The main types of LWRs are pressurized water reactors (PWR) and boiling water reactors (BWR).

RD&D activities focus on the development of technical and operational improvements that contribute to the long-term economic viability of nuclear power plants based on LWRs, such as: (i) improvements and/or standardisation of light water reactor design, including at different power ranges than presently commercialized; (ii) development of reactor-specific equipment; and (iii) development of specific test methodologies and apparatuses.

Light water reactors include RD&D related to all "heavy" components of a LWR-based nuclear plant, including the reactor, the nuclear fuel management system, the boiler, the cooling circuits, the turbine-generator and the associated control/command systems.

Excluding:

- Construction, aero-refrigerant systems and connection to grid *Ref. 414*
- High temperature H_2 production processes coupled with nuclear *heat sources* *Ref. 511*
- Electricity transmission and distribution *Ref. 62*

412 Other converter reactors

Definition

Other converter reactors refers to techniques, processes, equipment and systems to generate electricity in fission nuclear reactors that do not use ordinary water as both coolant and neutron moderator, including heavy water reactors (HWRs), high temperature reactors (HTRs) and advanced gas-cooled reactors (AGRs).

RD&D activities focus on: (i) research on and improvements of core reactor design; (ii) research on new materials needed by such designs, including their physical and chemical properties, resistance, life-time, processability, etc.; (iii) development of reactor-specific equipment; and (iv) development of test methodologies and apparatuses.

Other converter reactors includes RD&D related to all "heavy" components of a nuclear plant, including the reactor, the nuclear fuel management system, the boiler, the cooling circuits, the turbine-generator and the associated control/command systems.

Also including:

- Very high temperature reactors (VHTR)
- Super-critical water-cooled reactors (SCWR)

Excluding:

- Construction, aero-refrigerant systems and connection to grid *Ref. 414*
- High temperature H_2 production processes coupled with nuclear heat sources *Ref. 511*
- Electricity transmission and distribution *Ref. 62*

4121 Heavy water reactors (HWRs)

This row refers to nuclear reactors using heavy water (i.e. deuterium containing water) as a moderator.

4122 Other converter reactors

This row refers to super-critical water cooled reactors (SCWRs) and to all nuclear reactors which are not water-cooled.

4129 Unallocated other converter reactors

This row refers to activities relating to other converter reactors that cannot be allocated to one specific area of category 412 and where it is not possible to estimate the split between the two sub-categories.

413 Fuel cycle

Definition

Fuel cycle refers to techniques, processes, equipment and systems: (i) to supply nuclear fuel to reactors in order to produce electricity; and (ii) to manage and either reprocess or dispose of spent nuclear fuel.

Fuel cycle consists in a series of differing stages, notably including mining, enrichment, processing, transportation, storage, fissile material recycling and/or reprocessing, and waste treatment and disposal.

RD&D activities focus on: (i) optimising each step of the process; (ii) advanced reprocessing technologies, (*e.g.* advanced aqueous reprocessing and pyroprocessing); (iii) reducing the volumes of long-lived fission waste (*e.g.* through transmutation); and (iv) nuclear waste storage.

Also including:

- Ore, uranium and thorium extraction and conversion
- Transport of radioactive materials
- Closed fuel cycles
- Nuclear waste siting

4131 Fissile material recycling/reprocessing

This row refers to the separation of useful components (e.g. remaining uranium and newly created plutonium) from spent nuclear fuel and to their reprocessing for re-use.

4132 Nuclear waste management

This row refers to the collection, transport, processing, disposal and monitoring of spent nuclear fuel and other nuclear waste materials.

4133 Other fuel cycle

This row refers to all front-end steps of the cycle, including mining, enrichment and fabrication and to all other steps not included in (4131) or in (4132).

4139 Unallocated fuel cycle

This row refers to activities relating to the fuel cycle that cannot be allocated to one specific area of category 413 and where it is not possible to estimate the split between two or more of the sub-categories.

414 Nuclear supporting technologies

Definition

Nuclear supporting technologies refer to techniques, processes, equipment and systems not directly linked to the reactor nor the fuel cycle, however, that are applied when designing or operating a nuclear plant.

RD&D activities focus on: (i) the development of safeguard technologies and practice, in order to maintain the safety and integrity of nuclear plants and installations and to protect the surrounding populations and environment; (ii) enhanced fissile material control; and (iii) specific research on robotics and communication with a view to allowing for increasingly diverse unmanned actions in a potentially radioactive environment.

Also including:

- Construction, aero-refrigerant systems and connection to grid
- Cyber security of nuclear plants

Excluding:

- Nuclear ship *Out of scope*

4141 Plant safety and integrity

This row refers to the general integrity of nuclear plants and to nuclear safety of plant operators. Includes substation control (structure, corrosion, seismic protection systems) and system upgrading.

4142 Environmental protection

This row refers to general nuclear environmental protection including protection outside the plant.

4143 Decommissioning

This row refers to the definitive shutdown and/or to the removal from operation of all or parts of nuclear power plants and related nuclear fuel cycle installations.

4144 Other nuclear supporting technologies

This row refers, among others, to fissile material control, and to non-waste related siting studies (e.g. where to construct nuclear plants).

4149 Unallocated nuclear supporting technologies

This row refers to activities relating to nuclear supporting technologies that cannot be allocated to one specific area of category 414 and where it is not possible to estimate the split between two or more of the sub-categories.

415 Nuclear breeder

Definition

Nuclear breeder refers to techniques, processes, equipment and systems to generate electricity in reactors that generate more fuel than they consume, and thereby can be fed with non-enriched uranium or thorium.

RD&D activities focus on: (i) research on and improvement to core reactor design; (ii) research on new materials needed by such designs, including their physical and chemical properties, life-time, processability, etc.; and (iii) development of equipment, test methodologies and apparatuses, instrumentation and control systems specific to breeders.

Also including:

- Sodium-cooled fast reactor (SFR)
- Gas-cooled fast breeders (GFR)
- Lead-cooled fast reactor (LFR)
- Molten salt reactors (MSRs)

416 Other nuclear fission

Definition

Other nuclear fission refers to techniques, processes, equipment and systems related to nuclear fission without being specifically related to any of the technology areas above.

Other nuclear fission includes the sociological, economical and environmental impact of nuclear energy.

Excluding:

- Non energy-related applications of nuclear fission — *Out of scope*

419 Unallocated nuclear fission

Definition

Unallocated nuclear fission refers to techniques, processes, equipment and systems related to nuclear fission that cannot be allocated to one specific area of category 41 and where it is not possible to estimate the split between two or more of the sub-categories.

42 Nuclear fusion

421 Magnetic confinement

Definition

Magnetic confinement refers to techniques, processes, equipment and systems, based on magnetic fields, which create the conditions under which light nuclei, in their plasma state, fuse.

RD&D activities that focus on: (i) experiments, concepts and demonstration devices; (ii) research on plasma physics; (iii) research on materials to be used in nuclear fusion by magnetic confinement; (iv) research on magnetic confinement systems such as tokamaks and others; (v) research on fuel preparation and recycling; and (vi) research on sensors, measuring technologies, waste management and safety specifically applicable to the field of nuclear fusion by magnetic confinement.

Also including:

- Reverse-field pinches
- Stellarators
- Spherical tori

422 Inertial confinement

Definition

Inertial confinement refers to techniques, processes, equipment and systems based on heating and compressing a fuel (*e.g.* containing a mixture of deuterium and tritium, in the form of pellets), by means of high-energy beams of laser light, electrons or ions, thus creating the conditions under which light nuclei fuse.

RD&D activities focus on: (i) research on high power and ultra intense lasers"; (ii) research on materials to be used in nuclear fusion by inertial confinement; (iii) research on inertial confinement systems and plasma ignition devices using laser (direct, indirect or fast drive) or other methods; (iv) research on fuel preparation and recycling; and (v) research on sensors, measuring technologies and safety specifically applicable to the field of nuclear fusion by inertial confinement.

423 Other nuclear fusion

Definition

Other nuclear fusion refers to techniques, processes, equipment and systems for nuclear fusion not elsewhere specified.

It includes studies not related to a specific technology area above, such as fundamental research on fusion and associated modelling activities.

It also includes cross-cutting research on sensors, measuring technologies and safety issues applicable to nuclear fusion regardless of the confinement mode.

Excluding:

- Non energy-related applications of nuclear fusion — *Out of scope*

429 Unallocated nuclear fusion

Definition

Unallocated nuclear fusion refers to techniques, processes, equipment and systems related to nuclear fusion that cannot be allocated to one specific area of category 42 and where it is not possible to estimate the split between two or more of the sub-categories.

49 Unallocated nuclear fission and fusion

Definition

Unallocated nuclear fission and fusion refers to techniques, processes, equipment and systems related to nuclear fission and fusion that cannot be allocated to one specific area of group 4 and where it is not possible to estimate the split between the two sub-categories.

Group 5 • HYDROGEN AND FUEL CELLS

51 Hydrogen

511 Hydrogen production

Definition

Hydrogen (H_2) production refers to techniques, processes, equipment and systems to produce hydrogen and to purify it at levels acceptable for its further use as an energy source.

RD&D activities focus on improving the performances, output ranges and control systems of: (i) units producing hydrogen from hydrocarbons or carbon monoxide (*e.g.* steam methane reformers, water gas shift reactors); (ii) units separating hydrogen from other gases (*e.g.* pressure swing adsorbers); and (iii) units producing hydrogen by electrolysis of water.

Also including:

- Wind energy/hydrogen integration
- High-temperature production processes coupled with solar and/or nuclear heat sources

Excluding:

- RD&D aimed at producing hydrogen through water photolysis (both chemically or biologically) — *Ref 313 or 3413*
- Nuclear fusion — *Ref. 42*
- Supporting, measuring, monitoring and verifying technologies for H_2 — *Ref. 514*
- Hydrogen safety — *Ref. 514*
- Deuterium, tritium — *out of scope*

512 Hydrogen storage

Definition

Hydrogen storage refers to techniques, processes, equipment and systems to store small to large volumes of H_2 for further use. Hydrogen storage is divided into physical storage, where pure H_2 is stored under gaseous or liquid form, and chemical storage, where hydrogen atoms are reversibly bonded with other substances to form storable hydrides (e.g. metal hydrides).

RD&D activities focus on: (i) improving the performances of materials used in the manufacture of tanks for the physical storage of H_2 (*e.g.* lightweight, time-resistant); and (ii) developing both the fundamental understanding and the engineering capabilities to design cost-effective hydrogen chemical storage units.

By convention, RD&D activities aimed at designing and manufacturing hydrogen tanks to be mounted onboard road vehicles are to be assigned to row 131 and off-road vehicles are to be assigned to row 132.

Also including:

- Underground storage of large hydrogen volumes

Excluding:

- Hydrogen tanks mounted onboard vehicles *Ref. 13*
- Supporting, measuring, monitoring and verifying technologies for H_2 *Ref. 514*
- Hydrogen safety *Ref. 514*
- Siting for hydrogen infrastructures *Ref. 514*

513 Hydrogen transport and distribution

Definition

Hydrogen transport and distribution refer to techniques, processes, equipment and systems to convey hydrogen from where it has been produced or stored in large volumes to where it will be consumed.

RD&D activities focus on: (i) improving the performances of materials used in the compression, liquefaction and gasification of hydrogen; and (ii) on reducing the cost of hydrogen transportation by pipelines over large distances.

Excluding:

- Hydrogen refuelling stations and dispensers *Ref. 514*
- Supporting, measuring, monitoring and verifying technologies for H_2 *Ref. 514*
- Hydrogen safety *Ref. 514*
- Siting for hydrogen infrastructures *Ref. 514*
- Hydrogen distribution networks inside industrial premises *Ref. 515*

514 Other infrastructure and systems

Definition

Other infrastructure and systems refers to techniques, processes, equipment and systems not elsewhere classified and aimed at facilitating a safe use of hydrogen as a source of energy.

RD&D activities focus on: (i) the design and industrialisation of hydrogen-specific sensors and meters; and (ii) performance tests guaranteeing a safe and secure development of hydrogen as an energy source. They include a significant amount of demonstration work aimed at facilitating H_2 acceptance by the general public

By convention, *other infrastructure and systems* includes refuelling stations (dispensers) for hydrogen-fuelled vehicles.

Also including:

- Siting for hydrogen infrastructures
- Supporting, measuring, monitoring and verifying technologies for H_2
- Hydrogen safety

Excluding:

- Hydrogen distribution networks inside industrial premises *Ref. 515*

515 Hydrogen end-uses (including combustion, excluding fuel cells and vehicles)

Definition

Hydrogen end-uses refer to techniques, processes, equipment and systems needing or consuming hydrogen as a source of energy.

RD&D activities focus on finding areas where the property of the hydrogen flame is valued by end-users (e.g. electronics, soldering, glass working, etc.) and on improving the performances of the equipment which they use.

Also including:

- Hydrogen distribution networks inside industrial premises

Excluding:

▪ Hydrogen tanks to be mounted on-board on-road vehicles	*Ref. 131*
▪ Hydrogen tanks to be mounted on-board off-road vehicles	*Ref. 132*
▪ Hydrogen refuelling stations and dispensers	*Ref. 514*
▪ Supporting, measuring, monitoring and verifying technologies for H_2	*Ref. 514*
▪ Hydrogen safety	*Ref. 514*
▪ Fuel cells	*Ref. 52*
▪ Use of hydrogen as a cooling agent, and not as a fuel	*out of scope*
▪ Hydrogen end-uses when H_2 is not a source of energy	*out of scope*

519 Unallocated hydrogen

Definition

Unallocated hydrogen refers to techniques, processes, equipment and systems related to hydrogen that cannot be allocated to one specific area of category 51 and where it is not possible to estimate the split between two or more of the sub-categories.

52 Fuel cells

Fuel cells are electrochemical devices which convert the energy of a chemical reaction directly into electricity, with heat as a by-product. In fuel cells, the fuel and oxidant are stored externally, enabling them to continue operating as long as fuel and oxidant are supplied.

Most fuel cells use the oxygen contained in the ambient air around the fuel cell as oxidant, and either hydrogen or methanol (or another hydrocarbon) as fuel.

521 Stationary applications

Definition

Stationary applications refer to techniques, processes, equipment and systems to conceive and engineer fuel cells aimed at providing power or power and heat for stationary use, including for residential use, emergency power supply, and combined heat and power plants.

Stationary applications are commonly envisioned in the 1 kW to 100 MW power range.

RD&D activities focus on: (i) research on materials, including new catalysts; (ii) research on electrolytes, including membranes; and (iii) the design of fuel cells, including their control and command systems and their integration in complex combined heat and power plants.

Also including:

- Proton exchange membrane fuel cells
- Phosphoric acid fuel cells
- Molten carbonate fuel cells
- High-temperature solid oxides fuel cells
- Distributed power generation by fuel cells

Excluding:

- Supporting, measuring, monitoring and verifying technologies related to fuel cells *Ref. 523*

522 Mobile applications

Definition

Mobile applications refer to techniques, processes, equipment and systems to conceive and engineer fuel cells aimed at providing power or power and heat for mobile use, including on-road, off-road and specialty vehicles (*e.g.* warehouse trucks, planes, ships, submarines, wheelchairs, etc.).

Mobile applications are commonly envisioned in the 0.1 kW to 100 kW power range.

RD&D activities not only focus on materials and electrolytes, as for stationary applications, but also on all design and cost issues linked to the manufacture of larger series.

Excluding:

- Refuelling stations *Ref. 523*
- Supporting, measuring, monitoring and verifying technologies related to fuel cells *Ref. 523*

523 Other applications

Definition

Other applications refers to techniques, processes, equipment and systems to conceive and engineer fuel cells aimed at providing power for uses other than stationary and mobile, such as portable applications.

Portable applications are commonly envisioned in the 1 to 100 W power range.

RD&D activities not only focus on materials and electrolytes, as for stationary applications, but also on using liquid fuels, such as methanol, and on specific miniaturisation, durability and cost issues linked to portable applications.

Other applications also include supporting, measuring, monitoring and verifying technologies related to fuel cells, as well as health, safety and environment activities.

Also including:

- Life cycle analyses related to fuel cells
- Direct methanol fuel cells

Excluding:

- Batteries for portable devices *Ref. 1232*

529 Unallocated fuel cells

Definition

Unallocated fuel cells refers to techniques, processes, equipment and systems related to fuel cells that cannot be allocated to one specific area of category 52 and where it is not possible to estimate the split between two or more of the sub-categories.

59 Unallocated hydrogen and fuel cells

Definition

Unallocated hydrogen and fuel cells refers to techniques, processes, equipment and systems related to hydrogen and fuel cells that cannot be allocated to one specific area of group 5 and where it is not possible to estimate the split between the two sub-categories.

Group 6 • OTHER POWER AND STORAGE TECHNOLOGIES

61 Electric power generation

611 Power generation technologies

Definition

Power generation technologies refer to techniques, processes, equipment and systems to convert mechanical energy into electrical energy.

RD&D activities focus on: (i) enhancing the performance and reducing the cost of devices (e.g. alternators) which are connected to engines or turbines and produce electric power; and (ii) developing novel generation routes (*e.g.* based on magneto-hydrodynamics), or generation equipment (*e.g.* superconducting generating machines) aimed at generating electric power.

Also including:

- CHP (combined heat and power) not covered elsewhere
- Components and boilers for electric power generation not covered elsewhere

Excluding:

- Vehicle-mounted electric generators *Ref. 13*
- Thermo-electricity *Ref. 141*
- Thermo-acoustics *Ref. 141*
- Diesel generators *Ref. 214*
- Piezoelectricity *Ref. 613*

612 Power generation supporting technologies

Definition

Power generation supporting technologies refer to techniques, processes, equipment and systems to assist power generation.

RD&D activities focus on: (i) minimising the environmental footprint of power generation, such as thermal pollution and air, water and noise pollution from power generation units not covered elsewhere; and (ii) developing sensors and IT systems to ensure an optimised performance of the power generation devices.

Power generation supporting technologies include measurement, monitoring and verification of power generation units.

Also including:

- Advanced cooling technologies and use of non-traditional cooling water sources

Excluding:

- Vehicle mounted power generation supporting technologies *Ref. 13*

613 Other electric power generation

Definition

Other electric power generation refers to techniques, processes, equipment and systems not elsewhere specified.

Power generation technologies include electricity generators not classified elsewhere, such as those based on piezoelectricity.

Also including:

- Distributed power generation not elsewhere specified with the exception of vehicle mounted systems

Excluding:

- Thermo-electricity *Ref. 141*
- Thermo-acoustics *Ref. 141*
- Diesel generators *Ref. 214*
- Distributed wind technologies *Ref. 321*
- Distributed power generation by fuel cells in vehicle mounted systems *Ref. 521*

619 Unallocated electric power generation

Definition

Unallocated electric power generation refers to techniques, processes, equipment and systems related to electric power generation that cannot be allocated to one specific area of category 61 and where it is not possible to estimate the split between two or more of the sub-categories.

62 Electricity transmission and distribution

621 Transmission and distribution technologies

Definition

Transmission and distribution technologies refer to techniques, processes, equipment and systems to transfer electrical energy, from the generating power source to consumers.

Transmission refers to the upstream part of a power network, from the power plant to a substation close to the consumer, where electricity is carried under high voltage.

Distribution refers to the downstream part of the network, from substations (where high voltage power is converted into lower voltages, down to domestic voltage) to consumers.

RD&D activities focus on increasing the performance of transmission and distribution devices including life cycle analyses, and on exploring new routes for electricity transmission and distribution such as use of novel materials or high temperature superconductivity.

Also including:

- Underground transmission and distribution of electricity

Excluding:

- Industrial electric equipment, including drives, contactors and starters *Ref. 112*
- Residential and commercial electric equipment, including switches *Ref. 122*
- Grid communication, control systems and integration *Ref. 622*
- Electrical storage *Ref. 631*

6211 Cables and conductors (superconducting, conventional, composite core)

This row refers to all cable and conductor technologies, including conventional, superconducting and composite-core.

6212 AC/DC conversion

This row refers to technologies and devices that convert alternating current into direct current and vice versa.

6213 Other transmission and distribution technologies

This row refers to devices other than those in rows 6211 and 6212 (*e.g*. transformers, insulators, circuit breakers, fault-current devices, power electronics, etc.) and to transmission and distribution technologies not elsewhere specified, including wireless power transmission.

6219 Unallocated transmission and distribution technologies

This row refers to activities relating to transmission and distribution technologies that cannot be allocated to one specific area of category 621 and where it is not possible to estimate the split between two or more of the sub-categories.

622 Grid communication, control systems and integration

Definition

Grid communication, control systems and integration refer to techniques, processes, equipment and systems to manage a transmission and distribution power network so that supply and demand match, failures are anticipated and prevented, and interoperability between grids is granted.

RD&D activities also include IT technologies aimed at: (i) improving or developing suitable metering infrastructure devices, including communication capability; (ii) grid modelling and forecasting; and (iii) preventing curtailment through enhanced security protocols.

Also including:

- Phasor measurement units and fault recorders
- Advanced power system visualisation and control tools
- Renewables integration, including distributed systems

Excluding:

- Energy systems analysis *Ref. 71*

6221 Load management (including renewable integration)

This row refers to balancing the supply of electricity in order to ensure secure and reliable operation of the power system.

6222 Control systems and monitoring

This row refers to sensors and other devices to monitor power flows, power quality and power-related costs.

6223 Standards, interoperability and grid cyber security

This row refers to developing grid standards, maintaining grid security and allowing for power to be carried between grids.

6229 Unallocated grid communication, control systems and integration

This row refers to activities relating to grid communication, control systems and integration that cannot be allocated to one specific area of category 622 and where it is not possible to estimate the split between two or more of the sub-categories.

629 Unallocated electricity transmission and distribution

Definition

Unallocated electricity transmission and distribution refers to techniques, processes, equipment and systems related to electricity transmission and distribution that cannot be allocated to one specific area of category 62 and where it is not possible to estimate the split between the two sub-categories.

63 Energy storage (non-transport applications)

631 Electrical storage

Definition

Electrical storage refers to techniques, processes, equipment and systems that allow electricity to be stored for later use or converted to another form of energy.

All forms and capacities of electrical storage are included in this category, with the exception of electric vehicle batteries and of portable batteries with residential and/or commercial end-use.

RD&D activities include: (i) improving energy storage density and cycling performance, including research into advanced electrolytes and electrodes; (ii) superconductivity; and (iii) advanced mechanics for the design of large equipment, such as air compressors.

Also including:

- Life-cycle analyses for batteries
- Battery management
- Siting of large electrical storage facilities

Excluding:

- Batteries for portable devices *Ref. 1232*
- Electric vehicle batteries *Ref. 1311*
- Hydrogen storage *Ref. 512*
- Fuel cells *Ref. 52*
- Grid communication, control systems and integration *Ref. 622*
- Thermal storage *Ref. 632*

6311 Batteries and other electrochemical storage (excluding vehicles and general public portable devices)

This row refers to batteries and accumulators, regardless of their technologies, but excludes fuel cells. Includes battery management.

6312 Electromagnetic storage

This row refers to the storing of electricity by using super capacitors and magnetic properties of superconducting magnets.

6313 Mechanical storage

This row refers to the conversion of electrical energy into mechanical energy, allowing for a further reconversion back to electricity. The most common forms of mechanical storage of energy are pumped hydro, compressed air energy storage (CAES) and flywheels (kinetic storage).

6314 Other storage (excluding fuel cells)

This row includes photochemical storage.

6319 Unallocated electrical storage

This row refers to activities relating to electrical storage that cannot be allocated to one specific area of category 631 and where it is not possible to estimate the split between two or more of the sub-categories.

632 Thermal energy storage

Definition

Thermal storage refers to techniques, processes, equipment and systems using air, liquid or chemicals in reservoirs to maintain a constant temperature for later use or as a heat exchange.

RD&D activities focus on developing materials and chemicals offering enhanced thermal storage performance.

RD&D activities also focus on designing thermal storage systems suitable for concentrating solar power units.

Also including:

- Sensible/latent heat storage for cooling or heating purposes
- Distributed thermal storage technologies
- Water-based technologies
- Molten salt technologies
- Phase-change materials

Excluding:

▪ Building design and envelope	*Ref. 121*
▪ Heating, cooling and ventilation technologies	*Ref. 1223*
▪ Solar heating and cooling	*Ref. 311*
▪ Solar thermal power and high-temperature applications	*Ref. 313*

639 Unallocated electrical storage

Definition

Unallocated electrical storage refers to techniques, processes, equipment and systems related to electrical storage that cannot be allocated to one specific area of category 63 and where it is not possible to estimate the split between the two sub-categories.

69 Unallocated other power and storage technologies

Definition

Unallocated other power and storage technologies refers to techniques, processes, equipment and systems related to power and storage technologies that cannot be allocated to one specific area of group 6 and where it is not possible to estimate the split between two or more of the sub-categories.

Group 7 • OTHER CROSS-CUTTING TECHNOLOGIES OR RESEARCH

71 Energy system analysis

Definition

Energy system analysis refers to the sociological, economical and environmental impact of energy which is not specifically related to one technology area listed in the categories above.

It also includes systems analysis related to energy RD&D not covered elsewhere, behavioural and other social science research into energy, and mathematical research, such as algorithmic search or modelling, related to energy and not covered in the categories above.

72 Basic energy research that cannot be allocated to a specific category

Definition

Basic energy research that cannot be allocated to a specific category refers to basic research where the final application may not be attributable to a specific technology listed in previous sections.

73 Other

Definition

Other refers to: (i) energy technology information dissemination; and (ii) studies not related to a specific technology area listed in previous categories.

***Important note**: Please make sure that row 73 does not represent too large an amount of your total RD&D spending. See part I of the present Guidelines.*

MEMO ITEMS

01 Smart grids

Definition

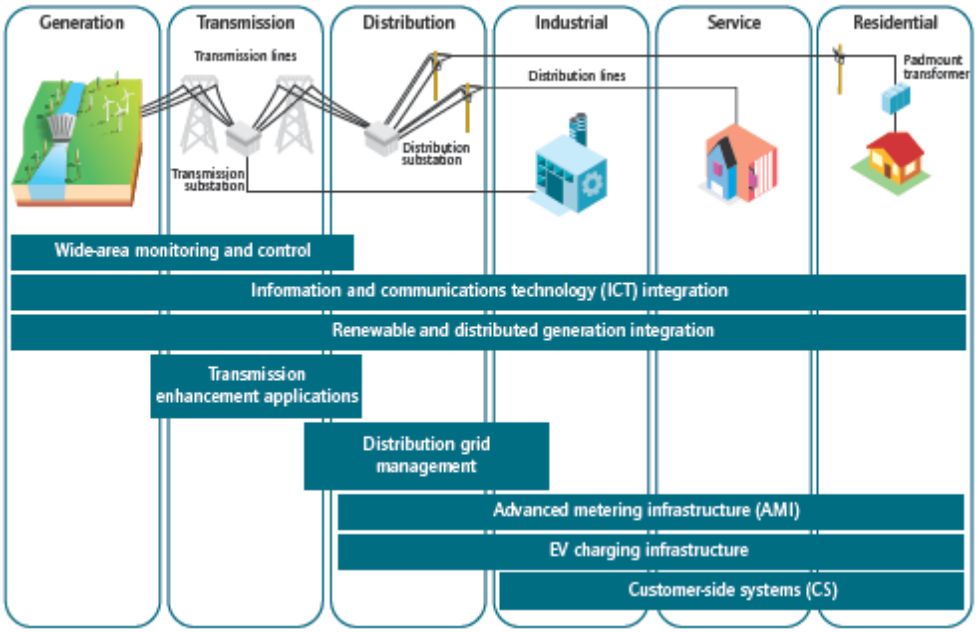
A smart grid is an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end-users. Smart grids co-ordinate the needs and capabilities of all generators, grid operators, end-users and electricity market stakeholders to operate all parts of the system as efficiently as possible, minimising costs and environmental impacts while maximising system reliability, resilience and stability.

"Smart grids" is a memo item created to give a global vision on RD&D efforts concerning this critical issue for modern energy management.

Therefore, it not only encompasses rows (621) "Transmission and distribution technologies" and (622) "Grid communication, control systems and integration", but also the part of row (1221) dedicated to smart metering, all of row (1314) which deals with electric vehicle infrastructure and is related to connecting electric vehicles to the grid, as well as the part of row (71) dealing with energy system analysis that is part of the smart grid concept.

The many smart grid technology areas – each consisting of sets of individual technologies – span the entire grid, from generation through transmission and distribution to various types of electricity consumers. A brief summary of smart grid technology areas has been given below.[4] The description that follows is to facilitate the understanding of what is included under smart grids and in no way attempts to separate the level of maturity of the technology – i.e. whether at the R&D, demonstration or deployment stage.

Summary of smart grid technology areas



Source: Technology Roadmap: Smart Grids, IEA/OECD, 2011.

4. The following description of smart grids has been taken from the publication *Technology Roadmap: Smart Grids*, IEA/OECD, 2011.

Wide-area monitoring and control

Real-time monitoring and display of power-system components and performance, across interconnections and over large geographic areas, help system operators to understand and optimise power system components, behaviour and performance. Advanced system operation tools avoid blackouts and facilitate the integration of variable renewable energy resources. Monitoring and control technologies along with advanced system analytics – including wide-area situational awareness (WASA), wide-area monitoring systems (WAMS), and wide-area adaptive protection, control and automation (WAAPCA) – generate data to inform decision making, mitigate wide-area disturbances, and improve transmission capacity and reliability.

Information and communications technology integration

Underlying communications infrastructure, whether using private utility communication networks (radio networks, meter mesh networks) or public carriers and networks (Internet, cellular, cable or telephone), support data transmission for deferred and real-time operation, and during outages. Along with communication devices, significant computing, system control software and enterprise resource planning software support the two-way exchange of information between stakeholders, and enable more efficient use and management of the grid.

Renewable and distributed generation integration

Integration of renewable and distributed energy resources – encompassing large scale at the transmission level, medium scale at the distribution level and small scale on commercial or residential building – can present challenges for the dispatchability and controllability of these resources and for operation of the electricity system. Energy storage systems, both electrically and thermally based, can alleviate such problems by decoupling the production and delivery of energy. Smart grids can help through automation of control of generation and demand (in addition to other forms of demand response) to ensure balancing of supply and demand.

Transmission enhancement applications

There are a number of technologies and applications for the transmission system. Flexible AC transmission systems (FACTS) are used to enhance the controllability of transmission networks and to maximise power transfer capability. The deployment of this technology on existing lines can improve efficiency and defer the need for additional investment. High voltage DC (HVDC) technologies are used to connect offshore wind and solar farms to large power areas, with decreased system losses and enhanced system controllability, allowing efficient use of energy sources remote from load centres. Dynamic line rating (DLR), which uses sensors to identify the current carrying capability of a section of network in real time, can optimise utilisation of existing transmission assets, without the risk of causing overloads. High-temperature superconductors (HTS) can significantly reduce transmission losses and enable economical fault-current limiting with higher performance, though there is a debate over the market readiness of the technology.

Distribution grid management

Distribution and sub-station sensing and automation can reduce outage and repair time, maintain voltage level and improve asset management. Advanced distribution automation processes real-time information from sensors and meters for fault location, automatic reconfiguration of feeders, voltage and reactive power optimisation, or to control distributed generation. Sensor technologies can enable condition- and performance-based maintenance of network components, optimising equipment performance and hence effective utilisation of assets.

Advanced metering infrastructure

Advanced metering infrastructure (AMI) involves the deployment of a number of technologies – in addition to advanced or smart meters[5] that enable two-way flow of information, providing customers and utilities with data on electricity price and consumption, including the time and amount of electricity consumed. AMI will provide a wide range of functionalities:

- Remote consumer price signals, which can provide time-of-use pricing information.
- Ability to collect, store and report customer energy consumption data for any required time intervals or near real time.
- Improved energy diagnostics from more detailed load profiles.
- Ability to identify location and extent of outages remotely via a metering function that sends a signal when the meter goes out and when power is restored.
- Remote connection and disconnection.
- Losses and theft detection.
- Ability for a retail energy service provider to manage its revenues through more effective cash collection and debt management.

Electric vehicle charging infrastructure

Electric vehicle charging infrastructure handles billing, scheduling and other intelligent features for smart charging (grid-to-vehicle) during low energy demand. In the long run, it is envisioned that large charging installation will provide power system ancillary services such as capacity reserve, peak load shaving and vehicle-to-grid regulation. This will include interaction with both AMI and customer-side systems.

Customer-side systems

Customer-side systems, which are used to help manage electricity consumption at the industrial, service and residential levels, include energy management systems, energy storage devices, smart appliances and distributed generation.[6] Energy efficiency gains and peak demand reduction can be accelerated with in-home displays/energy dashboards, smart appliances and local storage. Demand response includes both manual customer response and automated, price-responsive appliances and thermostats that are connected to an energy management system or controlled with a signal from the utility or system operator.

5. The European Smart Meters Industry Group (ESMIG) defines four minimum functionalities of a smart meter: remote reading, two-way communication, support for advanced tariff and payment systems, and remote disablement and enablement of supply.
6. Residential small-scale generation equipment on customer premises falls under both categories of consumer-side systems and renewable and distributed energy systems.

There are a number of hardware and systems/software associated with each technology area and these have been listed below. Within the smart grid technology landscape, a broad range of hardware, software, application and communication technologies are at various levels of maturity. Some technologies are still in the R&D stage, some have proven themselves over time, but many – even if mature – have yet to be demonstrated on a large scale. Again, this description is given to facilitate the understanding of what is included under smart grids and in no way attempts to separate the level of maturity of the technology – i.e. whether at the R&D, demonstration or deployment stage.

Smart grid technologies

Technology area	Hardware	Systems and software
Wide-area monitoring and control	Phasor measurement units (PMU) and other sensor equipment	Supervisory control and data acquisition (SCADA), wide-area monitoring systems (WAMS), wide-area adaptive protection, control and automation (WAAPCA), wide-area situational awareness (WASA)
Information and communication technology integration	Communication equipment (Power line carrier, WIMAX, LTE, RF mesh network, cellular), routers, relays, switches, gateway, computers (servers)	Enterprise resource planning software (ERP), customer information system (CIS)
Renewable and distributed generation integration	Power conditioning equipment for bulk power and grid support, communication and control hardware for generation and enabling storage technology	Energy management system (EMS), distribution management system (DMS), SCADA, geographic Information system (GIS)
Transmission enhancement	Superconductors, FACTS, HVDC	Network stability analysis, automatic recovery systems
Distribution grid management	Automated re-closers, switches and capacitors, remote controlled distributed generation and storage, transformer sensors, wire and cable sensors	Geographic information system (GIS), distribution management system (DMS), outage management system (OMS), workforce management system (WMS)
Advanced metering infrastructure	Smart meter, in-home displays, servers, relays	Meter data management system (MDMS)
Electric vehicle charging infrastructure	Charging infrastructure, batteries, inverters	Energy billing, smart grid-to-vehicle charging (G2V) and discharging vehicle-to-grid (V2G) methodologies
Customer-side systems	Smart appliances, routers, in-home display, building automation systems, thermal accumulators, smart thermostat	Energy dashboards, energy management systems, energy applications for smart phones and tablets

What should be reported in the questionnaire?

Part of 1221 (optional)	Building energy management systems (incl. smart meters) and efficient internet and communication technologies
	+
1314 (optional)	Electric vehicle infrastructure
	+
621	Transmission and distribution technologies
	+
622	Grid communication, control systems and integration
	+
Part of 71	Energy system analysis that is part of the smart grid concept, including consumer behaviour, sociological aspects, dynamic consumer engagement, etc.
	+
Smart grid figures not identified in previous categories	

= Smart grids

02 Electric vehicles

Definition

"Electric vehicles" is a memo item created to give a global vision on RD&D efforts in this domain.

Therefore, it aggregates the part of row (1312) related to motors and power electronics for electric vehicles, the part of row (1311) related to batteries and row (1314) related to infrastructures connecting electric vehicles to the grid.

Electric vehicles shall be understood as fully electric, and therefore exclude both hybrid electric vehicles and hydrogen-fuelled ones.

Electric vehicles only refer to on-road vehicles.

What should be reported in the questionnaire?

Part of 1311 (optional)	Vehicle batteries/storage technologies
	+
Part of 1312 (optional)	Advanced power electronics, motors, and EV/HEV/FCV systems
	+
1314 (optional)	Electric vehicle infrastructure
	+
Electric vehicle figures not identified in previous categories	

= **Electric vehicles**

03 Energy storage

Definition

"Energy storage" is a memo item created to give a global vision on RD&D efforts placed on the issue of storing energy to better match power production and consumption.

Therefore, it not only encompasses row (63) "Energy storage (non transport applications)", but also rows (1232) and (1311) related to batteries and row (512) related to hydrogen storage, due to the many present and future interactions between power generation and hydrogen.

Conversely, there are many fewer interactions between power generation and fossil fuel storage; therefore, storage of oil and gas (part of row (212)) is excluded from energy storage.

What should be reported in the questionnaire?

1232 (optional)	Batteries for portable devices
	+
1311 (optional)	Vehicle batteries/storage technologies
	+
512	Hydrogen storage
	+
63	Energy storage (non-transport applications)
	+
Energy storage figures not identified in previous categories	

= Energy storage

ANNEX

Annex 1. RD&D Budget Questionnaire

Millions, national currency

One sheet to be filled out for RD&D (excluding state-owned enterprises) and one sheet for state-owned enterprises.	Year	
	R&D	Demon-stration
BUDGETARY STAGE (see Section IV.2 on reporting issues)		
FISCAL YEAR STARTING		
1 ENERGY EFFICIENCY (sum of rows 11 to 19)		
11 Industry		
111 Industrial techniques and processes		
112 Industrial equipment and systems		
113 Other industry		
119 Unallocated industry		
12 Residential and commercial buildings, appliances and equipment		
121 Building design and envelope		
1211 Building envelope technologies		
1212 Building design		
1219 Unallocated building design and envelope		
122 Building operations and efficient building equipment		
1221 Building energy management systems (incl. smart meters) and efficient internet and communication technologies		
1222 Lighting technologies and control systems		
1223 Heating, cooling and ventilation technologies		
1224 Other building operations and efficient building equipment		
1229 Unallocated building operations and efficient building equipment		
123 Appliances and other residential/commercial		
1231 Appliances		
1232 Batteries for portable devices		
1233 Other residential/commercial		
1239 Unallocated appliances and other residential/commercial		
129 Unallocated residential and commercial buildings, appliances and equipment		
13 Transport		
131 On-road vehicles		
1311 Vehicle batteries/storage technologies		
1312 Advanced power electronics, motors and EV/HEV/FCV systems		
1313 Advanced combustion engines		
1314 Electric vehicle infrastructure (incl. smart chargers and grid communications)		
1315 Use of fuels for on-road vehicles (excl. hydrogen)		
1316 Materials for on-road vehicles		
1317 Other on-road transport		
1319 Unallocated on-road vehicles		
132 Off-road transport and transport systems		
133 Other transport		
139 Unallocated transport		

14 Other energy efficiency		
141 Waste heat recovery and utilisation		
142 Communities		
143 Agriculture and forestry		
144 Heat pumps and chillers		
145 Other energy efficiency		
149 Unallocated other energy efficiency		
19 Unallocated energy efficiency		
2 FOSSIL FUELS: OIL, GAS and COAL (sum of rows 21 to 29)		
21 Oil and gas		
211 Enhanced oil and gas production		
212 Refining, transport and storage of oil and gas		
213 Non-conventional oil and gas production		
214 Oil and gas combustion		
215 Oil and gas conversion		
216 Other oil and gas		
219 Unallocated oil and gas		
22 Coal		
221 Coal production, preparation and transport		
222 Coal combustion (incl. IGCC)		
223 Coal conversion (excl. IGCC)		
224 Other coal		
229 Unallocated coal		
23 CO_2 capture and storage		
231 CO_2 capture/separation		
232 CO_2 transport		
233 CO_2 storage		
239 Unallocated CO_2 capture and storage		
29 Unallocated fossil fuels		

3 RENEWABLE ENERGY SOURCES (sum of rows 31 to 39)		
31 Solar energy		
311 Solar heating and cooling		
312 Solar photovoltaics		
313 Solar thermal power and high-temp. applications		
319 Unallocated solar energy		
32 Wind energy		
321 Onshore wind technologies		
322 Offshore wind technologies (excl. low wind speed)		
323 Wind energy systems and other technologies		
329 Unallocated wind energy		
33 Ocean energy		
331 Tidal energy		
332 Wave energy		
333 Salinity gradient power		
334 Other ocean energy		
339 Unallocated ocean energy		
34 Biofuels (incl. liquid biofuels, solid biofuels and biogases)		
341 Production of liquid biofuels		
3411 Gasoline substitutes (incl. ethanol)		
3412 Diesel, kerosene and jet fuel substitutes		
3413 Algal biofuels		
3414 Other liquid fuel substitutes		
3419 Unallocated production of liquid biofuels		
342 Production of solid biofuels		
343 Production of biogases		
3431 Thermochemical		
3432 Biochemical (incl. anaerobic digestion)		
3433 Other biogases		
3439 Unallocated production of biogases		
344 Applications for heat and electricity		
345 Other biofuels		
349 Unallocated biofuels		
35 Geothermal energy		
351 Geothermal energy from hydrothermal resources		
352 Geothermal energy from hot dry rock (HDR) resources		
353 Advanced drilling and exploration		
354 Other geothermal energy (incl. low-temp. resources)		
359 Unallocated geothermal energy		
36 Hydroelectricity		
361 Large hydroelectricity (capacity of 10 MW and above)		
362 Small hydroelectricity (capacity less than 10 MW)		
369 Unallocated hydroelectricity		
37 Other renewable energy sources		
39 Unallocated renewable energy sources		

4 NUCLEAR FISSION and FUSION (sum of rows 41 and 49)		
41 Nuclear fission		
411 Light water reactors (LWRs)		
412 Other converter reactors		
4121 Heavy water reactors (HWRs)		
4122 Other converter reactors		
4129 Unallocated other converter reactors		
413 Fuel cycle		
4131 Fissile material recycling / reprocessing		
4132 Nuclear waste management		
4133 Other fuel cycle		
4139 Unallocated fuel cycle		
414 Nuclear supporting technologies		
4141 Plant safety and integrity		
4142 Environmental protection		
4143 Decommissioning		
4144 Other nuclear supporting technologies		
4149 Unallocated nuclear supporting technologies		
415 Nuclear breeder		
416 Other nuclear fission		
419 Unallocated nuclear fission		
42 Nuclear fusion		
421 Magnetic confinement		
422 Inertial confinement		
423 Other nuclear fusion		
429 Unallocated nuclear fusion		
49 Unallocated nuclear fission and fusion		
5 HYDROGEN and FUEL CELLS (sum of rows 51 and 59)		
51 Hydrogen		
511 Hydrogen production		
512 Hydrogen storage		
513 Hydrogen transport and distribution		
514 Other infrastructure and systems		
515 Hydrogen end-uses (incl. combustion; excl. fuel cells and vehicles)		
519 Unallocated hydrogen		
52 Fuel cells		
521 Stationary applications		
522 Mobile applications		
523 Other applications		
529 Unallocated fuel cells		
59 Unallocated hydrogen and fuel cells		

6 OTHER POWER and STORAGE TECHNOLOGIES (sum of rows 61 to 69)		
61 Electric power generation		
611 Power generation technologies		
612 Power generation supporting technologies		
613 Other electric power generation		
619 Unallocated electric power generation		
62 Electricity transmission and distribution		
621 Transmission and distribution technologies		
6211 Cables and conductors (superconducting, conventional, composite core)		
6212 AC/DC conversion		
6213 Other transmission and distribution technologies		
6219 Unallocated transmission and distribution technologies		
622 Grid communication, control systems and integration		
6221 Load management (incl. renewable integration)		
6222 Control systems and monitoring		
6223 Standards, interoperability and grid cyber security		
6229 Unallocated grid communication, control systems and integration		
629 Unallocated electricity transmission and distribution		
63 Energy storage (non-transport applications)		
631 Electrical storage		
6311 Batteries and other electrochemical storage (excl. vehicles and general public portable devices)		
6312 Electromagnetic storage		
6313 Mechanical storage		
6314 Other storage (excl. fuel cells)		
6319 Unallocated electrical storage		
632 Thermal energy storage		
639 Unallocated energy storage		
69 Unallocaated other power and storage technologies		
7 OTHER CROSS-CUTTING TECHNOLOGIES or RESEARCH (sum of rows 71 and 73)		
71 Energy system analysis		
72 Basic energy research that cannot be allocated to a specific category		
73 Other		
TOTAL BUDGET (sum of rows 1 to 7)		

MEMO ITEMS:		
01 Smart grids		
Part of 1221 (optional) Building energy management systems (incl. smart meters) and efficient internet and communication technologies		
1314 (optional) Electric vehicle infrastructure		
621 Transmission and distribution technologies		
622 Grid communication, control systems and integration		
Part of 71 Energy system analysis that is part of the smart grid concept		
Smart grid figures not identified in previous categories		
02 Electric vehicles		
Part of 1311 (optional) Vehicle batteries/storage technologies		
Part of 1312 (optional) Advanced power electronics, motors, and EV/HEV/FCV systems		
1314 (optional) Electric vehicle infrastructure		
Electric vehicle figures not identified in previous categories		
03 Energy storage		
1232 (optional) Batteries for portable devices		
1311 (optional) Vehicle batteries/storage technologies		
512 Hydrogen storage		
63 Energy storage (non-transport applications)		
Energy storage figures not identified in previous categories		

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