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Update 2020

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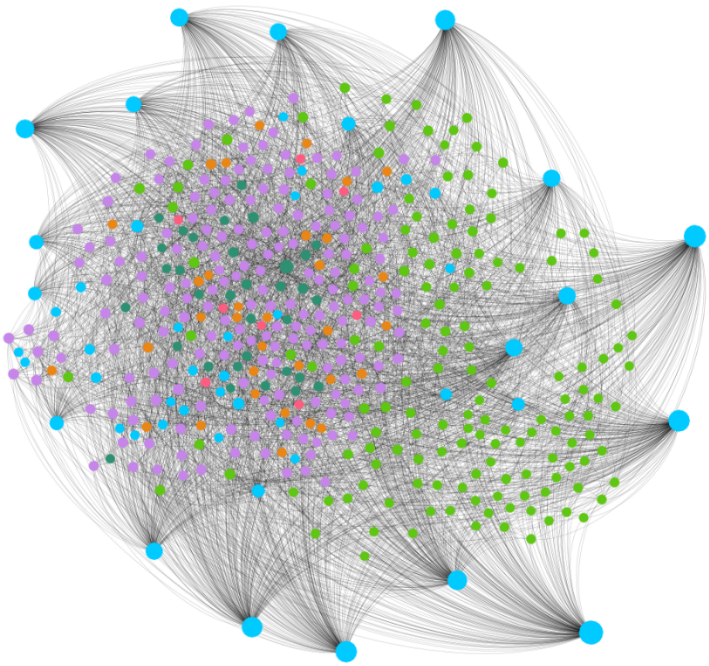

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Mapping of activities in Technology Collaboration Programmes (TCPs)
in the Energy Technology Network of the
International Energy Agency (IEA)

Update 2020

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Österreichische Energieagentur – Austrian Energy Agency

Vienna, April 2021

A project report in the frame of the programme

IEA Research Cooperation
Part of open4innovation

on behalf of Austrian Federal Ministry for Climate Action, Environment, Energy,
Mobility, Innovation and Technology

Preface

This project was initiated by the End-Use Working Party of the International Energy Agency. The End-Use Working Party guides 14 of total 38 Technology Collaboration Programmes (TCPs) and has thematic linkages to several TCPs of the Renewable Energy Working Party and the Working Party on Fossil Fuels. The intention of this project was to update the previous mapping exercise from 2018 and to visualize the current activities of the IEA Energy Technology Network and to identify possible gaps and overlaps. It demonstrates a basis for further coordination and collaboration between TCPs and Working Parties.

The mapping includes 209 ongoing projects (tasks, annexes). 35 methods such as type of R&D, standardisation or education are defined and assigned. User-friendly interfaces were developed for selected questions (nachhaltigwirtschaften.at/iea-visualisations), which enable a quick analysis of the most important correlations: Interactive tools (in English) show all TCPs and tasks that focus on a selectable topic or work on the same topics. Furthermore, all countries involved in a topic can be identified. An interactive world maps shows the cooperation of Austria, a treemaping shows the focus of public Austrian R&D funding and thematic links to TCPs.

Mag.[a] Sabine Mitter
Chair of the End Use Working Party
June 2021

About this handbook

For more than 45 years, IEA's now called Technology Collaboration Programme sets the most impactful legal framework for international cooperation in research and technology in the energy field. About 40 TCPs (the individual technology collaboration programmes) are reporting to three working parties – one for renewable energy technologies, one for fossil energy and the third one covering all end use sectors – and one coordination group for nuclear fusion. These working parties were established by the Committee on Energy Research and Technology (CERT). CERT, Working Parties and TCPs (the individual technology collaboration programmes) but also member state's policymakers and individual organisations and experts are challenged by the amount of possibilities for cooperation.

To get a better overview and to identify possible gaps and overlaps, in 2017 the Austrian delegation in the End Use Working Party offered to carry out comprehensive analysis. The Austrian Energy Agency (AEA) was than appointed by the Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK) to gather, analyse and last visualize the relevant data. For the update 2020/2021 described In this handbook, a focus was put on further improving the accessibility to the dataset by developing web visualizations for the most common use cases.

For the visualization, all ongoing tasks in summer 2020 of all TCPs of IEA's Technology Collaboration Program were analysed. Web-based interfaces were developed for selected questions, which allow a quick analysis of the most relevant correlations. Five interactive visualisations – two of them in German with a focus on the Austrian situation, and three interfaces in English language covering all countries – are hosted on https://nachhaltigwirtschaften.at/iea-visualisations

The overall dataset (graph-based) is available for individual customized analysis[1]. This dataset also contains further information on the internal structure of the technology program (allocation to various IEA Working Parties), the research expenditures of the participating countries and a classification of the type of activities etc. that could not be displayed in the web-based interfaces due to high complexity and requirements of user friendliness. The intention of this handbook is to give some background information on the dataset, present the web interfaces and – if the web interfaces do not suffice – point the way to more thorough, custom analysis of the raw dataset with graph tools like neo4j and Cypher.

[1] Note regarding the General Data Protection Regulation (GDPR), effective from 25 May 2018: the database does not include any personalized data.

Contents

1 Data, taxonomies and classification

No single dataset serves the needs for this kind of mapping of activities of the IEA Energy Technology Network. Therefore different sets of data have been identified, linked and analysed. The present dataset is based mainly two different "families" of information.

Firstly, the existing and publicly available information of the Energy Technology Network itself was assessed. Secondly, the public IEA database for RD&D expenditures/budgets proved complementary and was very valuable for this purpose. In addition to this data, a set of 35 methods was developed to classify the type of activity carried out. All data sources were interlinked, based on publicly available information and expert knowledge.

1.1 The IEA Energy Technology Network

For more than 45 years, IEA's now called Technology Collaboration Programme sets the most impactful legal framework for international cooperation in research and technology in the energy field. Some TCPs (the individual technology collaboration programmes) terminated during the last decades, some were merged, but others still operate since the starting years of IEA in the mid-seventies of the last century. Also additional challenges resulted in new TCPs.

Today, about 40 TCPs are reporting to three working parties – one for renewable energy technologies, one for fossil energy and the third one covering all end use sectors – and one coordination group for nuclear fusion. These working parties and the coordination group were established by the Committee on Energy Research and Technology (CERT). Work is funded by participants only, and there is a close cooperation with the IEA-secretariat in Paris, which also cares about the legal framework.

Most of the TCPs are sub-structured in projects, called tasks or annexes. In this mapping exercise, all these tasks / annexes are named "activities". Eventually 266 activities have been recorded (57 of them already being closed at the date of publication of this handbook). Publicly available sources like TCP-websites and annual reports have been complemented by the information TCPs provide to their working parties (annual briefs etc.). TCPs were informed about the data collection process beforehand, so they could update their websites accordingly.

TCPs are managed by an Executive Committee (ExCo). For reasons of data structure and processing, each ExCo has been registered as an own activity, too.

For a list of all registered activities, see annex 5.2

Member States and other countries, together with sponsors, can join a TCP in a dedicated process. After being a member of a TCP, usually each country can participate in activities, which are of interest to them. For this mapping exercise, the participation of countries has been identified from available sources. For this purpose, the ISO-Code of countries was applied (see annex 5.6).

1.2 IEA RD&D Statistics

All member countries of the International Energy Agency are obliged to yearly record all energy-related research, development and first-of-a-kind demonstration public expenditures.

Table 4
Information on Government Energy RD&D Budgets (A)
Millions, national currency

Years requested: 2014, 2015 estimated and 2016 estimated One sheet to be filled out for RD&D (excluding state-owned enterprises) and one sheet for state-owned enterprises. BUDGETARY STAGE (see instructions on reporting issues) FISCAL YEAR STARTING	Year	
	R&D	Demon-stration
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		

Figure 1-1: Structure of questionnaire for reporting expenditures/budgets (Source: QUESTIONNAIRE FOR IN-DEPTH ENERGY POLICY REVIEWS 2015-16 CYCLE IEA/SLT (2015)4)

To allocate activities in the field of energy, a categorization with a 4-digit-level is applied. This taxonomy - together with an extensive description of this survey - can be found in the report: IEA Guide to Reporting Energy RD&D Budget/Expenditure Statistics (2011). The taxonomy proved suitable to classify the thematic activities of the TCPs for this mapping exercise and is provided in annex 5.4.

The IEA RD&D database can be accessed under the following link: https://www.iea.org/subscribe-to-data-services/energy-technology-rdd

1.3 Methods

Until the start of the predecessor project, there was no commonly accepted classification available to describe the type of activity. Therefore, a set of 35 so called "methods" was developed. Eventually, each of the 266 activities was assigned to up to three different methods (one method as a minimum), based on publicly available information on the activities (see Table 1-1). For a more detailed definition of the methods, see annex 5.3.

Method	Abbrev.	Number of related Activities	Number of related *ongoing* Activites
Applied research	ARES	118	93
Policies and legislation	POLE	44	32
Testing	TEST	32	19
Best practice	BEST	29	20
Standards	STND	29	21
Technological development	TEDE	26	23
Market development and deployment	MADE	24	15
Market analysis	MRKT	23	16
Administration	ADMN	22	21
Consumer behaviour and behaviour change	CONS	22	16
Environmental aspects	ENVI	19	16
Planning	PLAN	18	14
System analysis and integration	SYST	17	13
Basic research	BASC	16	12
Monitoring	MONI	15	9
Outreach and raising awareness	OUTR	15	12

Method	Abbrev.	Number of related Activities	Number of related *ongoing* Activites
Safety and health issues	SAFE	12	11
Life cycle and technology assessment	LCSA	10	8
Costs	COST	9	9
Digitalization, protection of data privacy	DATA	9	7
Reduction of greenhouse gases	GHGR	9	8
Project database	PROJ	9	6
Resource assessment and forecasting	REAS	9	9
Cost reduction	CORE	8	6
Operational performance	OPER	8	7
Conferences	CONF	7	7
Modelling and scenarios	SZEN	7	4
Awards	AWRD	6	6
Education and training	EDUC	6	6
Market introduction	INTR	5	3
First-of-its-kind demonstration	FOIK	4	3
Roadmaps	ROAD	4	3
Products	PROD	2	2
Security of supply	SECS	2	2
Energy management systems and audits	EMSA	0	0

Table 1-1: Table of 35 methods (AEA)

1.4 Initiatives

Seven multilateral initiatives in the areas of biofuels as well as hydrogen & fuel cells were included in the updated dataset. This additional data allows some preliminary analysis on country participation in IEA TCPs in these two topics versus other international initiatives, dedicated challenges in Mission Innovation or initiatives in the Clean Energy Ministerial. Countries participation in these initiatives is voluntary, similar to their engagement in TCPs. The list does not claim to be exhaustive. If this kind of analysis will be found robust and valuable, more initiatives can be included in future updates. The simplicity of enriching an pre-existing dataset by linking it to new information illustrates one of the great advantages of graph based datasets.

Initiative	Link
Biofuture Platform	http://www.biofutureplatform.org/
Global Bioenergy Partnership GBEP	http://www.globalbioenergy.org/
Mission Innovation Challenge 4 Sustainable Biofuels	http://mission-innovation.net/our-work/innovation-challenges/sustainable-biofuels/
International Partnership for Hydrogen and Fuel Cells in the Economy IPHE	https://www.iphe.net/
Mission Innovation Challenge 8 Renewable and Clean Hydrogen	http://mission-innovation.net/our-work/innovation-challenges/ren
Hydrogen Initiative Linz Declaration	https://www.eu2018.at/calendar-events/political-events/BMNT-2018-09-17-Informal-TTE.html
Clean Energy Ministerial Hydrogen Initiative CEM H2I	https://www.iea.org/programmes/clean-energy-ministerial-hydrogen-initiative

Table 1-2: Multilateral initiatives in the database

1.5 Assumptions and Limitations

Due to limited time, budget and/or available robust information some assumptions had to be made:

1. Some tasks report to more than one TCP (so called joint tasks). For this exercise, such activities were assigned to each TCP individually, but the information of cooperation is not included in the dataset.

2. Because it was not possible to classify the extent of work, budget and resources of single activities (no detailed information on activities and their budgets available) all activities are weighted equally. In reality, this simplification will lead to slightly biased results, as some tasks/annexes are much more active than others.

3. No differentiation of IEA member states, accession, association and other countries was made.

4. No sponsors (a type of participation in a TCP for non-governmental bodies) and international organisations have been processed.

5. The role of the European Union (EU) and the European Commission (EC) varies over TCPs. While the participation of the European Commission – often in parallel to some EU member states - was not included in the dataset, the participation of the European Union (on behalf of EU member states) in the Fusion TCPs was included as such.

6. Data was collected and assessed in September 2017 and Updated in August 2020. No further updates have been applied.

7. Only ongoing and planned activities were collected. Closed Activities are only reported if they have been closed between the last and the current update (between September 2017 and 2020).

8. In case of conflicting information from different sources (e.g. different information on participating countries), an assessment was made by the authors.

It has to be stated, that in principle these simplifications could be avoided in further exercises due to the design of the database – if time, budget and access to information allow. For the proper quantification of activities, new procedures and reporting would have to be established.

2 Structure of the Dataset

2.1 Description of Data Structure

The design and understanding of the structure (i.e. meta-graph) of the graph model is a fundamental process. Within the neo4J browser the function *db.schema* returns the meta graph of the model, which allows a visual examination of the model. This includes all node-types and all relationships. Simultaneously it allows validating the correct representation of the underlying data.

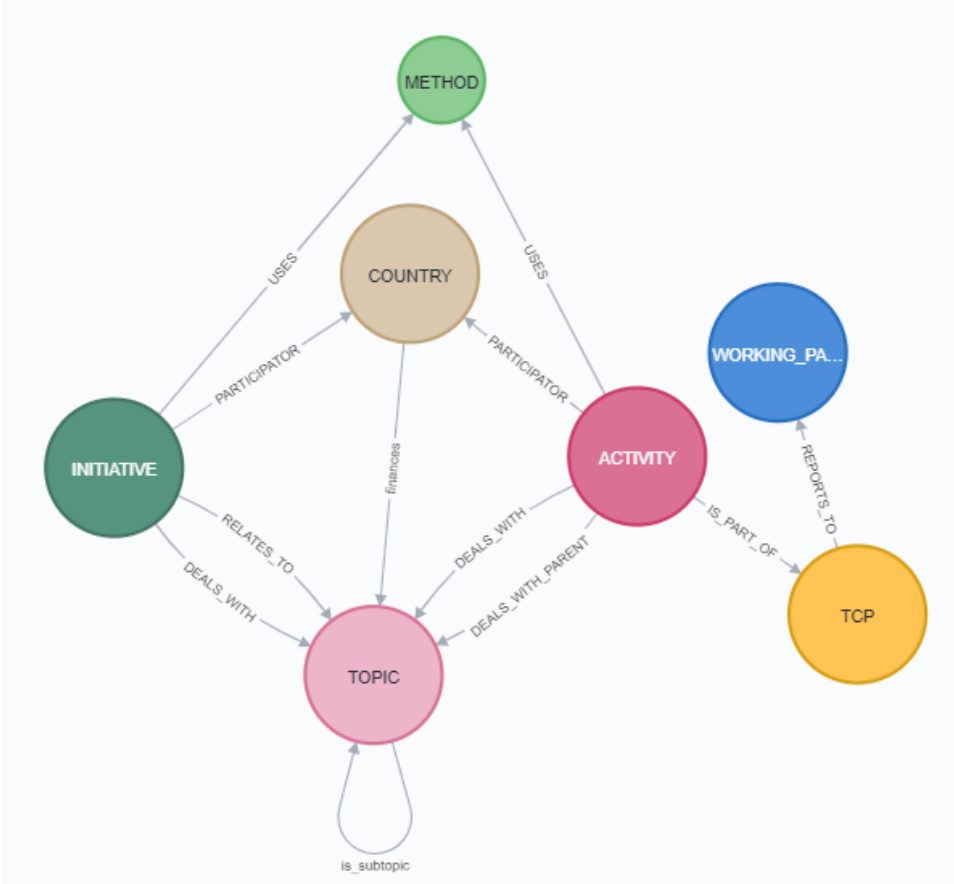


Figure 2-1: Meta-graph of the IEATCP graph database

The TCP–activities (or tasks/annexes) are the central entity of the IEATCP graph model. Activities are associated with the respective TCP. The TCPs are associated with the respective working party. This part of the model is hierarchically structured. This sub-graph resembles the structure of the organization of the IEA research efforts. Both organizational levels are implemented as nodes and result in the following pattern[2]:

```
(ACTIVITY)-[IS_PART_OF]-(TCP)-[REPORTS_TO]-(WORKING_PARTY)
```

[2] Round brackets "(…)" represent node types (also called "labels"), while square brackets "[…]" represent relationship types.

Every activity has participating countries[3]. These countries are represented by independent nodes. If a country participates in an activity, a relationship of the type “participator” is created. The resulting pattern is

```
(COUNTRY)-[PARTICPATOR]-(ACTIVITY)
```

The activity itself uses specific methods, based on what kind of work they are doing (see chapter 1.3). Each activity was assigned 1 to 3 methods. The methods themselves are nodes and are connected to the activity via the relationship type “uses” - so that the pattern

```
(ACTIVITY)-[USES]-(METHOD)
```

results. Every activity also has associated IEA-topics, based on the energy field they are dealing with. Each activity was assigned to up to three different IEA-topics. If an activity deals with a topic, a relation type “deals_with” is created. The resulting pattern is

```
(ACTIVITY)-[DEALS_WITH]-(TOPIC)
```

Note that the IEA taxonomy for RD&D expenditures has a 4 level hierarchical structure which goes from low detail (e.g. first level topic number 3: “Renewable Energy Sources” to high details (e.g. fourth level topic number 3.4.1.4 “Algal Biofuels”) (See annex 5.4). When linking activities to IEA-topics it was tried to be as accurate as possible and link the activities to the topic number with the highest level of detail. However, in order to allow aggregated analyses of upper hierarchy levels connecting to activities, additional edges of the type “DEALS_WITH_PARENT” were established from each activity to all superior taxonomy levels. E.g. If activity “A” was assigned to topic 3.4.1.4, four edges are created:

```
(Activity)-[DEALS_WITH]-(IEA-Topic 3.4.1.4)
(Activity)-[DEALS_WITH_PARENT]-(IEA-Topic 3.4.1)
(Activity)-[DEALS_WITH_PARENT]-(IEA-Topic 3.4)
(Activity)-[DEALS_WITH_PARENT]-(IEA-Topic 3).
```

An additional connection between country and IEA-topics represents the respective research budgets declared by the countries (see chapter 1.2). All country IEA-topic combinations have a relationship of the type “finances”. This relationship has an attribute that resembles the associated budget of the respective year (e.g. Budget_2017, Budget_2018 etc.).

This structure allows analysing the data with conventional descriptive statistical means, but also to create sub-sets of data based on specific research questions. This allows formulating very specific questions and leads to interesting insights of the organisation of the IEA–TCP framework. An extensive list with all node properties is given in Annex 5.5.

2.2 The Complete Graph

Linking all the above mentioned data sources into one graph data model results in a model with 617 nodes and 10,847 different relationships between these nodes. The complete dataset is available for download[4] in .graphml, .csv or .json format, which can be imported into NEO4J (or any other graph based database system).

[3] Participating non-governmental bodies were not considered.
[4] https://www.nachhaltigwirtschaften.at/en/iea/visualisations/

However, in order to answer detailed research questions it is necessary to create smaller sub-sets of data that correspond to the question asked. With the Neo4Js query language "Cypher" we have a mighty tool at hand, which allows us to do just that. Because writing such queries requires a fair bit of effort, and in order to improve the accessibility of the dataset, a set of 5 interactive web visualizations (three of them in English language) was created that allows answering some of the most frequent questions.

2.3 IEA-Topics, Related Activities and Working Parties

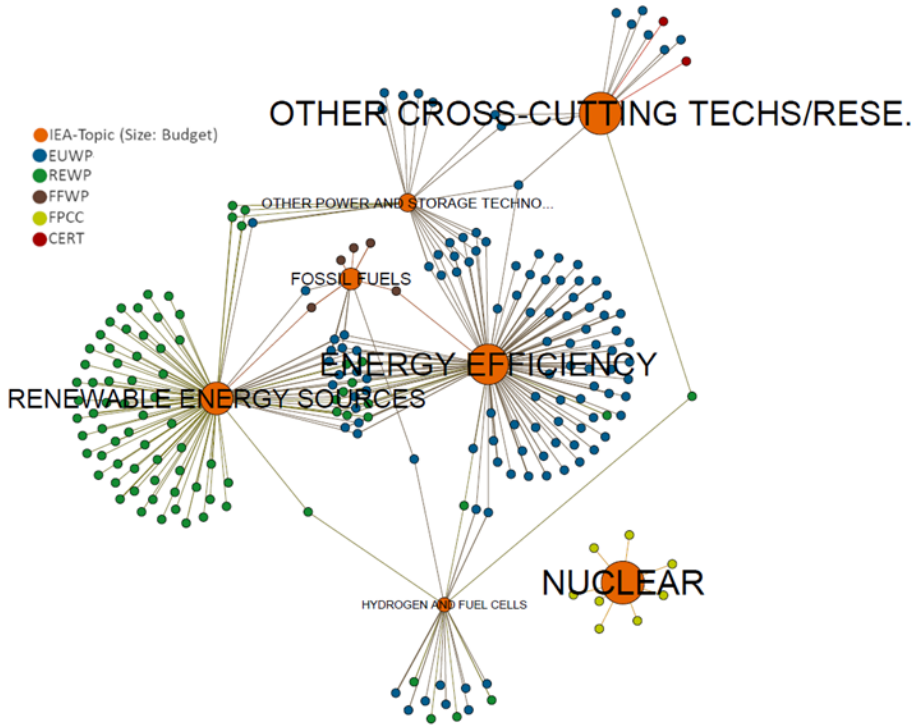


Figure 2-2: Graph: IEA-topics on level 1 (orange, node size corresponds to the official RD&D budget 2019) and TCP-activities (non-orange nodes) and related TCP-working parties (see color code in legend).

Figure 2-2 shows how IEA-topics and TCP-activities are interrelated in form of a graph. Orange nodes represent the seven main IEA-topics (node size corresponds to the official RD&D budget 2015), non-orange nodes represent TCP-activities.

As we can see, the topics "Energy Efficiency" and "Renewable Energy Sources" have a relatively big public budget for R&D (sum of all IEA member states), and also a relatively large number of associated activities.

On the contrary, "Nuclear" is also relatively important with regard to their RD&D budget, but has much less associated activities. Here some "fundamentals" have to be taken into account. IEA TCP generally do not cover nuclear fission, and the TCPs in nuclear fusion are represented in the database with one activity for each TCP.

The topic "Hydrogen and Fuel Cells" shows many activities with regard to the size of their comparable small RD&D budget.

3 Interactive Web-Visualisations

In order to improve the accessibility to the full dataset, five specific analysis have been prepared as interactive web visualisations. They are available at

nachhaltigwirtschaften.at/iea-visualisations

and comprise

- Worldwide Cooperations by Topic (for Austria, only available in German)
- Priorities in R&D Funding (budget for Austria and link to national project database, only available in German)
- Finding TCPs focusing on a Topic (Available in English)
- Finding other TCPs sharing the same Topic (Available in English)
- Finding all countries engaged in a certain Topic (Available in English)

The work was carried out by the Austrian Energy Agency and WIENFLUSS information.design.solutions KG on behalf of the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK).

3.1 Worldwide Cooperations (Language: German, Focus: Austria)

The interactive world map (zoomable) shows the cooperation of Austria and Austrian organisations in the technology programmes (TCPs) of the International Energy Agency (IEA) with 49 countries worldwide. Each TCP can comprise several tasks (activities), which can differ both thematically and through the participation of other countries.

The home screen shows all of Austria's cooperation across all of the IEA's thematic areas. By selecting a specific thematic area, the cooperations can be filtered. The thematic areas correspond to the IEA survey structure for recording R&D expenditures. The seven main topics are broken down into sub-topics. The thickness of the connecting lines between Austria and another country increases with the number of cooperations. Clicking on an actively displayed country shows the number of joint activities (task participations). If a topic has been selected, the respective TCPs in which these cooperations take place are also listed.

The visualisation is permanently available at
https://nachhaltigwirtschaften.at/de/iea/visualisierungen/weltweite-kooperationen.php

Figure 3. Austria's worldwide cooperations in context of the IEA Technology Cooperation Program. Available in German language only at https://nachhaltigwirtschaften.at/de/iea/visualisierungen/weltweite-kooperationen.php (27.4.2021)

3.2 Priorities in R&D Funding (Language: German, Focus: Austria)

The areas of the "Treemap" Visualisation show the proportion of public-sector investments in energy research in Austria in the year currently available (currently 2019). The priorities decrease from the left (top) to the right (bottom). In the lower section, all technology cooperation programmes running in August 2020 can be found

(8 TCPs for nuclear fusion were combined). Clicking on a topic in the treemap shows the breakdown by sub-topic; the bottom area shows the TCPs that have activities (tasks) in the respective topic area. The topics correspond to the IEA survey structure for recording R&D expenditures. If Austria participates in the respective TCP, a link to a national information service with detailed information on Austrian participation (publications, events, experts…) is provided.

The visualization is permanently available at
https://nachhaltigwirtschaften.at/de/iea/visualisierungen/energieforschungsausgaben.php

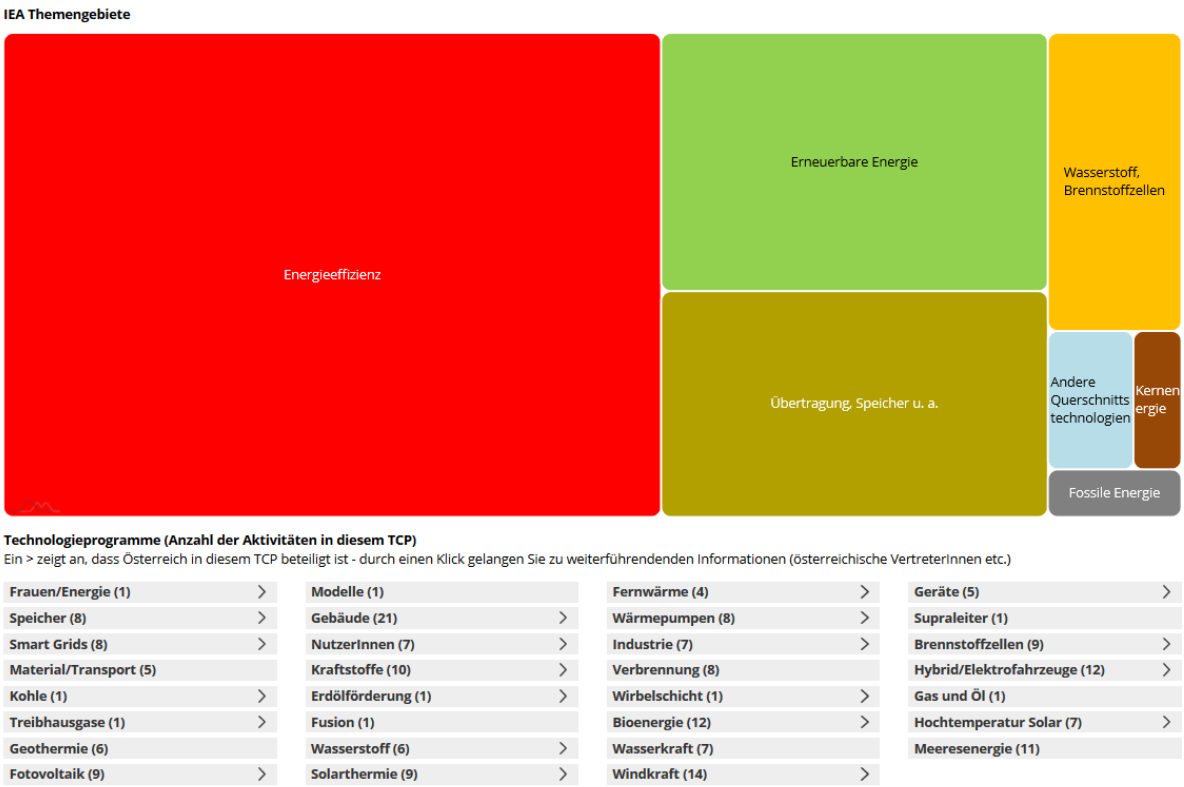


Figure 4: Austria's priorities in R&D funding, treemap visualisation. Available at https://nachhaltigwirtschaften.at/de/iea/visualisierungen/energieforschungsausgaben.php (27.4.2021)

3.3 Visualisation of IEA TCPs: Finding TCPs focussing on a topic (English)

After selecting a topic (as default "hydrogen" has been set), this graph shows all tasks (activities) focussing on the selected topic. The topics are structured according to the IEA energy RD&D budget/expenditure statistics. Additionally, you can see the related Technology Collaboration Programmes (TCPs). Activities which had been ongoing in Summer 2020 from all IEA-TCPs are covered in this analysis. You can re-arrange the different bubbles to better meet the needs of your analysis. If a TCP consists of more than one task (activity), it also contains one entry in the database labelled "ExCo-Activities".

The visualization is permanently available at https://nachhaltigwirtschaften.at/en/iea/visualisations/tcps-focussing-on-a-topic.php (27.4.2021)

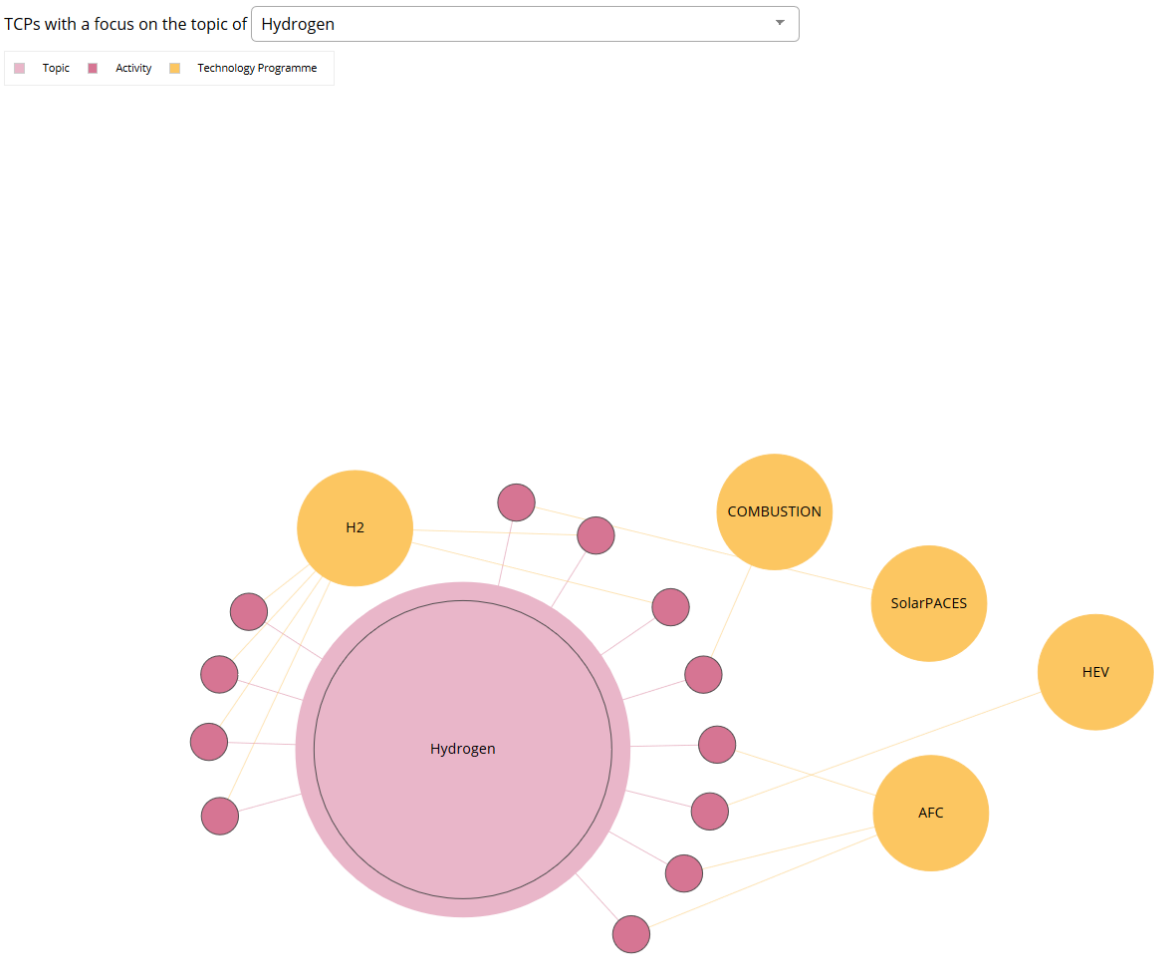


Figure 5: Finding TCPs focusing on a Topic. Available at https://nachhaltigwirtschaften.at/en/iea/visualisations/tcps-focussing-on-a-topic.php (27.4.2021)

3.4 Finding other TCPs sharing the same Topic (English)

After selecting a Technology Collaboration Programme (TCP) – as default the TCP on Advanced Fuel Cells is displayed – this graph shows all other TCPs sharing at least one common topic. The topics are structured according to the IEA energy RD&D budget/expenditure statistics. Activities which had been ongoing in Summer 2020 from all IEA-TCPs are covered in this analysis. You can re-arrange the different bubbles to better meet the needs of your analysis.

The Visualisation is permanently available at https://nachhaltigwirtschaften.at/en/iea/visualisations/tcps-sharing-the-same-topic.php

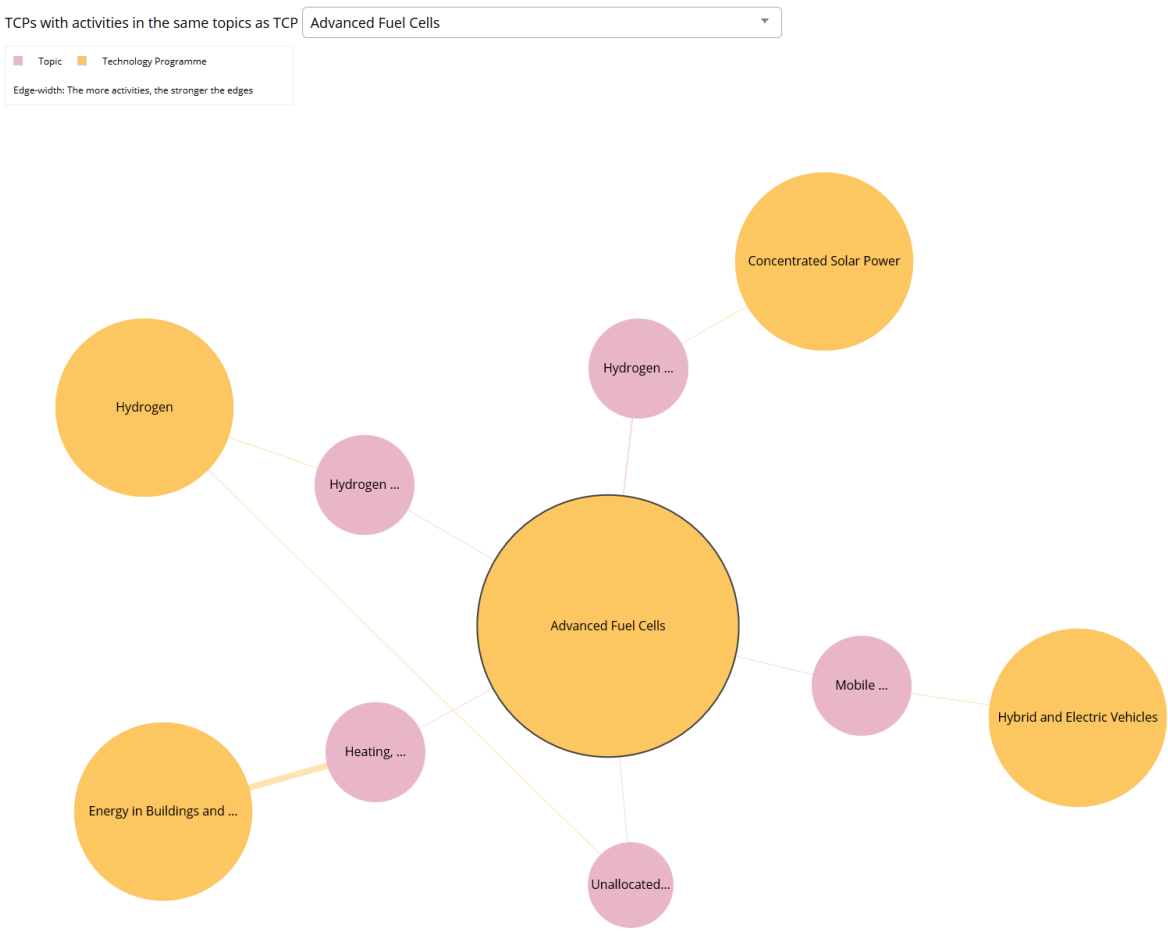


Figure 6: Finding TCPs sharing a topic. Available at https://nachhaltigwirtschaften.at/en/iea/visualisations/tcps-sharing-the-same-topic.php (27.4.2021)

3.5 Finding all countries engaged in a certain Topic (English)

After selecting a topic (as default Biofuels is displayed), this graph shows all tasks (activities) having a focus in that particular topic. The topics are structured according to the IEA energy RD&D budget/expenditure statistics. Activities which had been ongoing in Summer 2020 from all IEA-TCPs are covered in this analysis. Countries participation in these tasks are displayed as black bubbles with their ISO 3166-1 Code. Due to extensive processing requirements, it can take a moment to display the full graph. If a TCP consists of more than one task (activity), it also contains one entry in the database labelled “ExCo-Activities”. The TCP membership in general is reflected in the “ExCo-Activities”. Selecting one country (mouse-over), all participations in the selected topic are displayed (with the TCP as additional information). You can re-arrange the different bubbles to better meet the needs of your analysis.

The Visualisation is permanently available at
https://nachhaltigwirtschaften.at/en/iea/visualisations/tcps-countries-sharing-topics.php

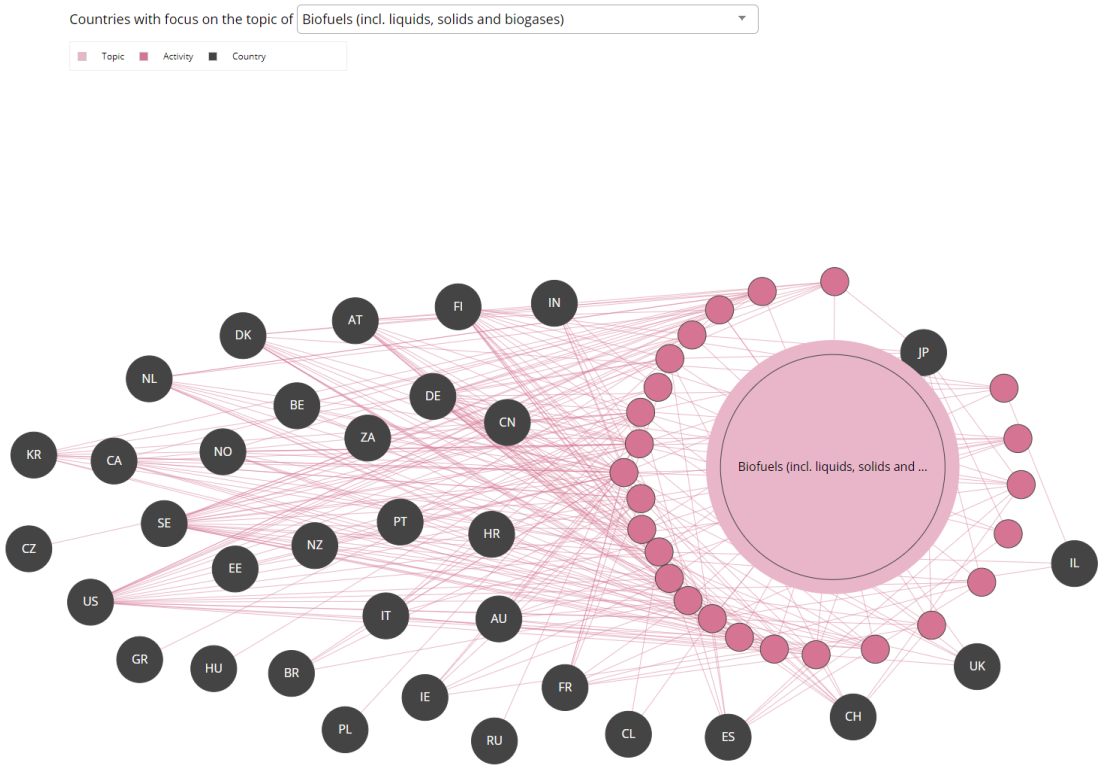


Figure 7: Finding all countries engaged in a certain Topic; Available at https://nachhaltigwirtschaften.at/en/iea/visualisations/tcps-countries-sharing-topics.php (27.4.2021)

4 Custom Analysis

As already stated above, the full graph carries too much information to be very useful in answering specific research questions. Also the newly developed interactive web visualizations only cover some specific questions, but leave many more questions – e.g. related to structure, methods, initiatives, budgets etc. – unanswered. More detailed analysis can be done using specific graph tools like neo4j and its graph query language Cypher. The following chapter requires some basic knowledge about cypher and graph based data structures and having neo4j installed on your computer. For a basic introduction to graph based data structures in general, and neo4j and Cypher in particular, see Annex 5.1. Once neo4j is in place and the data is imported, the user can start writing his own queries to answer specific research questions.

The following section aims to provide some guidance on which kind of questions can be asked, and how they can be answered using neo4j and Cypher as basic tools. Please note that it is not possible to give guidance on every possible utilisation of this dataset, as the specific use depends on the users' preferences and interests. However, altering the given Cypher queries slightly (e.g. by changing the name of the TCP or the country) can serve as a starting point for more refined analyses.

4.1 Example Queries – Topics, TCPs and Working Parties

Observation: There seem to be a lot of hydrogen related activities in TCPs, yet the RD&D budget for the IEA-topic 5 "Hydrogen and fuel cells" is relatively small.

Question: In which working parties and TCPs can we find currently active activities that are allocated to the IEA-topic "5.1 Hydrogen"? In which TCPs is Austria participating?

Cypher Query:

```
MATCH (top:TOPIC{Number:"51"})--(act:ACTIVITY)--(tcp:TCP)--(wp:WORKING_PARTY)
where toInteger(act.End)>=2020
return top.Name,wp.Name, Count(act),tcp.Name, Exists((tcp)--(act)--
(:COUNTRY{ISO:"AT"}))
```

Answer: Figure 4-1 shows a screenshot of the list resulting from the above cypher query. As we can see REWP and EUWP (with its coordination group on transport) is involved. The most related activities can be found in the TCP "Hydrogen", but there are also 6 other activities in 4 more TCPs dealing with the topic "Hydrogen". Austria is involved in 6 out of 12 Hydrogen related activities.

top.Name	wp.Name	Count(act)	tcp.Name	Exists((tcp)–(act)–(:COUNTRY{ISO:"AT"}))
"Hydrogen"	"REWP"	2	"Hydrogen"	true
"Hydrogen"	"REWP"	4	"Hydrogen"	false
"Hydrogen"	"REWP"	1	"Concentrated Solar Power"	true
"Hydrogen"	"EUWP-TR"	1	"Hybrid and Electric Vehicles"	true
"Hydrogen"	"EUWP-TR"	1	"Advanced Fuel Cells"	false
"Hydrogen"	"EUWP-TR"	1	"Energy Conservation and emissions reduction in combustion"	false

Figure 4-1: In which working parties and TCPs can we find activities that are allocated to the IEA-topic „5.1 Hydrogen“? In which is Austria participating?

A slight modification of the query code yields graphical results:

```
MATCH (top:IEA_Topic{Number:51})--(act:ACT)--(tcp:TCP)--(wp:working_party)
return top,wp,act,tcp
```

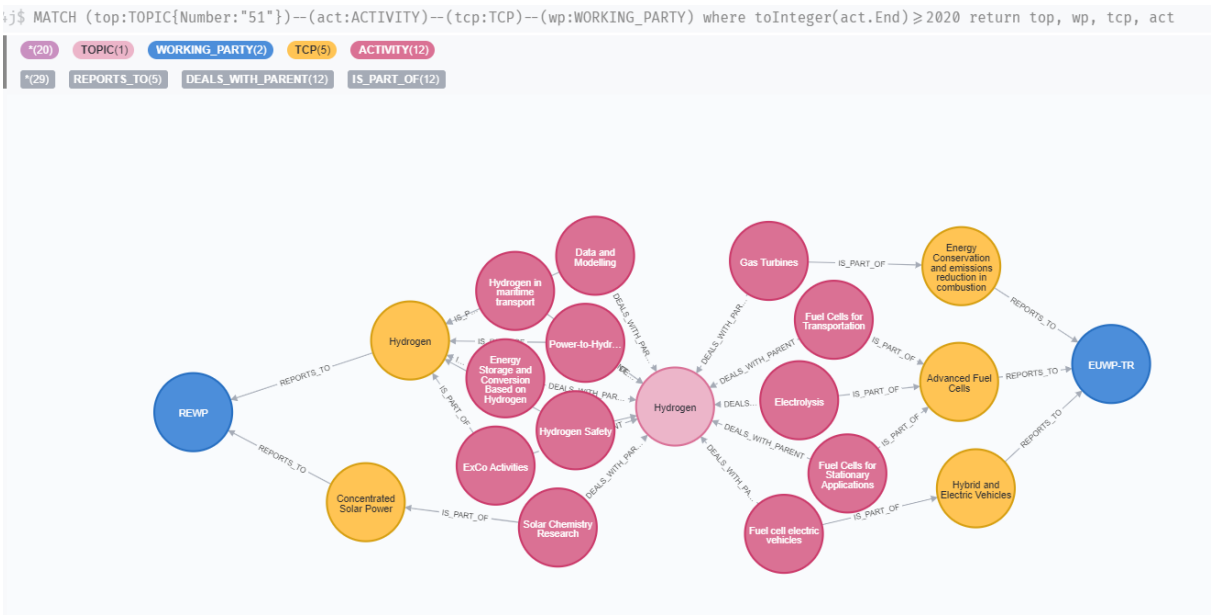


Figure 4-2: In which working parties and TCPs can we find activities that are allocated to the IEA-topic “5.1 Hydrogen”?

4.2 Example Queries – Methods and Working Parties

Question: Which activities within TCPs of the Working Party on Renewable Energy Technologies (REWP) are working in the field of policy (including roadmaps), legislation and standardisation (method POLE, ROAD and STND, see chapter 5.3)?

Cypher Query:

```
match (a:ACTIVITY)--(b:METHOD)
where b.Abbreviation IN ["POLE", "ROAD", "STND"] AND a.WORKING_PARTY ="REWP"
return a,b
```

Answer: Figure 4-3 shows which tasks in TCPs allocated to REWP are using the defined methods, and how they are interrelated.

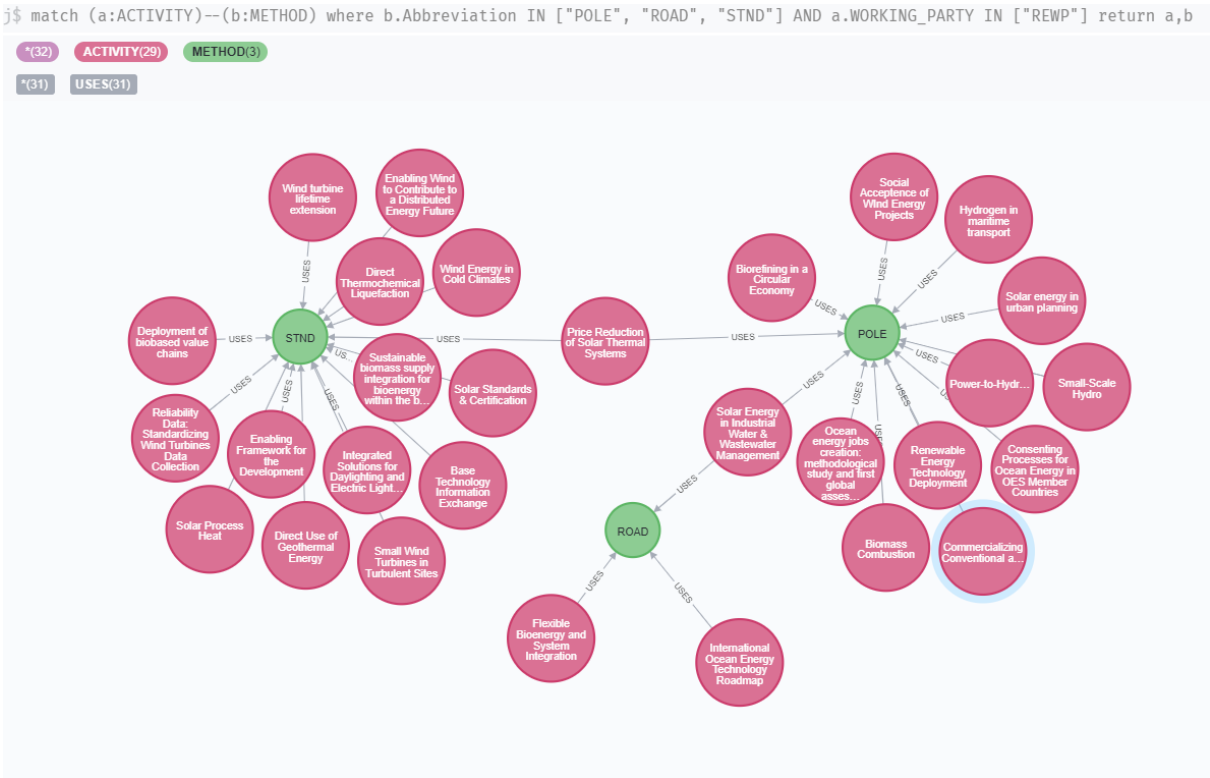
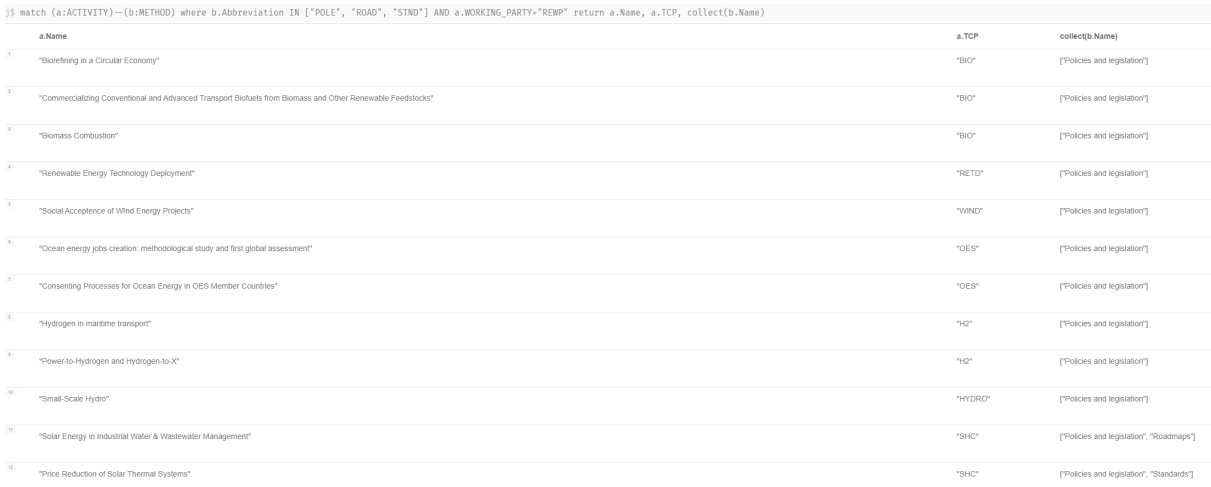


Figure 4-3: Which activities within the REWP are working in the field of policy and legislation?

If the output as a list is preferred, the following query can be used, yielding the table given in Figure 4-4.

Cypher Query:

```
match (a:ACTIVITY)--(b:METHOD)
where b.Abbreviation IN ["POLE", "ROAD", "STND"] AND a.WORKING_PARTY="REWP"
return a.Name, a.TCP, collect(b.Name) (a:ACT)--(b:METH)
```



```
j$ match (a:ACTIVITY)--(b:METHOD) where b.Abbreviation IN ["POLE", "ROAD", "STND"] AND a.WORKING_PARTY="REWP" return a.Name, a.TCP, collect(b.Name)
```

	a.Name	a.TCP	collect(b.Name)
1	"Biorefining in a Circular Economy"	"BIO"	["Policies and legislation"]
2	"Commercializing Conventional and Advanced Transport Biofuels from Biomass and Other Renewable Feedstocks"	"BIO"	["Policies and legislation"]
3	"Biomass Combustion"	"BIO"	["Policies and legislation"]
4	"Renewable Energy Technology Deployment"	"RETD"	["Policies and legislation"]
5	"Social Acceptence of WInd Energy Projects"	"WIND"	["Policies and legislation"]
6	"Ocean energy jobs creation: methodological study and first global assessment"	"OES"	["Policies and legislation"]
7	"Consenting Processes for Ocean Energy in OES Member Countries"	"OES"	["Policies and legislation"]
8	"Hydrogen in maritime transport"	"H2"	["Policies and legislation"]
9	"Power-to-Hydrogen and Hydrogen-to-X"	"H2"	["Policies and legislation"]
10	"Small-Scale Hydro"	"HYDRO"	["Policies and legislation"]
11	"Solar Energy in Industrial Water & Wastewater Management"	"SHC"	["Policies and legislation", "Roadmaps"]
12	"Price Reduction of Solar Thermal Systems"	"SHC"	["Policies and legislation", "Standards"]

Figure 4-4: Which activities within the EUWP are working in the field of policy and legislation (table output)?

4.3 Example Queries – TCP-Specific questions

Question: Which other TCPs are working on the same topics as ISGAN?

Cypher Query:

```
MATCH (tcp:TCP{Abbreviation:"ISGAN"})--(activities:ACTIVITY)--
(topics:TOPIC{Last:True})--(other_activities:ACTIVITY)--(other_tcps:TCP) RETURN
tcp, activities, topics, other_activities, other_tcps
```

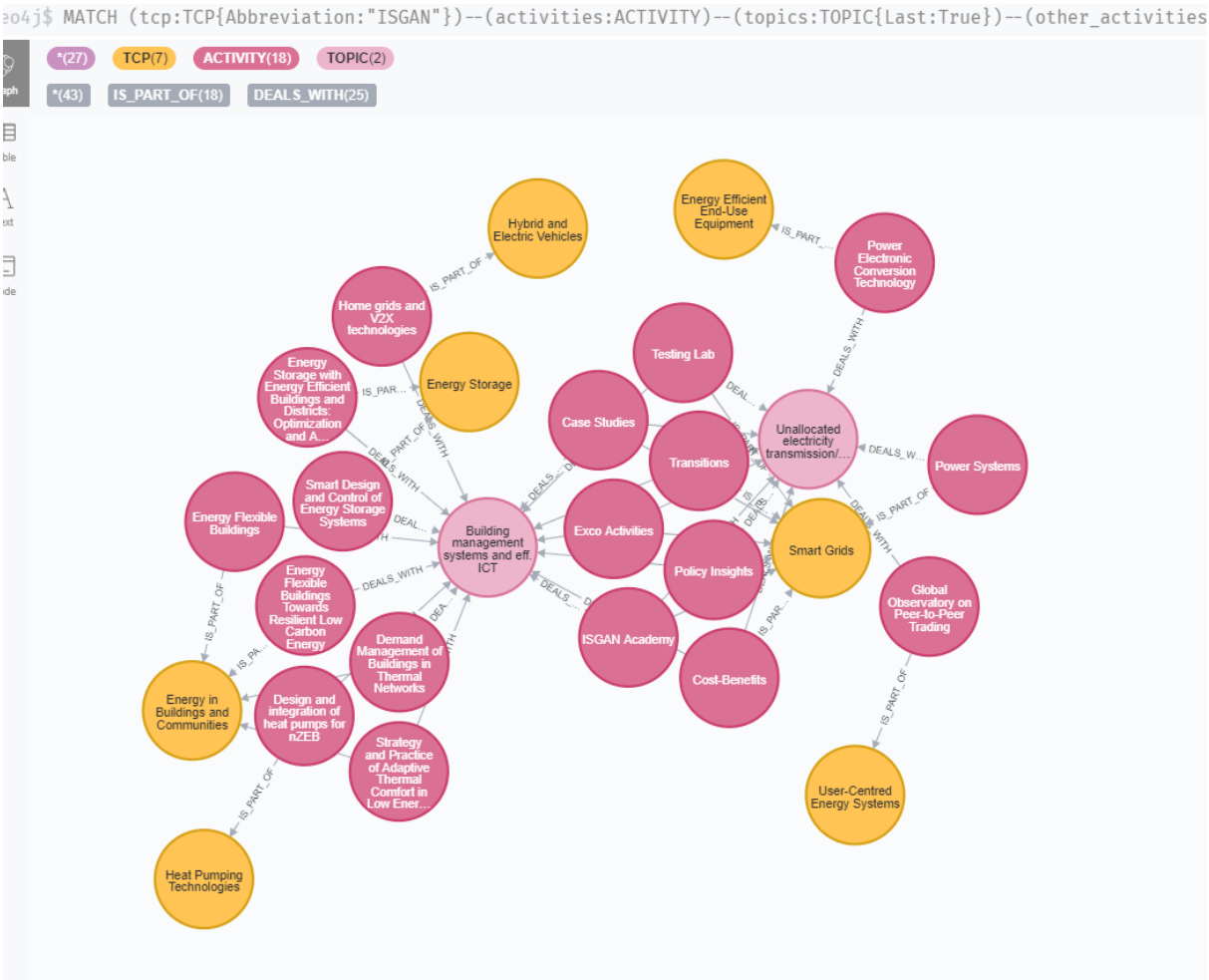


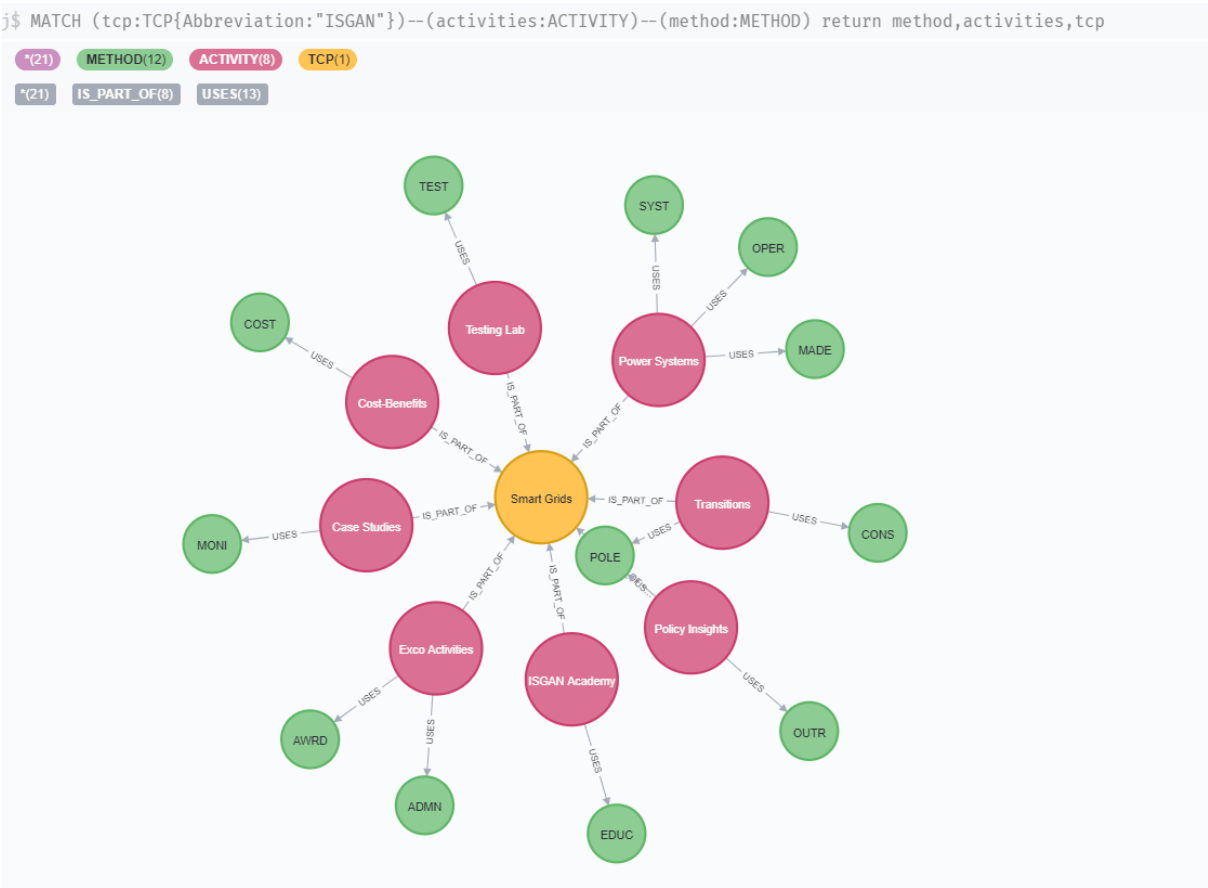
Figure 4-5: Which other TCPs are working on the same topics as ISGAN?

Question: Which methods are used by ISGAN?

Cypher Query:

```
MATCH (tcp:TCP{Abbreviation:"ISGAN"})--(activities:ACTIVITY)--(method:METHOD)
return method,activities,tcp
```

Answer: The graph shows which methods are used by which activity. Interestingly there is only one method that is used by multiple activities (POLE), all others are used only once. This reflects the dedicated sectorial approach chosen by this TCP.



5 Annexes

5.1 Graph Principles, Platform and Tools

5.1.1 Graph Database – Basic Principles

In computing, a database is a form of organized data collection. Besides being a secure form of data storage, the underlying idea behind a database is to enable the accessibility of the data and its inherent information. The database is managed by a (generic or specialized) database management system (DBMS). This DBSM allows users to interact (e.g. defining, updating and querying) with the database in an easy and comfortable manner.

Today most DBs store the data and the respective meta-information in linked tables (Relational Database). These links between the tables are based on keys (e.g. indices), and allow complex functions (such as joins), which include more than one table.

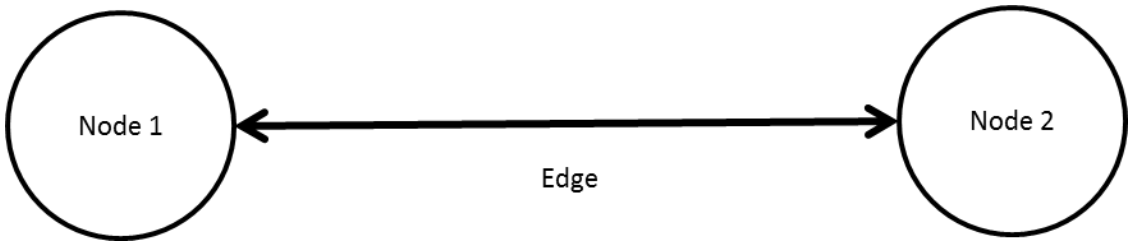


Figure 5-1: Basic concept of a graph: Two nodes are connected by an edge

In contrast to the relational database, a graph database employs nodes, edges and properties instead of tables to represent and store the data (see NoSQL). This concept is based on the general graph theory. Figure 5-1 illustrates this concept. A node describes a single entity respectively an object of the dataset. In other words, a node describes a single observation, with all its properties. An edge describes the relation that links two nodes. This link can represent different kind of relationships. Typical types of relationships between two nodes are 'knowing', 'owning' or 'funded'. As a simple memory aid the construction of small sentences can help to understand or develop a new graph model (compare Figure 5-2).

Pattern: **Subject** (Node1) **verb** (edge) **object** (Node2).

Example: *John knows Karen.*

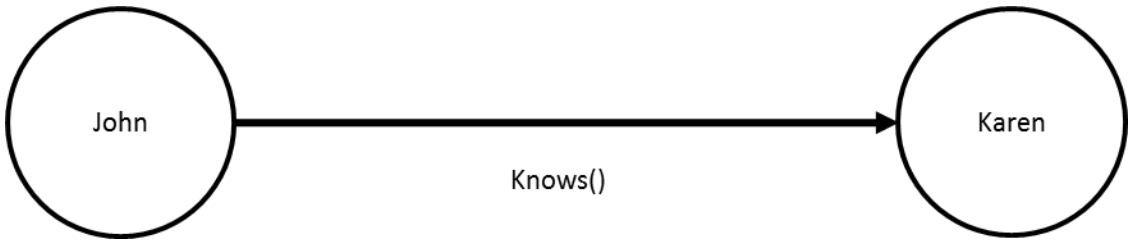


Figure 5-2: Basic example of a graph representing the relationship between two persons.

This characteristic enables a graph model to represent and store the data in a comprehensive format. Both - nodes and edges - can be described with additional properties. This allows to store properties of the objects (e.g. 'age', 'birthday', etc.) within the graph. It also allows to base queries (e.g. filter) on these properties. The structure of a graph also allows traversing through the database in a logical manner. E.g., what are the names of my friend's friends?

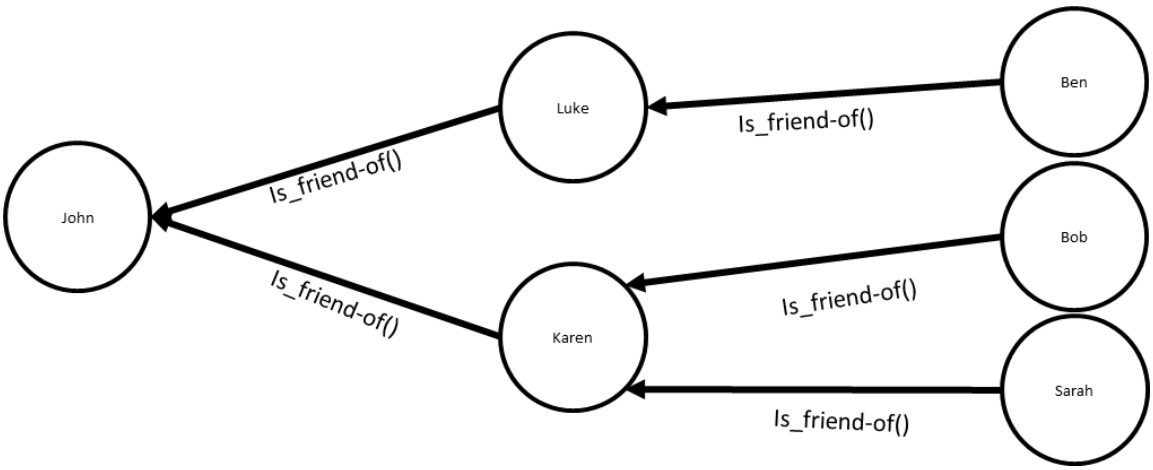


Figure 5-3: Graph example with multiple nodes and edges

This particularity allows designing, updating and analysing the graph data base without a deeper understanding of the underlying structure or technology. Typically, a graph database also increases the speed of complex queries on large datasets. There are two main reasons we finally chose a graph database over a relational database, to model the environment of the IEA-TCPs: On the one hand, the comprehensive data structure allows interested parties to quickly understand the structure of the model and the relationships between the different entities. On the other hand, the advanced visualization options allow a presentation-friendly display of the underlying data and the respective patterns.

5.1.2 Neo4j Graph Platform

Graph databases and models require a database framework. There are several different (open-source and commercial) solutions available on the market. The most common platform is called "Neo4J". Neo4J is implemented in Java and uses Cypher as query language. It also provides APIs (Application Programming Interface) for other programming languages (Python, JavaScript), which allow a distributed application of the models. Additionally, the framework includes a browser interface. This interface allows the visual examination of the model and its structure (this feature has proven very helpful during the development of the model). The model itself can be exported (as .csv, .json, .jsonl or as .graphml file) and be reloaded into other frameworks, which are able to interpret this file format.

In order to use (query or update) the IEA-TCP-graph model it is required to install a Neo4J or a similar framework. However, since the model was developed in Neo4J it is recommended using this framework. The download of a non-commercial version of Neo4J is available at their homepage[5].

[5] https://neo4j.com/

5.1.3 Query Language Cypher

The communication with the database itself is based on a standardised query language. Commands written in this language can be interpreted by database frameworks. The query language used by Neo4J databases is called Cypher. Cypher is a declarative graph query language that allows for expressive and efficient querying and updating of a property graph. Cypher is a relatively simple but powerful language.

Cypher is based on property graph models, where nodes (entities) can have labels and properties and edges (relationships) must be of a certain type (see above). Properties are key value pairs, where the key is represented by a certain keyword (e.g. 'birthday' or 'name') and the corresponding value (05-02-1960 or "John"). The syntax of Cypher is more or less based on SQL and ASCII word art. Users, who are familiar with SQL, will find many similarities within the set of keywords and native functions. The complete and detailed documentation of Cypher can be found here[6]. In order to work with the data model in its current state a basic knowledge of the query language is required. Therefore, a quick and simple introduction of the basic cypher syntax is provided at this point.

Cypher is based on the 'Property Graph Model', which in addition to the standard graph elements of nodes and edges (which are called *relationships* in Cypher) adds labels and properties as concepts. Nodes may have zero or more labels, while each relationship has exactly one relationship type. Nodes and relationships also have zero or more properties in form of a keyword and some value representing the expression of this property.

The two central concepts of Cypher are the nodes and the edges. Within the Cypher syntax, this is accommodated by a special convention of formatting:

Round brackets refer to nodes. This shall resemble a circle representing a node. After the colon, the type of the node is defined.

```
(Nodename:Nodetype)
```

Edges are referred to by square brackets and each left and right a minus symbol with an optional 'greater' sign. This shall resemble a labelled arrow.

```
-[Edgename:Edgetype]->
```

The nametag is always limited to a query and loses its validity outside of the query while the type is an attribute of the node or edge. Referring to Figure 5-2 the syntax fetching the relationship between two people looks something like this:

MATCH (Johnny: Person {name: 'John'})-[:knows]->(Kari :Person{name: 'Karen'}) **RETURN** ALL

MATCH is a Cypher´s specific keyword. It triggers a search process where the subsequent pattern is *matched*. MATCH is followed by the starting node of the traversal. The key-value pairs within the curly braces define the expression of the attributes of the nodes or edges. Within the variable "Johnny" all nodes with the type "Person" and the name-attribute: "John" are stored. The second part of the query (-[:knows]->) describes a unidirectional relationship of type "knows" without any additional information. The third part of the query again is a node. This node matches all nodes of the type "person" with the name-attribute "Karen" as "Kari". The RETURN keyword causes the return of the subsequently defined values. In this example the keyword "ALL" refers to all matched

[6] https://neo4j.com/docs/developer-manual/current/cypher/

values, without any additional filter or information extraction. The return value is therefore a string representation of the nodes and edges. The complete query can be summarised as follows:

Match (search) all persons with the name John, who knows another person with the name Karen and return all available information of this pattern (node-relationship- node- constellation).

This basic example illustrates the comprehensiveness of queries written in Cypher. This advantage of graph-based models allows more complex or longer queries. Nonetheless, it is important to understand the underlying schemata of the graph model in order to formulate meaningful queries.

5.1.4 Used Software Versions

We used Neo4j Version 4.1.0 for the implementation of the graph database.

The visualisations were generated with Gephi Version 0.9.2.

5.2 Activites

A Value of „9999“ for end year means, that there was no Information on the run time of the task / annex available.

Activity Name	TCP	Start Year	End Year
Electric Motor systems	4E	2008	9999
Electronic Devices and Networks	4E	2014	9999
ExCo Activities	4E	2008	9999
Power Electronic Conversion Technology	4E	2019	9999
Solid State Lighting	4E	2010	9999
Electrolysis	AFC	2014	2024
ExCo Activities	AFC	1995	9999
Fuel Cells for Portable Applications	AFC	2014	2024
Fuel Cells for Stationary Applications	AFC	2014	2024
Fuel Cells for Transportation	AFC	2014	2024
Modelling of Fuel Cells Systems	AFC	2014	2024
Polymer Electrolyte Fuel Cells	AFC	2014	2024
Solid Oxide Fuel Cells	AFC	2014	2024
Systems Analysis	AFC	2014	2024
ExCo Activities	AMF	2004	9999
Fuel and Technology Alternatives in Non-Road Engines	AMF	2014	2017
Fuels for Efficiency	AMF	2015	2017
GDI Engines and Alcohol Fuels	AMF	2016	2019
Heavy Duty Vehicle Evaluation	AMF	2018	2020
Information Service & AMF Website (AMFI)	AMF	2004	9999
Lessons learned from Alternative Fuels Experience	AMF	2019	2020

Activity Name	TCP	Start Year	End Year
Methane Emission Control	AMF	2014	2018
Methanol as Motor Fuel	AMF	2018	2020
Real Driving Emissions and Fuel Consumption	AMF	2015	2019
Real World Emissions from Recreational Vehicles	AMF	2020	2022
Remote Emission Sensing	AMF	2020	2023
Sustainable Bus Systems	AMF	2015	2017
The Progress of Advanced Marine Fuels	AMF	2019	2022
Transport Decarbonisation	AMF	2019	2020
Value Proposition of Alcohol Fuels	AMF	2020	2021
Development of Thermoelectric Materials for Waste Heat Recovery	AMT	1999	9999
ExCo Activities	AMT	1986	9999
Integrated Surface Technology for Friction Reduction in Engines	AMT	1999	9999
Model-based Design of Tribological Coating Systems	AMT	1999	9999
Multi-Material Vehicle Lightweight Structures, Materials Joining Technology	AMT	2014	9999
Biomass Combustion	BIO	2016	2021
Biorefining in a Circular Economy	BIO	2016	2021
Climate and Sustainability Effects of Bioenergy within the broader Bioeconomy	BIO	2019	2021
Climate Change Effects of Biomass and Bioenergy Systems	BIO	2016	2018
Commercializing Conventional and Advanced Transport Biofuels from Biomass and Other Renewable Feedstocks	BIO	2016	2021
Deployment of biobased value chains	BIO	2016	2021
Direct Thermochemical Liquefaction	BIO	2016	2021

Activity Name	TCP	Start Year	End Year
Energy from Biogas	BIO	2016	2021
ExCo Activities	BIO	1977	9999
Flexible Bioenergy and System Integration	BIO	2019	2021
Gasification of Biomass and Waste	BIO	2016	2021
Material and Energy valorisation of waste in a Circular Economy	BIO	2016	2021
Sustainable biomass supply integration for bioenergy within the broader bioeconomy	BIO	2016	2021
Clean Energy Education and Empowerment	C3E	2017	9999
Clean Coal Centre	CCC	1975	9999
Combustion Chemistry	COMBUSTION	2014	2024
ExCo Activities	COMBUSTION	1977	9999
Gas Engines	COMBUSTION	2014	2024
Gas Turbines	COMBUSTION	2014	2024
Low Temperature Combustion	COMBUSTION	2014	2024
Solid Fuel Combustion	COMBUSTION	2016	2024
Soot	COMBUSTION	2016	2024
Sprays in Combustion	COMBUSTION	2014	2024
Climate Technology Initiative	CTI	2003	2017
Tokamak Programmes	CTP	1977	9999
Digitalisation of District Heating and Cooling	DHC	2018	2024
ExCo Activities	DHC	1983	9999
Hybrid Energy Networks	DHC	2017	2021
Integration of Renewable Energy Sources into existing District Heating and Cooling Systems	DHC	2019	2024

Activity Name	TCP	Start Year	End Year
Business Models for a more effective market uptake of EE Energy Services	DSM	2015	2019
Closing the Loop â€“ Behaviour Change in DSM, From Theory to Policies and Practice	DSM	2015	2019
ExCo Activities	DSM	2000	2019
Innovative Energy Services	DSM	2006	2019
Integration of DSM, EE, DG and RES	DSM	2005	2019
Air Infiltration and Ventilation Centre	EBC	1979	9999
Assessing Life Cycle Related Environmental Impacts Caused by Buildings	EBC	2016	2021
Building Energy Epidemiology: Analysis of Real Building Energy Use at Scale	EBC	2016	2020
Building Energy Performance Assessment Based on In-situ Measurements	EBC	2016	2021
Business and Technical Concepts for Deep Energy Retrofit of Public Buildings	EBC	2012	2017
Competition and Living Lab Platform	EBC	2018	2021
Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables	EBC	2017	2022
Cost-Effective Energy & CO2 Emissions Optimization in Building Renovation	EBC	2010	2017
Data-Driven Smart Buildings	EBC	2019	2024
Deep Renovation of Historic Buildings Towards Lowest Possible Energy Demand and CO2 Emissions	EBC	2017	2021
Definition and Simulation of Occupant Behaviour in Buildings	EBC	2013	2017
Demand Management of Buildings in Thermal Networks	EBC	2020	2025
Design and Operational Strategies for High IAQ in Low Energy Buildings	EBC	2014	2020
Energy Efficient Indoor Air Quality Management in Residential Buildings	EBC	2020	2025

Activity Name	TCP	Start Year	End Year
Energy Flexible Buildings	EBC	2014	2019
Energy Flexible Buildings Towards Resilient Low Carbon Energy Systems	EBC	2020	2024
ExCo Activities	EBC	1979	9999
Implementation of Energy Strategies in Communities	EBC	2013	2017
Indirect Evaporative Cooling	EBC	2020	2025
Integrated Solutions for Daylight and Electric Lighting	EBC	2018	2021
Long Term Performance of Super-Insulating Materials in Building Components and Systems	EBC	2013	2017
LowEx Communities - Optimised Performance of Energy Supply Systems with Exergy Principles	EBC	2013	2017
New Generation Computational Tools for Building & Community Energy Systems	EBC	2012	2017
Occupant-Centric Building Design and Operation	EBC	2018	2023
Positive Energy Districts	EBC	2020	2024
Resilient Cooling of Buildings	EBC	2018	2023
Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings	EBC	2014	2020
Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications	EBC	2018	2023
Towards Net Zero Energy Public Resilient Communities	EBC	2017	2021
Ventilative Cooling	EBC	2012	2017
Enhanced Oil Recovery	EOR	1977	9999
Environmental, Safety and Economic Aspects of Fusion Power	ESEFP	1977	9999
Energy Technology Systems Analysis	ETSAP	1977	9999
Fluidized Bed Combustion	FBC	1977	9999

Activity Name	TCP	Start Year	End Year
Fusion Materials	FM	1977	9999
Greenhouse Gas R&D	GHG	1991	9999
Gas and Oil Technologies	GOT	2013	9999
Data Collection and Information	GT	2010	9999
Deep Roots of Volcanic Geothermal Systems	GT	2014	9999
Direct Use of Geothermal Energy	GT	2013	9999
Emerging Geothermal Technologies	GT	2015	9999
Environmental Impacts of Geothermal Energy Development	GT	1997	9999
ExCo Activities	GT	1997	9999
Biological Hydrogen for Energy and Environment	H2	2014	2017
Data and Modelling	H2	2020	2024
Energy Storage and Conversion Based on Hydrogen	H2	2019	2024
ExCo Activities	H2	1977	9999
Hydrogen in maritime transport	H2	2017	2020
Hydrogen Safety	H2	2015	2021
Hydrogen-Based Energy Storage	H2	2013	2018
Life cycle sustainability assessment	H2	2014	2017
Local H2 Supply for Energy Applications	H2	2013	2016
Power-to-Hydrogen and Hydrogen-to-X	H2	2015	2020
Renewable Hydrogen Production	H2	2015	2018
Accelerated Ageing Testing for Li-ion Batteries	HEV	2012	2017
Assessment of environmental effects of electric vehicles	HEV	2016	2020
Batteries	HEV	2016	2020

Activity Name	TCP	Start Year	End Year
Battery Electric Buses	HEV	2016	2019
Critical Raw Material for Electric Vehicles	HEV	2018	9999
Electric Freight Vehicles	HEV	2019	9999
Electrified, connected and automated vehicles	HEV	2016	2019
EV City Casebook	HEV	2019	9999
ExCo Activities	HEV	1993	9999
Extreme Fast Charging	HEV	2016	2020
Fuel cell electric vehicles	HEV	2016	2020
Fuels and energy carriers for transport	HEV	2016	2017
Home grids and V2X technologies	HEV	2016	2018
Information Exchange	HEV	1993	9999
Interoperability of e-Mobility Services	HEV	2018	9999
Light-Electric-Vehicle Parking and Charging Infrastructure	HEV	2012	2020
Small Electric Vehicles	HEV	2016	2020
Wireless Power Transfer for EVs	HEV	2014	2019
Acoustic Signature of Heat Pumps	HPT	2017	2020
Advanced Cooling/Refrigeration Technologies Development	HPT	2018	2021
Comfort and Climate Box	HPT	2019	2021
Design and integration of heat pumps for nZEB	HPT	2016	2019
Domestic Hot Water Heat Pumps	HPT	2015	2018
ExCo Activities plus Heat Pump Center	HPT	1978	9999
Heat pump systems with low GWP refrigerants	HPT	2019	2021
Heat Pumps in District Heating and Cooling systems	HPT	2015	2017

Activity Name	TCP	Start Year	End Year
Heat Pumps in Multi-Family Buildings for space heating and DHW	HPT	2017	2020
Hybrid Heat Pumps	HPT	2015	2018
Industrial Heat Pumps, Second Phase	HPT	2016	2019
Internet of Things for Heat Pumps	HPT	2020	2022
Long term performance measurement of GSHP Systems serving commercial, institutional and multi-family buildings	HPT	2018	2021
High-Temperature Superconductivity	HTS	1999	9999
ExCo Activities	HYDRO	1995	9999
Hidden Hydro	HYDRO	2018	2025
Hydropower & Fish	HYDRO	2013	2025
Maintenance Works and Decision-Making for Hydro Facilities	HYDRO	2016	2025
Management Models for Hydropower Cascade Reservoirs	HYDRO	2015	2025
Managing the Carbon Balance in Freshwater Reservoirs	HYDRO	2007	2025
Small-Scale Hydro	HYDRO	1995	2017
Valuing Hydropower Services	HYDRO	2011	2025
Digitalization, Artificial Intelligence and Related Technologies for Energy Efficiency and GHG Emissions Reduction in Industry	IETS	2018	2023
Electrification in Industry	IETS	2019	2020
Energy Efficiency in the Iron and Steel Industry	IETS	2011	2020
ExCo Activities	IETS	2005	9999
Industrial Excess Heat Recovery	IETS	2011	2021
Industry-based Biorefineries	IETS	2008	2020
Membrane Processes in Biorefineries	IETS	2014	2020
Case Studies	ISGAN	2011	9999

Activity Name	TCP	Start Year	End Year
Cost-Benefits	ISGAN	2011	9999
Exco Activities	ISGAN	2011	9999
ISGAN Academy	ISGAN	2017	9999
Policy Insights	ISGAN	2011	9999
Power Systems	ISGAN	2011	9999
Testing Lab	ISGAN	2011	9999
Transitions	ISGAN	2016	9999
Nuclear Technology of Fusion Reactors	NTFR	1977	9999
Assessment of Environmental Effects and Monitoring Efforts for Ocean Energy	OES	2010	2020
Consenting Processes for Ocean Energy in OES Member Countries	OES	2014	9999
Cost of Energy for OE technologies	OES	2014	9999
ExCo Activities	OES	2001	9999
International Ocean Energy Technology Roadmap	OES	2015	2017
Ocean energy jobs creation: methodological study and first global assessment	OES	2019	9999
Performance Metrics International Framework for Ocean Energy	OES	2017	9999
Review, Exchange and Dissemination of Information on Ocean Energy Systems	OES	2001	9999
Status of OTEC and its Resource Assessment	OES	2016	9999
Tidal Energy Modelling Verification and Validation	OES	2018	9999
Wave Energy Modelling Verification and Validation	OES	2016	9999
WEB GIS Database	OES	2014	9999
Deploying PV Services in emerging and developing countries	PVPS	1998	2018

Activity Name	TCP	Start Year	End Year
Enabling Framework for the Development of BIPV	PVPS	2014	2020
ExCo Activities	PVPS	1993	9999
High Penetration of PV Systems in Electricity Grids	PVPS	2018	2022
Off-Grid and Edge-of-Grid Photovoltaic Systems	PVPS	2019	2021
Performance, Operation and Reliability of PV Systems	PVPS	2018	2021
PV and transport	PVPS	2018	2020
PV Sustainability Activities	PVPS	2018	2022
Solar Resource for High Penetration and Large Scale Applications	PVPS	2017	2020
Strategic PV Analysis & Outreach	PVPS	1993	9999
Plasma Wall Interaction	PWI	1977	9999
Renewable Energy Technology Deployment	RETD	2005	2017
Reversed Field Pinches	RFP	1977	9999
Stellarators and Heliotrons	SH	1977	9999
Application of PVT Collectors and New Solutions in HVAC Systems	SHC	2018	2020
Building Integrated Solar Envelope Systems for HVAC and Lighting	SHC	2016	2020
ExCo Activities	SHC	1977	9999
Integrated Solutions for Daylighting and Electric Lighting	SHC	2018	2021
Material and Component Development for Thermal Energy Storage	SHC	2017	2019
New Generation Solar Heating and Cooling	SHC	2014	2018
Price Reduction of Solar Thermal Systems	SHC	2015	2018
Renovating Historic Buildings Towards Zero Energy	SHC	2017	2021
Solar Energy in Industrial Water & Wastewater Management	SHC	2018	2022
Solar energy in urban planning	SHC	2013	2017

Activity Name	TCP	Start Year	End Year
Solar Heat and Energy in Urban Environments	SHC	2014	2017
Solar Neighbourhood Planning	SHC	2019	2023
Solar Process Heat	SHC	2020	2023
Solar Standards & Certification	SHC	2016	2018
Towards the Integration of Large SHC Systems into DHC Networks	SHC	2016	2020
ExCo Activities	SolarPACES	1977	9999
Solar Chemistry Research	SolarPACES	1999	2022
Solar Energy and Water Processes and Applications	SolarPACES	2012	2022
Solar Heat Integration in Industrial Processes	SolarPACES	1999	2022
Solar Resource Assessment and Forecasting	SolarPACES	2012	2022
Solar Technology and Advanced Applications	SolarPACES	1999	2022
Solar Thermal Electric Systems	SolarPACES	1999	2022
Spherical Tori	ST	2007	9999
Carnot Batteries	STORAGE	2020	2022
Comfort & Climate Box	STORAGE	2019	2021
Energy Storage with Energy Efficient Buildings and Districts: Optimization and Automation	STORAGE	2014	2017
ExCo Activities	STORAGE	1978	9999
Flexible Sector Coupling	STORAGE	2019	2022
Ground Source De-Icing and Snow Melting Systems for Infrastructure	STORAGE	2020	9999
Integration of Renewable Energies by Distributed Energy Storage Systems	STORAGE	2014	2017
Large Thermal Energy Storages for District Heating	STORAGE	2020	9999

Activity Name	TCP	Start Year	End Year
Modelling of Energy Storage for Simulation Optimization of Energy Systems	STORAGE	2020	9999
Smart Design and Control of Energy Storage Systems	STORAGE	2020	9999
Thermal Energy Storage for Cost-Effective Energy Management and CO2 Mitigation	STORAGE	2015	2018
Behavioural Insights Platform	USER	2019	2021
Business models and systems	USER	2018	2020
ExCo Activities	USER	2020	9999
Gender and Energy	USER	2020	2023
Global Observatory on Peer-to-Peer Trading	USER	2019	2023
Hard-to-Reach Energy Users	USER	2020	2024
Social License to Automate	USER	2019	2021
Analysis of Aerodynamic Measurement	WIND	2008	2017
Assessing Environmental Effects (WREN)	WIND	2013	2020
Base Technology Information Exchange	WIND	1987	2020
Computer Codes and Models for Offshore Wind Energy	WIND	2010	2020
Cost of Wind Energy	WIND	2008	2018
Downwind Turbine Technologies	WIND	2018	2020
Enabling Wind to Contribute to a Distributed Energy Future	WIND	2019	2022
ExCo Activities	WIND	1977	9999
Forecasting for Wind Energy	WIND	2016	2020
Ground Based Testing for Wind Turbines and Components	WIND	2013	2017
LIDAR: Wind Lidar Systems for Wind Energy Deployment	WIND	2011	2020
Power Systems with Large Amounts of Wind Power	WIND	2005	2020

Activity Name	TCP	Start Year	End Year
Quiet Wind Turbine Technologies	WIND	2018	2020
Reliability Data: Standardizing Wind Turbines Data Collection	WIND	2011	2016
Small Wind Turbines in Turbulent Sites	WIND	2008	2018
Social Acceptance of Wind Energy Projects	WIND	2007	2019
WAKEBENCH Benchmarking Wind Farm Flow Models	WIND	2010	2020
Wind Energy in Cold Climates	WIND	2001	2021
Wind Energy Systems Engineering: Integrated R, D&D	WIND	2015	2020
Wind turbine lifetime extension	WIND	2019	2022

5.3 Methods

ADMN [administration] This method is exclusively used for the activities of the Executive Committee of a TCP. It stands for usual management issues regarding the TCP.

ARES [applied research] This method is defined according to OECD´s Frascati Manual. It describes the original investigation undertaken in order to acquire new knowledge. Simulations and the technical and scientific steering of demonstration projects are also covered.

AWRD [awards] An award is granted on a regular basis. This award has to have an impact also outside this activity.

BASC [basic research] This method covers experimental or theoretical work undertaken primarily to acquire new knowledge. It has to be clearly oriented towards the development of energy-related technologies or services, according to the relevant definitions of the IEA-manual for RD&D statistics.

BEST [best practice] A database covering state of the art, examples of good or best practice or information on benchmarking.

CONF [conferences] Conferences are organised on a regular basis. Typically, over 100 participants are attending these events, also from outside the TCP. It is a well-established conference in the resp. field.

CONS [consumer behaviour and behaviour change] Studying the consumer or user is in the centre of this activity. His/her user behaviour is analysed, also questions of social acceptance or relevant social developments. The development of strategies to influence behavioural change is included, too. The rebound-effect also falls into this method.

CORE [cost reduction] Activities explicitly have the goal to reduce costs of technologies or services.

COST [costs] If an activity is allocated to this method, it collects cost data for technologies and services on a regular basis.

DATA [digitalization, protection of data privacy] This method contains questions dealing with digitalization, the collection and processing of huge amounts of data, but also issues of data privacy and data protection.

EDUC [education and training] Activities in the field of education and training have been developed and/or provided, including summer schools, webinars etc.

EMSA [energy management systems and audits] Here, energy management systems and audit schemes have been developed or improved.

ENVI [environmental aspects] Environmental aspects (including biodiversity) regarding the technology and its application are covered.

FOIK [first-of-its-kind demonstration] The activity plays a crucial role in the initialisation, development, realisation or monitoring of a first-of its-kind demonstration project.

GHGR [reduction of GHG] Activities encompass the analysis of emissions or the development of strategies to reduce emissions of greenhouse gases.

INTR [market introduction] The focus of these activities is to develop strategies for technologies which are ready for the market. Strategies can target a successful market introduction or to create niche markets.

LCSA [life cycle and technology assessment] Costs over the whole life cycle of a technology are evaluated. This category contains also sustainability assessments and evaluation of technologies and their implications.

MADE [market development and deployment] Following a successful market introduction (see INTR), the next step is gaining higher market shares for already mature technologies. The development of business models and financing tools can support the deployment. Certain measures to develop an already existing market also fall under this category.

MONI [monitoring] Activities under this method collect and analyse data from plants which are in operation. Long term case studies also fall under this category**.**

MRKT [market analysis] Markets are analysed (volumes, demand, willingness to pay etc.). Cost-benefit analysis and the identification of existing market barriers are also covered.

OPER [operational performance] Activities focus on the improvement of the operational performance of technologies and systems. The development of communication standards, dispatch rules, decision making processes, asset management and reliability and quality aspects in general also fall under this category.

OUTR [outreach and raising awareness] This method covers development or application of targeted activities to inform and mobilize society or stakeholders. It also covers activities for regional development and activities for developing and emerging countries.

PLAN [planning] The development or improvement of tools and processes for planning are in the centre of this category.

POLE [policies and legislation] Supporting the development of new and improved legislation and policies is in the centre of this activity.

PROD [products] Activities which fall under this method provide market surveys and extensive product information in a certain field of technology.

PROJ [project database] A database contains an extensive sample of projects or plants. Actualisations are carried out on a regular basis. If the focus is instead of a broad coverage on selected examples, see BEST. Products which are already on the market are covered under PROD. Analysing the data of a selected set of projects/plant is covered under MONI.

REAS (resource assessment and forecasting] Resources and their availability are in the focus, also the development of tools for their forecasting.

ROAD [roadmaps] Development of multinational roadmaps.

SAFE [safety and health issues] Human aspects of health and safety during the production and operation of a technology are covered here.

SECS [security of supply] Security of supply, but also quality aspects of systems like power grids etc. are covered within this method.

STND [standards] Activities allocated to this method can both carry out surveys on existing standards or engage in the development of new or improved standards.

SYST [system analysis and integration] Interdependencies of a technology in a system are the focus of this activity.

SZEN [modelling and scenarios] New modelling tools are developed under this activity. Alternatively, substantial activities have been carried out to adapt existing models to this technology.

TEDE [technological development] This method is defined according to OECD's Frascati Manual. It covers systematic work 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. Prototypes and pilots are also included in this category.

TEST [pre-standardisation, testing protocols and product testing] Activities cover the development, verification and implementation of testing procedures.

5.4 IEA-Topics

1 ENERGY EFFICIENCY

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

1 ENERGY EFFICIENCY

- 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

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

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

3 RENEWABLE ENERGY SOURCES

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

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

4 NUCLEAR FISSION and FUSION

423 Other nuclear fusion

429 Unallocated nuclear fusion

49 Unallocated nuclear fission and fusion

5 HYDROGEN and FUEL CELLS

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

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

6 OTHER POWER and STORAGE TECHNOLOGIES

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 Unallocated other power and storage technologies

7 OTHER CROSS-CUTTING TECHNOLOGIES or RESEARCH

71 Energy system analysis

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

73 Other

5.5 Node Properties

Node Type	Property Name	Description
ACTIVITY	Status	Status of the activity (planned/running/finished)
ACTIVITY	Start	Start year of the activity
ACTIVITY	End	End year of the activity
ACTIVITY	METHOD	List of assigned methods (for easier handling)
ACTIVITY	Name	English Name
ACTIVITY	Name_German	German Name
ACTIVITY	TCP	TCP to which the activity belongs

Node Type	Property Name	Description
ACTIVITY	TOPIC	List with up to three assigned IEA Topic number codes (for easier handling)
ACTIVITY	URL	Webpage of the Task / Annex
ACTIVITY	WORKING_PARTY	Working party of the assigned TCP
ACTIVITY	COUNTRY	List of ISO codes of countries participating at the task / annex.
METHOD	Name	Full English name
METHOD	Name_German	Full German name
METHOD	Abbreviation	4-letter Abbreviation of the method
METHOD	Class	Class of the method
COUNTRY	Name	Full name of the country
COUNTRY	ISO	Two digit ISO code of the country
COUNTRY	population	Population of the country in million
COUNTRY	lat/long	Latitude/longitude of the capital
COUNTRY	status	IEA membership status (MC - Member Country, AS - Associated Country, CC - Candidate Country, PC - Other status or partner Country)
TOPIC	Name	Full English name of the IEA-topic
TOPIC	Parent	Number of the parent topic node (“0” represents the root)
TOPIC	Last	True if the topic node represents the deepest available hierarchy level. Else False.
TOPIC	h_level	Number, 1 - 4. Describes the level of hierarchy the topic is located (1 = most aggregated level, 4 = most detailed level). Property implemented for easy filtering.
TOPIC	Number	Topic allocation code according to the IEA RD&D taxonomy
TOPIC	Last	Boolean. True if the given topic is the last topic in the hierarchy. Falls if it has more sub-topics. Property implemented for easy filtering.

Node Type	Property Name	Description
TCP	Abbreviation	Abbreviation of the TCP
TCP	Name	Full English name of the TCP
TCP	Name_German	Full German name
INITIATIVE	Name	Name of the multilateral initiative
WORKING_PARTY	Name	String with the short name of the working party. End-use working party is split up into its sub coordination groups.

5.6 Country Codes

Name	ISO-Code	Name	ISO-Code
Argentina	AR	Malaysia	MY
Australia	AU	Malta	MT
Austria	AT	Mauritania	MR
Belgium	BE	Mexico	MX
Brasil	BR	Monaco	MC
Bulgaria	BG	Morocco	MA
Canada	CA	Mozambique	MZ
Chile	CL	Namibia	NA
China	CN	Netherlands	NL
Colombia	CO	New Zealand	NZ
Costa Rica	CR	Nigeria	NG
Croatia	HR	Norway	NO
Cyprus	CY	Paraguay	PY
Czech Republic	CZ	Philippines	PH
Denmark	DK	Poland	PL
Egypt	EG	Portugal	PT
Estonia	EE	Qatar	QA
Fiji	FJ	Romania	RO
Finland	FI	Russia	RU
France	FR	Saudi Arabia	SA
Germany	DE	Singapore	SG

Name	ISO-Code	Name	ISO-Code
Ghana	GH	Slovak Republic	SK
Greece	GR	Slovenia	SI
Hungary	HU	South Africa	ZA
Iceland	IS	Spain	ES
India	IN	Sudan	SD
Indonesia	ID	Sweden	SE
Iran	IR	Switzerland	CH
Ireland	IE	Tanzania	TZ
Israel	IL	Thailand	TH
Italy	IT	Turkey	TR
Japan	JP	Ukraine	UA
Kazakhstan	KZ	United Arab Emirates	AE
Korea	KR	United Kingdom	UK
Laos	LA	United States	US
Latvia	LV	Uruguay	UY
Lithuania	LT	Venezuela	VE
Luxembourg	LU		

5.7 Links

Permanent link to the English landing page of the web visualisations

nachhaltigwirtschaften.at/iea-visualisations

Neo4j Graph Database

https://neo4j.com/

Alternative Frontend for neo4j

https://www.yworks.com/neo4j-explorer/

Gephi Graph visualization software

https://gephi.org/

6 List of figures

About the authors

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Andreas Indinger studied Physics at the University of Technology of Vienna. He has been working at Austrian Energy Agency since 2000 and heads the Centre for Research and Innovation. His main topics are R&D-policy and –programmes and he is responsible for surveys on R&D-expenditures. He is one of Austria's representatives in the Steering Group of the European SET-Plan and Austrian delegate and vice-chair of IEA's Renewable Energy Working Party.

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Lukas Eggler studied Renewable Energy Engineering and Management in Freiburg/Germany. He has been working at the Austrian Energy Agency since 2014 as expert for renewable energy sources and energy efficiency. In addition he is head-trainer of the AEA Academy course "Energy performance - indicators and baseline". Currently he is working in various projects on energy system modelling, data analysis and data visualisation.

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Lukas Zwieb has studied Environment and Bio Resource Management at the University of Natural Resources and Life Sciences in Vienna. He has been working at the AEA since 2016 as scientific support and developer. His main emphasis is the analysis of the energy market developments and the respective prices. Additionally, he is part of the development team of the internal database.

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