Grant Agreement number 842547

PV IMPACT

Actual execution of the Implementation Plan for Photovoltaics and monitoring the Implementation Plan's delivery

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Deliverable 4.3: Summary of the nature of PV research funded in Europe

Lead beneficiary: Becquerel Institute

Disclaimer of warranties

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842547. The sole responsibility for the content of this publication lies with the authors. It does not necessarily reflect the opinion of the European Commission. The European Commission is not responsible for any use that may be made of the information contained therein.

About PV IMPACT

PV IMPACT will try out a variety of approaches to stimulate PV research, development and innovation initiatives in Europe. The first part of the project will focus on inviting companies to matchmaking events so they can find partners with whom to work on future projects under EU and/or national funding schemes. The project will also target two specific industrial companies: ENEL Green Power and Photowatt. Another important part of the project will be to monitor progress in PV. Data will be collected on public spending in the EU, on private spending, on the kinds of projects being funded and on the overall performance of PV technology. Forecasts for future spending will be made according to various scenarios. The project will track whether improvements in the performance of technology are keeping pace with expectations and will make recommendations to European funding authorities.

PV IMPACT Partners

Document information

Title	Summary of the nature of PV research funded in Europe (Final report)
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Document history

Date	Revision	Prepared by	Approved by	Description & status
10/03/2022	0	BI		M35 final Report – First draft
30/4/2022	1	BI		Added information regarding funding sources for selected Member States
19/5/22	2	BI		Updated project assessment based on latest version of project database
31/05/22	3	BI	EUREC	Final version with the inclusion of more projects to the database

Dissemination level

PU	Public	X
RE	Restricted to a group specified by the Consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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1. Introduction

The Strategic Target Plan (SET-Plan) Implementation Working Group on Photovoltaics (IWG PV) has the target to monitor the execution of the Implementation Plan for PV (IP). More particularly, one of its objectives is to monitor the national funding of PV R&I activities that support the IP execution. Within this scope, one specific task of PV IMPACT within Work Package 4 is to set up a process for performing the monitoring of funded PV R&I projects and assess the alignment of the national R&I efforts with the Implementation Plan, identifying any potential gap (Task 4.3).
The final deliverable (D4.3) for this task is hence to provide a summary on the nature of the PV research funded in Europe assessing alignment with the Implementation plan. The present document is the final report at Month 35.

2. Steps and status

The defined steps for Task 4.3 are the following:

1. Set up a process for monitoring national R&I spending on PV projects
2. Collect the data
3. Assessment of the nature of the national funded research

All the steps have been completed. Their execution and outcome are described in the following section. Information for over 380 projects has been collected. This report includes an assessment of the extent to which the project database covers the overall RD&I budget for each country, as estimated from the IEA's online database (Energy technology RD &I budgets) and the evaluation of the nature of the funded research from national sources according to the SET-Plan from 2017. The results are presented in section 5 of this report.
Financial flows from EU programmes (such as Horizon 2020) to fund PV research have been excluded from the analysis. National contributions in interregional research projects have been included in the evaluation.

3. Set-up of monitoring process

Interactions with IWG PV and definition of the process

In order to establish an adequate and viable process for monitoring the nationally funded R&I projects, several cooperation calls were organized between PV Impact WP4 task's responsible partners and the IWG PV Chair during Q1 and Q2 2020 for reaching a final common agreement.

Based on the initial discussions, a formal proposal was made by PV Impact in January 2020 and submitted to the IWG PV representatives through the IWG PV Chair. This proposal included 3 options for the monitoring process:

1) Project Database

In this option, a database would be set up in which funded projects would be "continuously" fed-in by appropriate representatives of each country. In addition, the possibility to have this database made common to all energy technologies of the SET-Plan was suggested. This would give the advantage for the SET-Plan countries to have one single and formal reporting channel for all energy technologies. In this case, the initiative would hence be coordinated among the different JA-2 projects that support the respective Implementation Plans of the different energy technologies (see specific section below).

2) Reporting template

The second suggested option was the use of a reporting template to be filled in by the IWG PV country representatives.
In 2019, a specific template table had already been used to report on the funded projects in the scope of the SET-Plan Reporting exercise. This template had been sent out to the IWG PV country representatives to be completed. However, not all responded, and the picture obtained was only partial. The new template would hence be adapted and improved, and completion of the data would be closely followed up.

3) National data sources search by PV Impact

The third option proposed was to research national data sources by PV Impact. Alternatively, to the country representatives gathering the information as in the first two options, respective national data sources, from which data could be directly retrieved was shared with PV impact (when available). PV impact implemented then a data review procedure from these information sources on a project basis.

Following the feedback on this proposal gathered from the IWG PV country representatives in February 2020 and based also on the outcome of the SET-Plan Monitoring & Reporting Workshop organized on February 27, 2020, by the SET-Plan Secretariat with all IWGs, the use of a reporting template came out to be the broadly preferred option.
To avoid duplication of work, it was decided that the new Excel table associated to the reporting template to be edited by the SET-Plan Secretariat for the 2020 reporting exercise would be used, provided that the draft table would be shared with PV Impact WP4 to agree on the details of the required fields to fill in. This would ensure that the information reported through this template would appropriately match the needs for deliverable D4.3 to report on the detailed nature of funded PV research.

The draft of the template table was received and discussed in April in the IWG PV and PV Impact WP4. Based on their feedback, it was then finalized by the SET-Plan Secretariat in May.

During the discussions on the template, it was clarified that the projects to be reported by the IWG PV through the template would however not be an exhaustive list of the nationally funded projects but rather **a selection of "representative" (i.e., having the largest impact) projects relevant to the IP**. In addition, it was highlighted that not all SET-Plan countries with noticeable PV RD&I are represented in the IWG PV. As a consequence, following the IWG PV meeting of 12 May 2020, it was agreed upon a dual approach for the monitoring process:

- PV Impact will collect data on funded PV R&I projects based on a "bottom-up" approach, gathering the data directly from the owners/partners of projects, who will be reached to the best extent possible through PV Impact's network of partners and stakeholders identified in D4.1.
  For doing this data collection, a database was created on the PV Impact website to allow the reporting of projects with their relevant related information (IP activity covered, IP target addressed, funding scheme, budget, start and end dates…). The draft layout of this database is presented in annex 1. It will be updated to be completely aligned with the required fields agreed on in the final template before the official data collection starts.

- On the other hand, the SET-Plan Secretariat's template (see final table in annex 2) will be filled in by the IWG PV country representatives with the projects that are deemed "representative" according to the IWG PV's defined criteria. This will be done through a "top-down" approach, based on information from their national/regional funding agencies.

At the time of reporting to the SET-Plan Secretariat, the harmonisation of both sets of data has been performed by PV Impact. This will allow to map a precise and representative picture of the R&I efforts the different Member States are putting on activities and targets of the Implementation Plan. The nature of the R&D activity has been assessed as a function of the 6 R&I technology-related priority activities defined in the PV implementation plan and endorsed by the SET-Plan Steering Group in 2017[1]. This plan is being updated in 2022 by the IWG.
The 6 activities implemented in the assessment of the PV impact projects are presented in Table 3.1.

[1] https://etip-pv.eu/set-plan/pv-implementation-plan/

Table 3.1 Implementation activities according to the SET-Plan 2017

	Technology-**Related Implementation Plan activity(ies)**
1	PV for BIPV and similar applications
2	Technologies for silicon solar cells and modules with higher quality
3	New Technologies & Materials
4	Operation and diagnosis of photovoltaic plants
5	Manufacturing technologies
6	Cross-sectoral research at lower TRL

Interactions with the other JA-2 projects

In parallel to the discussions with the IWG PV on the monitoring process, contacts were also made with the other JA-2 projects supporting the Implementation Plans of the SET-Plan, with the aim to identify a possible common approach and the potential use of a common database.
Three of them (IMPACTS9, HORIZON-STE, SU-DG-IWG) replied with an initial interest for collaboration and one (IMPACTS9) did formally follow up on the proposal. However, based on the final process agreed on with the IWG PV and complexity/workload considerations, it was decided not to go further with the option of a common database for the time being.

In addition, PV Impact was contacted in April by the SUPEERA project[2] launched in January 2020 and which also has the objective to facilitate the execution of the SET-Plan Implementation Plans. Particularly, it seeks to improve the exchange of information between the actors involved in the different energy technologies and foster joint actions. Within this scope, a common project database could be created and the discussion in this regard is ongoing. Both PV Impact and SUPEERA projects have agreed to keep one another up to date in terms of the mapping work to ensure synergy and to avoid duplication of work. Potential exchange of collected data will be further discussed in the future.

[2] Support to the coordination of national research and innovation programmes in areas of activity of the European Energy Research Alliance (Grant agreement number: 949125)

4. Data collection

The monitoring process of R&I projects has been according to the plan agreed upon with the IWG PV and consisted of a dual approach. On the one hand, a "Bottom-up" data collection has been performed by PV Impact through partners and stakeholders, and on the other hand, a "top-down" reporting of representative projects has been performed by the IWG PV country representatives based on their national data sources.

Bottom-up approach

The database for the "bottom-up" data collection on R&I projects was created on the PV Impact website and the web application to collect data has been finalised. The final web database allows for data collection through the contribution of partners and stakeholders.

A request for reporting projects was disseminated throughout the network of PV Impact partners, as a result several stakeholders did report their projects into the database. Furthermore, some PV Impact partners have also directly reported information on nationally funded projects in their countries based on information retrieved from accessible existing national databases (e.g., Photowatt for France and EURAC for Italy). Transnational projects from Solar ERA Net website were also added to the database by partners (Photowatt, BI). In total, 115 projects were collected through the bottom-up approach.

Top-down approach

In addition, 109 projects were reported by the IWG country representatives through the SET-Plan reporting template.

National databases and other sources

An intensive population of the PV impact database was achieved thanks to the information compiled from national public databases (TopSector energie[3] for the Netherlands and Enargus[4] and the foerderportal[5] for Germany) with direct links obtained via the collaboration with the IWG. Information from the Austrian national funding was also partially compiled from the Energieforschung[6] webpage. International projects, financed through national funding from the ERA.NET program, were also added to the database.[7] The projects with sufficient available information and which were active between 2016 and 2021 have been included in the database. Overall, about 120 different projects were gathered from this path[8]. Ademe, the French agency for the ecological transition, features a list of 149 funded programs for the transition, but no

[3] https://www.topsectorenergie.nl/
[4] https://www.enargus.de/search/?q=photovoltaik
[5] https://foerderportal.bund.de/foekat/jsp/StartAction.do
[6] https://energieforschung.at
[7] https://www.solar-era.net/projects-results/
[8] Some national funded projects performed through international collaboration were mentioned in various databases

information regarding funding is available from this list[9]. Swiss funded projects were gathered from the Aramis database[10], conversion rates for CHF funding to euros were implemented assuming an average conversion value per year (Annex 4). Over 160 new projects were gathered from these sources. Norway's Research Council database is another lead for the addition of further projects in the future[11].

The methodology used to estimate the private flows in national funded projects was based on the information available from the funding sources. A python code was developed and implemented to perform this assessment for German and Dutch national financed projects. In both cases, considering that a high level of detail is available regarding the budget per organisation and the share for public funding depending on the organisation type or type of research performed, this information was used to recalculate the private funding involved in the projects. For other projects without such a clear data granulation, but clearly specifying that a partial grant was implemented, but without details about the public share in the total funding, a 10% private funding share was estimated in the analysis of the total funding. These values were aggregated for the total private R&D funding. These values are considered as a low estimate, since they do not cover private companies internal or external RD&D projects which are performed outside of national funding schemes. For more information on national funding sources for selected member states see Annex 3.

Data compilation

After elimination of duplicates, 387 projects were compiled, representing a total investment of 742M€ in PV research both from public and private funding sources. The starting date for these projects is in the range between 2015 and 2021. Though most of the projects started between 2016-2020. The results of the analysis of the projects collected until April 2022 is described in the next section.

[9] https://expertises.ademe.fr/programmes-projets-recherche
[10] https://www.aramis.admin.ch/
[11] https://prosjektbanken.forskningsradet.no/en

5. Results

Data gathering and segmentation

The project collection has led to over 387 projects. The intention has been to focus on projects funded by Member States (e.g., via internal funding or ERDF funding) and transnational projects (e.g., CO-FUND actions and INTERREG). H2020 projects were included by external sources in the database through the project website. Such projects have been excluded from the assessment. The project database is listed in an excel document where the most important parameters used for the analysis correspond to:

- Funding type
- Member state providing the funding
- Public funding in €
- Private funding in €
- Activity related to PV IP
- PV share of RD&I activities
- TRL (when information is available)

The following issues have been identified in the database:

i) For some projects, the RD&I activities are not entirely focused on PV RD&I and defining a % of share of overall budget is not always easy. We recommend, at least in CORDIS for H2020 projects and in future Horizon Europe projects, to ask the coordinators to provide a rough division of the work share/budget based on the technologies of interest.

ii) It is difficult to estimate the full share of private funding as part of the overall national R&D spending. As mentioned previously a (lowest) private funding estimate has been calculated by the PV impact team and added to the database, considering the private funding corresponding to projects co-funded by national schemes. The overall funding picture is missing information about privately financed research projects. Such information is not easily accessible.

iii) For projects covering various activities of the PV Implementation Plan and in case of lack of specific information we have assumed that either the budget is equally spread between activities, or an main activity has been selected and the whole budget provided to it.

Data Accessibility from national funding sources

EU Member States use different systems for the recording and categorization of R&D funding for energy related activities from national sources. Some Member States, such as Germany, the Netherlands and countries like Switzerland, provide downloadable files containing information based on their national segmentation. Others, like Austria, and Norway feature an energy R&D website where the information about the topic and the budget for the R&D projects can be obtained following a single-project data reading approach. France features a list of funded projects, but no details about financial information has been obtained from this list.

A fine-grained system matching the categories of national and IEA's RD&D Energy budget expenditure system is followed by both Austria and Germany. While the Netherlands follows a national based categorization (see Annex 3). For example: Austria report on Energy RD&D public expenditure in 2020 also following the IEA's guide[12] (see Figure 1) clearly outlines the distribution of national funding between the different type of energy related activities: energy efficiency, fossil fuels, renewable sources (with a split between the type of renewable between: wind, solar PV, solar thermal, solar heating, hydro, biofuels…), nuclear, hydrogen and fuel cells, other power technologies and storage, or other cross cutting sectors. It also shows how much funding

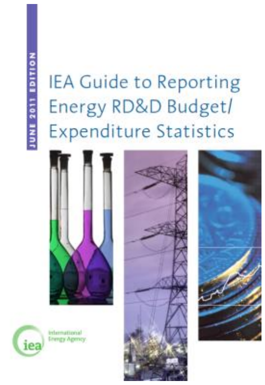


Figure 5-1:First page IEA Guide to reporting Energy RD&D Budget Expenditure Statistics

Data analysis

Based on the available information from the database, it is possible to start the mapping activity of funding at Member States level.

Analysis that can be carried out (depending on data availability):

- Mapping TOPIC of preference from the Implementation Plan at member state level (for total, public and private funding)
- Mapping overall budget per country for RD&I PV sector (normalized pro capita and year)
- Mapping % capture (Defined as funding in the database compared to overall budget for RD&I for PV in a specific country)

The first check carried out is to try to understand the relevance of the database. This has been done by comparing the share of the overall RD&I it captured vs national level funding as compiled by the International Energy Agency's (IEA) data service for some of the Member States, Norway and Turkey. From the IEA's information service hub, the "Detailed country RD&I budgets" report that provides RD&I expenditures by country at 2019 prices and exchange rates (meaning no adjustments needed to be made for inflation) was used. The IEA data is provided on a yearly basis, therefore it had to be summed up to reach a regional total segmented by year. In doing so, both the "Photovoltaics" category and the unallocated solar research budget have been considered as the max national budget for PV RD&D financing. Note that the IEA database presents solar research budgets split between: PV, solar thermal, solar heating and cooling and unallocated budget. This information is based on several sources: from surveys to the national contacts, to analysis of project databases[13]. See Annex 3 for a more detailed view of the IEA's reference data.

[12] IEA's Guide to Reporting Energy RD&D Budget / Expenditure Statistics: https://iea.blob.core.windows.net/assets/e1b79c1f-f0c0-4e84-b9b4-a89c4f95a12e/RDDManual.pdf

[13] https://www.iea.org/articles/energy-technology-rd-and-d-budgets-data-explorer

Table 5.1 shows the results in terms of % of budget captured by PV IMPACT between 2016-2020 compared to the RD&I budget from the IEA database in the same time period[14].

Table 5.1 Statistical data related to the budget spent between 2016 and 2020

Country	(1) PV impact TOTAL Budget (2016-2020) [M€]	(2) IEA ref 2016-2020 [M€]	(3) % budget from IEA ref	(4) Average annual Budget per capita [€ per capita/year]	(5) Aver. annual Budget vs GDP [€ / M€GDP/year]
Austria	12.0	43.7	27.6%	0.27	6.06
Belgium	4.7	25.2	18.8%	0.08	1.98
Bulgaria	0.2			0.01	0.61
Cyprus	3.5			0.80	30.77
Czech Republic	0.0	1.2	0.0%	0.00	0.00
Denmark	0.1	14.6	0.7%	0.00	0.07
Estonia	0.0	1.6	0.0%	0.00	0.00
Finland	1.3	27.4	4.7%	0.05	1.08
France	55.0	357.9	15.4%	0.16	4.51
Germany	400.4	433.5	92.4%	0.96	23.05
Greece	0.5			0.01	0.56
Hungary	0.0	0.2	0.0%	0.00	0.00
Ireland	0.0	2.1	0.0%	0.00	0.00
Israel	3.1			0.07	
Italy	73.8	104.4	70.7%	0.25	8.22
Netherlands	46.4	113.0	41.1%	0.54	11.42
N. Macedonia	0.1				
Norway	2.8	57.6	4.9%	0.11	1.57
Poland	0.6	24.8	2.4%	0.00	0.23
Portugal	0.5			0.01	0.43
Slovakia	0.0	1.7	0.0%	0.00	0.00
Slovenia	0.1			0.01	0.41
Spain	11.5	67.7	17.0%	0.05	1.85
Sweden	2.9			0.06	1.20
Switzerland	29.5	165	17.9%	0.69	9.03
Turkey	1.2	12	10.0%	0.00	0.36
United Kingdom	3.0	185	1.6%	0.01	0.24
Transnat.	5.4				
Grand Total	**658.8**	**1595.2**	41.3%	0.23	7.54

(1) captured PV R&D budget for the 2016-2020 range by the PV impact database [M€]
(2) IEA research RD&D budget for the same time period [M€]
(3) % of RD&I budget captured by PV IMPACT as compared to overall RD&I budget for the PV sector, as extracted from the IEA database for PV related project[15](in grey countries with missing data) [%]
(4) Average annual PV R&D budget (captured by the PV impact database between 2016-2020) per capita [in € per person per year]
(5) Average annual PV R&D budget (captured by the PV impact database between 2016-2020) as a function of the national GDP in 2019 [in € per million€ GDP per year]

[14] http://wds.iea.org/wds/Common/Login/Login.aspx (login as: GUEST Password: GUEST)
[15] Covering both the specific RD&D PV budget and the unallocated solar research budget from the IEA database

The information in the previous table shows that the PV impact database achieved an average coverage of 17.1% per country also covered by the IEA database in the same period. In this period, the total budget covered by the PV impact database covers 41.7% of the budget covered by the IEA for the countries researched. The highest level of detail captured, corresponds to Germany data, with a 90% budget coverage from the total solar PV and unallocated spending from the reference. The budget per capita has been calculated using the Eurostat records for the national population in 2019. The country with the highest captured budget per capita in the PV impact database is Germany with an annual 0.96€ spending per capita. According to the data compiled by the IEA RD&D, the highest investment per capita is found in Switzerland, with an annual 3.84€ per capita spending.

Figure 5-2 displays the PV R&D budget covered by PV impact as compared to the IEA ref, excluding transnational funding. As before, the comparison is performed for data relating to projects starting in the 2016-2020 period. The data corresponds to the ratio between the annual average and the corresponding national GDP for 2019. The results are presented as euro per million euro of GDP per year. The figure provides a visual display of the extent of coverage of the project as compared to the reference. Considering the overall data, the top countries for PV research spending as a function of GDP are: Switzerland, Norway, France, the Netherlands, Cyprus, Germany and Finland respectively.

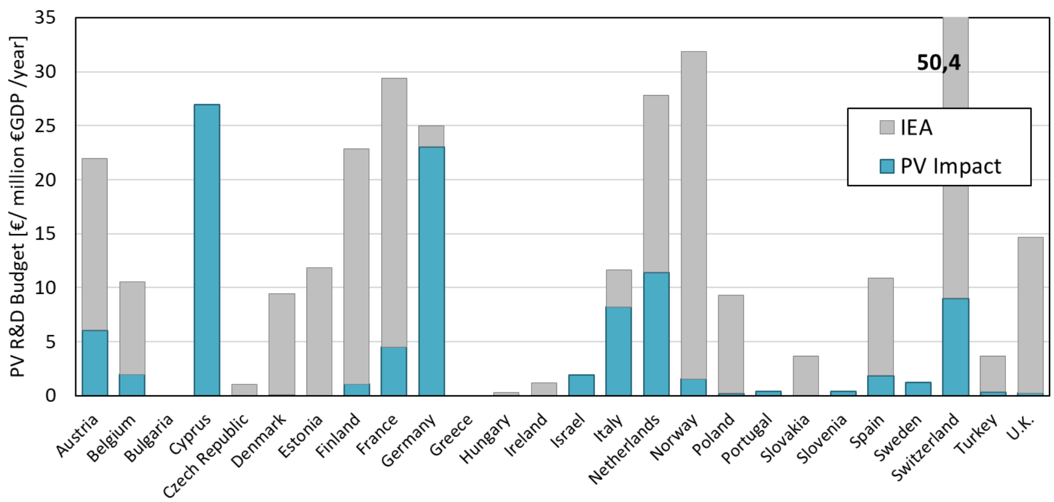


Figure 5-2 Total annual budget for PV research covered by PV impact in € per million € GDP for various countries, highlighting the share covered by PV impact per country as compared to the total reference (annual data averaged between 2016-2020).

The focus of the following section is based on the full data analysis from the PV impact database, encompassing projects starting between 2015 until 2021. Table 5.2 shows the status summary of the PV impact database at the end of May 2022 including all 387 projects, their data aggregation at national level and the budget assigned to each activity of the Implementation Plan. The database reaches a total budget ~745M€, from which ~501M€ are from public spending and ~245M€ are from private sources. The most prominent activity in terms of budget and its share over the overall national budget has been identified for each country. The countries represented in the TWG/IWG are highlighted in green in Table 5.2. Both Figure 5-3 (a) (a) and Figure 5-3 (b) show the overall budget depending on strategic topic from the SET-Plan. The left plot shows that the highest shares are distributed between technologies for Si cells and modules for higher quality (topic 2) and new technologies and materials (topic 3). The right-side plot shows the segmentation depending on the funding source, where the highest private share is obtained for topic 2 and the highest share of public funding for topic 3.

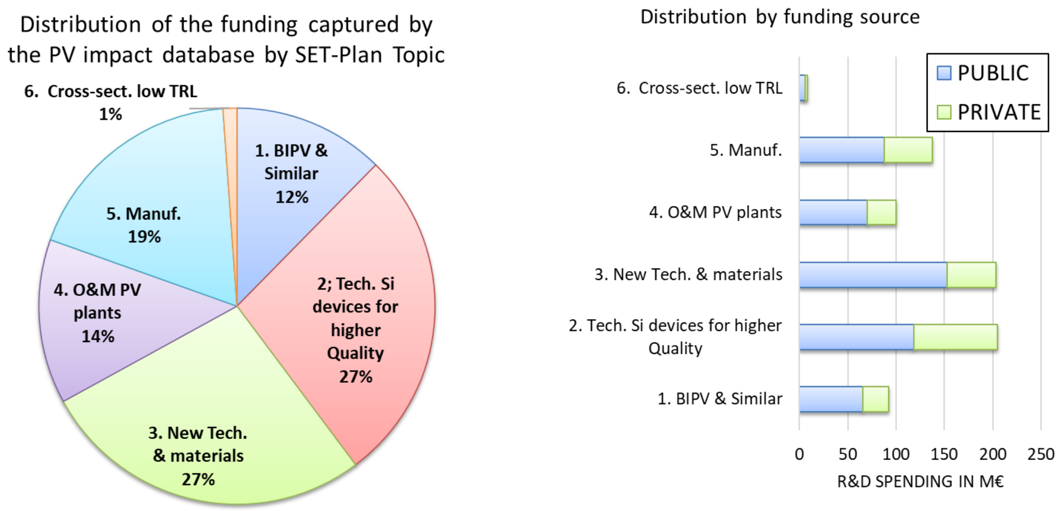


Figure 5-3 Budget share by SET-Plan topic for all countries confound (a) for the total budget, (b) by funding source type.

Table 5.2: Summary of the database as of end of May 2022 (projects started between 2015-2021). Analysis on IP activities carried out at TOTAL budget level. In green IWG countries.

	TOTAL [M€]	PUBLIC [M€]	PRIVATE [M€]	Proj.	IP Activity 1 [M€]	IP Activity 2 [M€]	IP Activity 3 [M€]	IP Activity 4 [M€]	IP Activity 5 [M€]	IP Activity 6 [M€]	MAX [M€]	Top Topic per country	Topic Share
Austria	12.4	9.1	3.3	25	0.5	0.6	6.8	4.1	0.3	0.0	6.8	3 - New Tech. & materials	55%
Belgium	5.7	4.3	1.4	11	2.1	0.0	1.0	2.2	0.4	0.0	2.2	4 - Operations & diagnosis of PV plants	39%
Bulgaria	0.2	0.2	0.0	1	0.2	0.0	0.0	0.0	0.0	0.0	0.2	1 - PV for BIPV and similar applications	100%
Cyprus	4.5	4.3	0.2	20	0.8	0.1	1.2	2.4	0.0	0.0	2.4	4 - Operations & diagnosis of PV plants	54%
Czech Republic	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0			
Denmark	0.1	0.1	0.0	1	0.0	0.0	0.0	0.1	0.0	0.0	0.1	4 - Operations & diagnosis of PV plants	100%
Estonia	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0			
Finland	1.3	0.6	0.7	3	0.0	0.0	0.3	0.0	1.0	0.0	1.0	5 - Manuf. Tech.	75%
France	55.0	26.6	28.4	40	21.7	2.5	7.7	7.0	15.5	0.6	21.7	1 - PV for BIPV and similar applications	39%
Germany	435.9	315.2	120.7	168	42.1	105.6	141.1	57.9	82.7	6.6	141.1	3 - New Tech. & materials	32%
Greece	0.5	0.5	0.0	2	0.5	0.0	0.0	0.0	0.0	0.0	0.5	1 - PV for BIPV and similar applications	100%
Hungary	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0			
Ireland	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0			
Israel	3.1	1.6	1.5	6	0.0	0.8	0.5	1.8	0.0	0.0	1.8	4 - Operations & diagnosis of PV plants	58%
Italy	73.8	22.3	51.5	18	2.5	34.5	3.1	2.1	31.5	0.0	34.5	2 – Tech. Si SC & modules with higher quality	47%
Luxembourg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0			
Netherlands	49.4	35.0	14.4	65	8.2	10.2	11.7	6.2	13.2	0.0	13.2	5 - Manuf. Tech.	27%
Norway	21.1	9.6	11.5	15	0.9	6.4	1.9	4.3	7.7	0.0	7.7	5 - Manuf. Tech.	37%
Poland	0.6	0.4	0.2	2	0.6	0.0	0.0	0.0	0.0	0.0	0.6	1 - PV for BIPV and similar applications	100%
Portugal	0.5	0.5	0.0	4	0.0	0.1	0.3	0.0	0.1	0.0	0.3	3 - New Tech. & materials	66%
Slovakia	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0			
Slovenia	0.1	0.1	0.0	1	0.0	0.0	0.1	0.0	0.0	0.0	0.1	3 - New Tech. & materials	100%
Spain	12.8	9.8	3.0	39	1.7	2.1	3.3	3.7	1.8	0.2	3.7	4 - Operations & diagnosis of PV plants	29%
Sweden	2.9	2.1	0.8	6	0.0	0.0	1.7	0.5	0.6	0.0	1.7	3 - New Tech. & materials	59%
Switzerland	48.6	43.9	4.7	90	8.3	7.3	15.1	5.2	11.7	0.9	15.1	3 - New Tech. & materials	31%
Turkey	7.6	7.3	0.3	17	0.0	2.1	2.8	2.6	0.1	0.1	2.8	3 - New Tech. & materials	37%
United Kingdom	3.0	1.6	1.4	9	0.0	0.7	2.2	0.1	0.0	0.0	2.2	3 - New Tech. & materials	72%
Transnational (unallocated)	6.6	6.0	0.6	6	2.0	0.0	2.3	0.0	2.3	0.0	2.3	5 - Manuf. Tech.	35%
Grand Total	745.8	501.2	244.7	550.0*	92.2	204.5	203.1	100.2	137.4	8.4	204.5	2 - Tech Si SC & modules with higher quality	27%

Some projects are spread over various member states and therefore counted twice when aggregating the budget. The financing is segmented as per national financing.

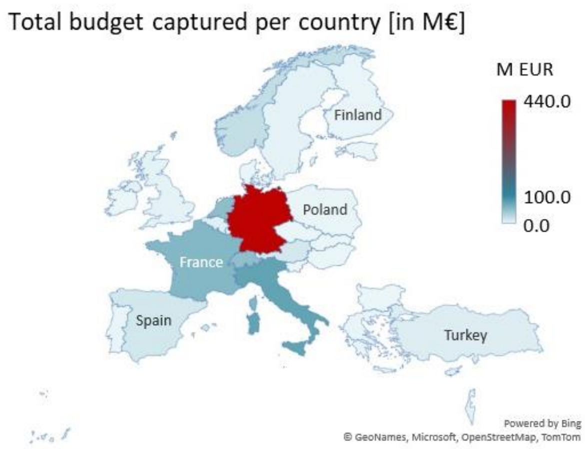


Figure 5-4: Mapping of TOTAL national budgets captured by PV IMPACT. [in million Euros.]. The overall budget covered in the database is 745M€

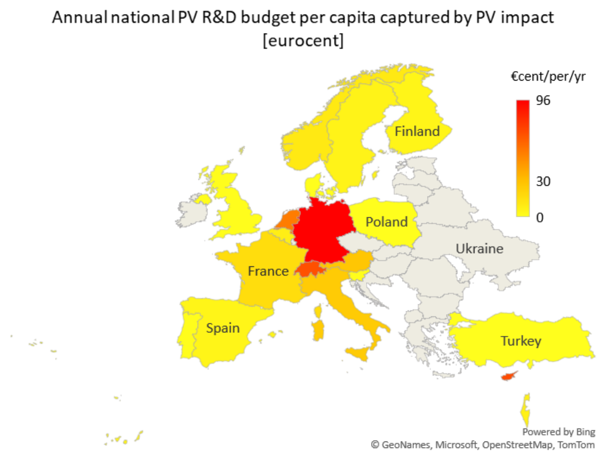


Figure 5-5: Annual national PV R&D budget per capita captured by PV IMPACT in eurocent per capita per year (average calculated for data between 2016-2020)

Figure 5-4 displays a map of the sum of the national budgets captured by PV impact. The highest budget captured by the database was for Germany, with an overall budget close to 436 M€. Figure 5-5 shows the average annual budget between 2019-2020 per capita. Also in this scope the highest allocated budget captured by the project corresponds to Germany with an annual budget of 0.96€/person/year.

Figure 5-6 displays a map of the highest funded topic per country with the intensity of the color corresponding to the percentage of the national budget for PV research. It is worth mentioning that low TRL activites are not highly represented in this database. The most likely source for this discrepancy, is that most of the funding sources analyzed provide inputs for research at higher TRL levels. It is also possible that cross-sectoral research receives a wider funding for example as part of the basic university funding, which hasn't been studied during this project.

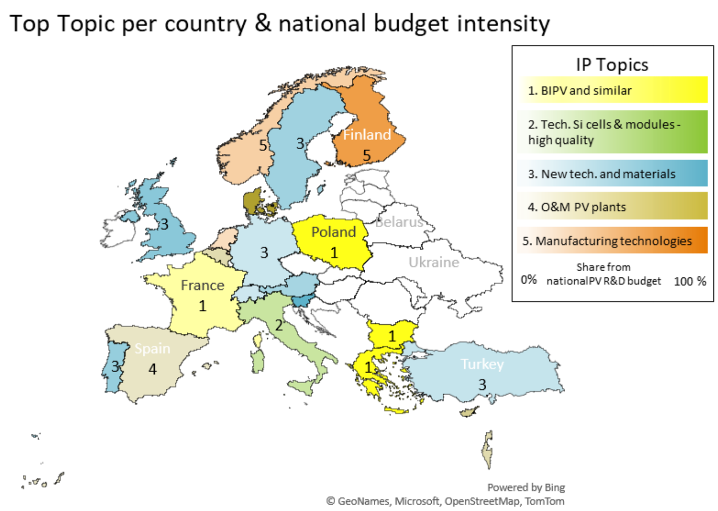
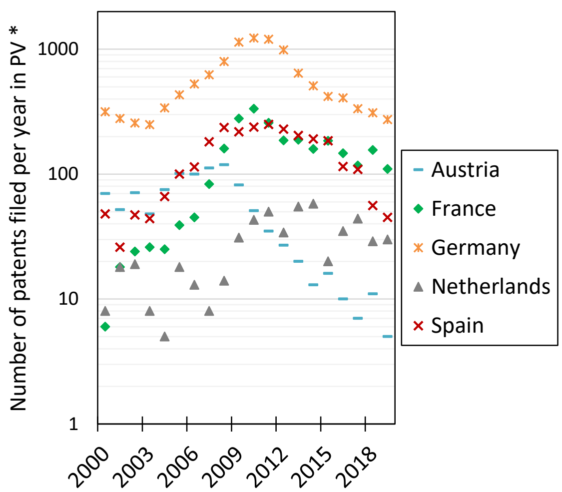


Figure 5-6: TOP IP topic for each country and relative intensity from the national budget.

The distribution share between the different activities varies strongly from country to country. Following takes are obtained from the reading of this data. France features a stronger budget on BIPV and similar topics. Spain's main budget share is divided between O&M for PV plants and New Technologies and Materials (with a slightly higher funding for O&M applications). Switzerland displays a strong focus towards new technologies and materials. Through a single large-scale project, Italy's captured budget shows a stronger orientation towards technologies for silicon solar cells and modules with higher quality, but the total budget is quite similar for manufacturing technologies

The number of patents produced between 2000-2019 for selected member states is shown in **Figure 5-7**, as gathered from the IRENA patent database for solar photovoltaic patents[16]. Germany has the highest number of patent applications from the countries studied. A peak in the total number of patents is observed around 2010 with a steady decline in applications until 2019. **Figure 5-8** shows annual and a cumulative comparison of patents filed both by the EU-27 and China for the same period. EU-27 had a higher number of annual applications until 2005. From then onwards, the total number of PV patents filed in China strongly outnumbers the EU-27, with over 30 times more patents filed on a yearly basis in 2019 and about 7 times more cumulative patents filed from 2000 until 2019.



*according to the IRENA database

Figure 5-7 Patents filed per year in the PV sector for selected Member States.[16]

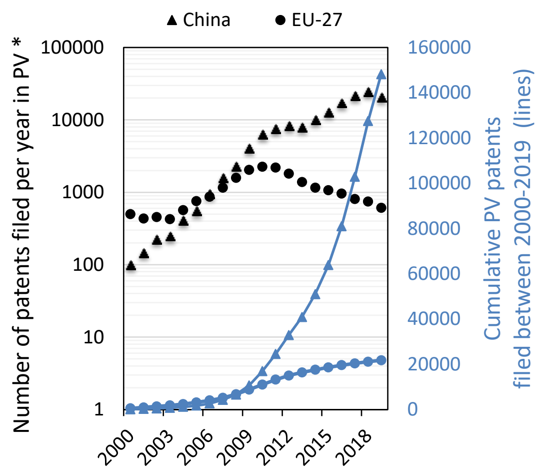


Figure 5-8 Annual and cumulative patents in the PV sector (EU-27 vs China).[17]

[16] From Irena's Inspire platform (PV-thermal patents have been excluded from the assessment) https://www.irena.org/Statistics/View-Data-by-Topic/Innovation-and-Technology/Patents-Evolution

[17] From Irena's Inspire platform (PV-thermal patents have been excluded from the assessment) https://www.irena.org/Statistics/View-Data-by-Topic/Innovation-and-Technology/Patents-Evolution

6. Conclusion and further steps

The database of the PV impact project enabled the assessment of (1) 387 projects which started in the period of 2015-2021; (2) the budget distribution based on the SET-Plan topics and (3) the creation of RD&D budget maps displaying the budget distribution of national funding for PV research according to these topics. The total budget analyzed represents 41% of the budget captured by the IEA reference in the same period (considering both PV and unallocated funding for the IEA's solar research). The highest annual funding per person captured by the database is for Germany, while in the IEA's database Switzerland shows a stronger budget allocation per person for PV research. The share distribution per topic observed for the different member states shows that the strategies are varied, ranging from focusing on a single topic, to two or a regular distribution between most of the topics. Cross sectoral research at low TRL has not been well captured by the database. The strong link between PV impact and the IWG has contributed to inform the IWG about the evolution of the orientation of the national funding. This information will hopefully contribute to the update of the new SET Plan by the IWG, which is currently in process, in order to adhere more closely to the current research needs of the industry and the society.

Further steps

National databases such as the ones from Germany, the Netherlands and Switzerland with the possibility to download the information in a workable format are an excellent tool to improve statistical analysis. It would be desirable to implement data management principles such as the FAIR guidelines for data treatment for these sources too. Ideally, the information regarding national funded projects should be **F**indable, **A**ccesible, **I**nteropeable and **R**eusable.

Moreover, specific guidelines for the statistical recording of national funding data at the source for funding at Member State level, such as those suggested by the IEA Reporting Energy RD&D Budget Expenditure Statistics[25] would be a highly recommended first step to improve the impact assessment of R&D spending. A second step would consist of the alignment of the national R&D budgets according to the SET-Plan topics; and thereby keeping a record of the implementation of these funds according to the strategic orientations at the funding source.

7. Contacts

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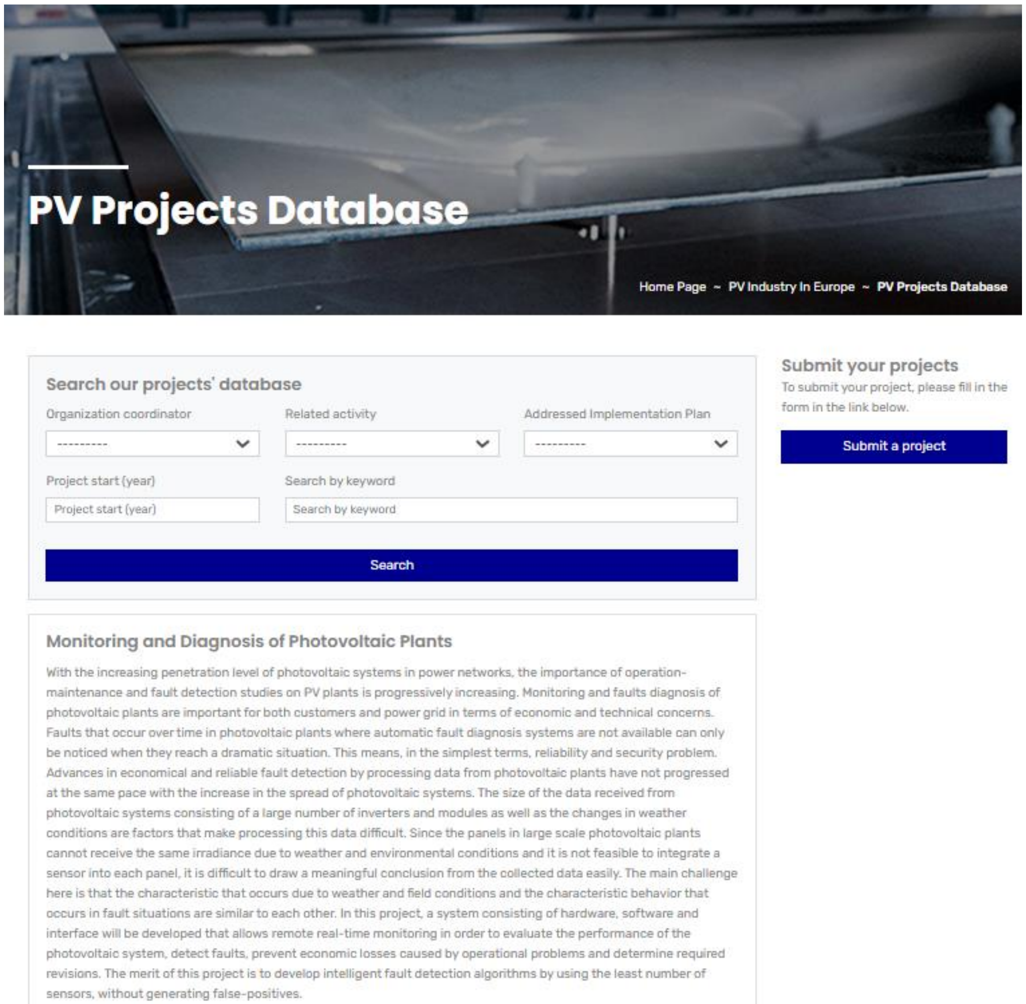
8. Annexes

Annex 1: Project database layout

Project database layout (finalized in June 2020)



Annex 2: SET-Plan project reporting template

Overview of the project database input requirements:

- Title
- Funding scheme
- Funding country
- Region
- Lead country
- Project coordinator
- Contact person
- Email address
- Project website
- Short project description
- Total budget
- EU funding
- National funding
- Regional funding
- Type of instrument
- PV percent
- Project start
- Project end
- Implant activities
- Addressed implant targets
- TRL
- Comments

Annex 3: Funding sources and structure for selected Member States

A list of relevant information about national databases and the funding institutions obtained during the execution of PV impact[18].

(1) **Germany:** Funding from the Federal Ministry of Economic Affairs and Energy - BMWi (called Ministry for Economic Affairs and Climate Action since 2021) was included. Germany manages all R&D expenditures with an electronic accounting system profile, including a fine-grained categorisation system matching national and IEA energy R&D reporting. This enables a 100% coverage of the R&D expenditures for the energy sector by the IEA database. As mentioned previously the Enargus[4] and the Foerderportal[5] databases gather the information relevant for these projects. A nice cross-sectoral overview of the total expenses for energy research. The Enargus database presents a segmentation of the investments done in PV research as shown in according to a categorization based PV technologies, quality assurance, manufacturing, circular economy, systems, basic research and others.

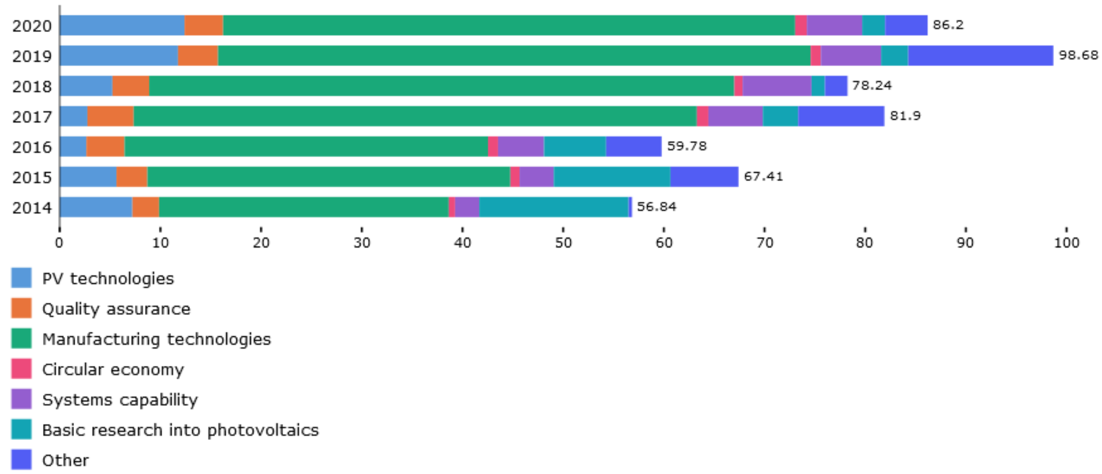


Figure 8-1 Expenditures in PV research [M€] from the German Federal Government between 2014-2020, according to the national segmentation (PV technologies, quality assurance, manufacturing technologies, circular economy, systems capability, basic research into PV, other)

It is worth mentioning that according to the 7th Energy Research program, which started in 2018 and is one of the main funding mechanisms for German PV research, "the primary R&D need is in industry-oriented research with rapid economic implementation". In 2018 the funding was tailored in respect to the European Strategic Energy Technology Plan (SET-Plan).

[18] Focus provided in this report for funding sources included in the PV Impact database

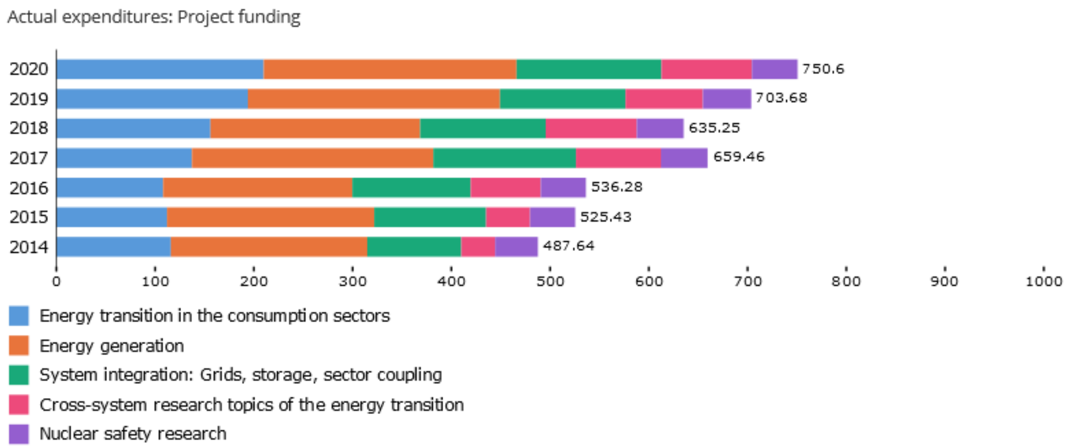


Figure 8-2 Distribution of energy-related funding for RD&D in Germany between 2014-2020 [in M€] (split in Energy transition in the consumption sector, energy generation, system integration, cross-system research topics, and nuclear safety research)

(2) **Netherlands**: there are over 1900 research projects in the Topsector energie[3] database. This wide list covers topics well beyond the PV sector. The projects are funded via various programs. Figure 8-3 shows an overview of some of the funding programs in the Netherlands depending on the maturity level of the technology. These programs cover a wide energy innovation spectrum. The PV impact database includes projects funded by the following programs: PPS-toeslag, Hernieuwbare Energie (HER+) and EZ Energie Innovatie (DEI+) (see Figure 8-3). Further information about Dutch funding programs can be found at the RVO webpage. A recent report from the RVO compiled the subsidies provided for energy innovations depending on the TRL level of the solutions.

(3) Figure 8-4 summarizes the share of the R&D budget financed for energy-related R&D projects (including PV projects) as a function of the TRL level for 2019 and 2020[19]. Depending on the specifications of the funding program: fundamental research is publicly financed by 100%, while industrial research can be financed 50% and industrial development by 25%.

[19] Monitoring report RVO Energy innovation 2020, published in May 2021 [accessible via the following link https://www.rvo.nl/sites/default/files/2021/07/Rapportage-RVO-Energie-innovatie-regelingen-2020-versie-voor-online-publicatie.pdf]

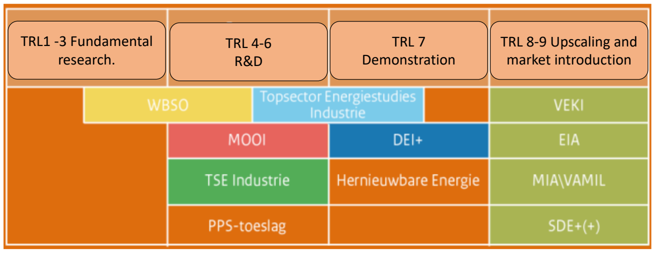


Figure 8-3 Funding instruments available for energy innovations, including PV research, in the Netherlands[20]

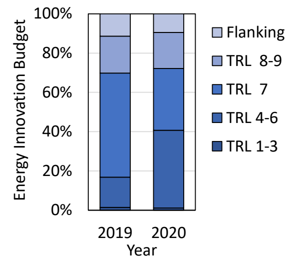


Figure 8-4 Budget distribution by TRL level for energy innovation research projects. Subsidies opened between 2019 and 2020 in the Netherlands. Energy funding covers topics beyond PV research.[8]

(4) **Belgium** There is a strong regional aspect to the public funding in Belgium. Innovation research is for example a regional competency, while security of supply is a federal one. Various funding agencies provide subsidies for PV-research, including in Flanders: Flanders Innovation and Enterpreneurship-VLAIO[21] (with O&O projects, SBO projects, and Proeftuinen), Speerpunktclusters (such as ICON, SBO's, Moonshots, interclusters, Research Foundation Flanders-FWO[22] . There is cofounding by provinces in the Flemish region through EFRO-funding and Interreg funding. Innoviris and Brussels environment provide funding in Brussels, while the Wallonian region, finances R&D projects by its energy public service[23] and public research departments[24]. Interregional cooperation in Belgium is organized through BELSPO projects. The Energy Transition Funds are a federal financing source and can be used for projects working towards the guarantee the security of supply at federal level.

(5) **Austria:** the main agencies/institutions providing R&D funding for energy topics in Austria are the Austrian Research Promotion Agency (FFG), the Kommunalkredit Public Consulting (KPC) for first of its kind demonstrations, the Austrian Science Fund (FWF) for energy related basic research and the Austria Wirtschaftservice (AWS) for seed financing programs.

[20] https://www.rvo.nl/onderwerpen/co%E2%82%82-reductie-industrie/innovatietraject
[21] https://www.vlaio.be/nl/andere-doelgroepen/flanders-innovation-entrepreneurship
[22] https://www.fwo.be/en/
[23] https://energie.wallonie.be/fr/recherche-et-developpement-en-energie.html?IDC=8180
[24] https://recherche.wallonie.be/home.html

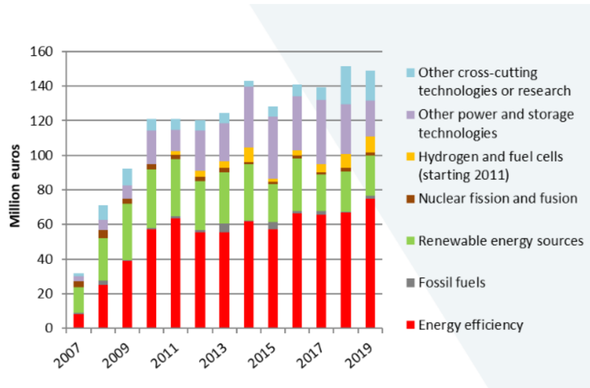


Figure 8-5 Budget distribution for energy-related RD&D activities in Austria

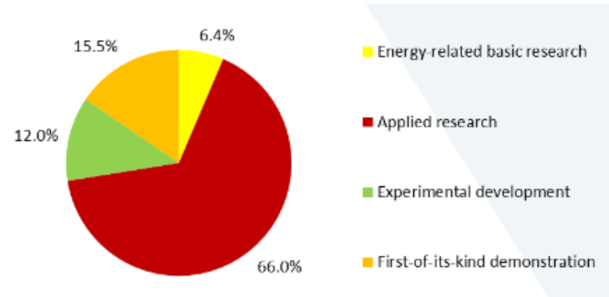


Figure 8-6 Budget distribution of energy-related RD&D activities in Austria in 2019 as a function of the TRL level

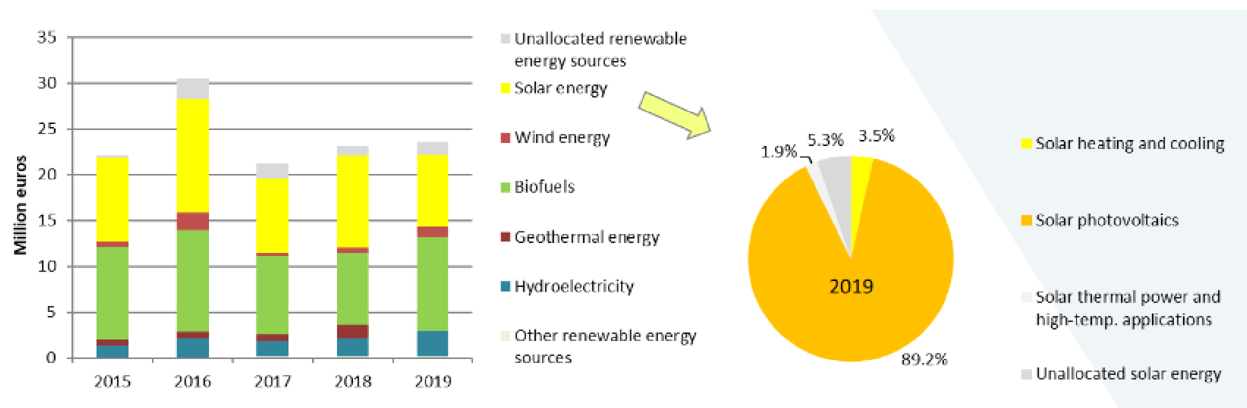


Figure 8-7 Budget distribution for renewables RD&D in Austria (left) with a distribution of the budget for solar research for 2019 depending on the type of solar research (right)

Annex 4: Raw Data from IEA's Energy technology RD&D Budgets for solar research

The following tables present the budgets gathered by the IEA's Energy technology RD&D Database. As can be seen in Table 8.1 RD&D budgets for solar photovoltaics from the IEA Energy technology DatabaseTable 8.1 the record for PV allocated budget for some member states seems to disappear after a certain period (such is the case for Italy and Spain), whereas the unallocated solar research budget is increasing for these countries in the same time period (see Table 8.2. Therefore the analysis performed in this report is based in the data shown in Table 8.3, which considers the sum of both PV budget and unallocated solar research budget as the maximal total PV budget that a Member State provided for the RD&D of PV in the time frame evaluated.

Table 8.1 RD&D budgets for solar photovoltaics from the IEA Energy technology Database[25]

	Belgium	**Czech Republic**	**Denmark**	**Estonia**	**Finland**	**France**	**Germany**	**Hungary**	**Ireland**	**Italy**	**Luxembourg**	**Netherlands**	**Norway**	**Poland**	**Portugal**	**Slovak Republic**	**Spain**	**Switzerland**	**Turkey**	**United Kingdom**	**TOTAL**
Solar PV	***71.5***	***5.6***	***89.8***	***3.8***	***1.6***	***1181.2***	***1279.4***	***0.2***	***14.8***	***182.4***	***0.0***	***332.6***	***144.3***		***2.6***	***9.1***	***50.6***	***407.0***	***10.9***	***61.2***	***3848.6***
2000			2.5			9.6	49.7			19.1	0.0	17.0	1.0		0.0		4.5	16.4	0.019	2.3	122.3
2001			5.1			10.6	37.4			19.4		21.7	1.3		0.1		3.4	16.4	0.027	3.2	118.6
2002						32.2	30.9		0.0	13.4		21.3	1.9		0.1		3.6	1.5	0.273	7.8	113.1
2003			1.5			19.7	38.4		0.1	13.4		18.0	1.8		0.0		6.5	13.5	0.04	6.8	119.7
2004			3.0			28.5	31.2		0.0	13.0			1.3		0.0		1.9	11.4	0.05	8.7	99.1
2005		0.4	3.0		0.2	43.3	53.4		0.1	12.8		16.5	1.3				2.3	11.1	0.18	13.2	157.8
2006		0.2	4.6		1.4	49.1	49.1		0.2	15.8		13.5	1.9		0.0		4.5	10.0	0.07		150.3
2007	9.6	0.2	7.7			64.8	42.4		0.5	20.2		14.4	5.2		0.1		5.9	10.6	0.10		181.7
2008			6.5			68.3	62.9		2.4	32.4		17.4			0.1	1.4	7.1	15.0	0.10		213.6
2009			5.2			87.2	55.3		2.5	22.8		31.8			0.4	1.6	4.8	15.7	0.13	1.9	229.1
2010			8.2			70.4	60.1		3.4			32.3	17.7		0.2	1.7		15.4			209.3
2011	6.7	1.6	9.9	1.1		59.8	67.0		3.6			33.5	18.0		0.0			19.2			220.5
2012	9.5	1.0	6.8			50.4	74.6		1.4			32.9	13.1		0.4			19.3			209.5
2013	7.9	0.6	4.5	0.8		84.9	63.4					26.8	11.5		0.5	3.7	1.7	16.4		0.1	222.7
2014	6.9	0.6	7.9	0.5		85.6	57.1					19.1	9.2		0.4	0.5		26.6			214.5
2015	6.8	0.0	3.6	0.5		84.7	73.1						10.4		0.3	0.0		27.1		0.1	206.6
2016	5.3	0.0	2.6	0.3		79.8	69.5						12.4			0.0		33.0	0.68	7.1	210.7
2017	1.2	0.0	1.4	0.7		68.3	90.5						11.5				2.0	35.4	0.77	5.9	217.8
2018	2.7	0.2	1.8			65.7	83.1						8.7			0.1		36.3	0.81	0.0	199.6
2019	7.2	0.4	2.4			55.9	102.3		0.3				8.0			0.0		29.5	7.59	1.5	215.0

[25] https://www.iea.org/articles/energy-technology-rd-and-d-budgets-data-explorer

2020	7.7	0.3	1.6			62.4	88.0	0.2	0.3			16.4	8.0			0.0	2.3	27.4	0.13	2.6	217.3

Table 8.2 Unallocated solar PV RD&D Budget from IEA Energy Technology Database[14]

	Belgium	**Czech Republic**	**Denmark**	**Estonia**	**Finland**	**France**	**Germany**	**Hungary**	**Ireland**	**Italy**	**Luxembourg**	**Netherlands**	**Norway**	**Poland**	**Portugal**	**Slovak Republic**	**Spain**	**Switzerland**	**Turkey**	**United Kingdom**	**TOTAL**
Unallocated solar energy	***1.8***	***1.4***	***23.1***	***0.7***	***85.7***	***122.0***	***0.0***		***3.4***	***374.4***		***160.2***	***19.1***	***63.4***	***0.1***	***7.3***	***237.9***	***14.1***	***11.24***	***307.5***	***1433.3***
2000							0.0														0.0
2002						0.0															0.0
2004						0.0											0.0	0.0			0.0
2005							0.0											0.0			0.0
2006																				1.6	1.6
2007					1.5	0.0														11.9	13.4
2008		0.3			2.6	0.0							6.5								9.4
2009		0.4			7.5									5.5			11.0			20.4	44.8
2010		0.4	3.4		1.3	0.1			0.1			1.6		4.9			23.1	1.4		38.1	74.3
2011	0.4		2.2		3.0	33.1			0.3	61.3		0.6		9.2		3.0	58.4	1.3		13.9	186.8
2012	0.0		3.5		7.4	41.9			0.1	48.2		0.0		5.3	0.0	2.7	34.9	0.5		12.4	157.0
2013	0.1		5.8		22.7	7.0				52.2		1.1		3.2	0.0		11.8	4.7		13.8	122.5
2014	0.1		1.5		5.0	6.4			0.7	68.0		2.6	0.0	6.5	0.0		19.1	1.1	5.55	13.6	130.2
2015	0.0	0.0	1.8		7.2	7.7			0.8	40.3		57.6	3.6	4.0	0.0		16.3	2.0	3.31	13.8	158.4
2016			2.3		3.6	6.0			0.6	24.8		27.4	3.2	2.9		1.2	15.0	2.2	0.40	22.3	112.0
2017			2.0		5.6	3.9			0.3	25.1		23.8	5.7	3.0		0.1	5.9	0.3	0.99	17.0	93.6
2018				0.3	7.0	4.3			0.5	26.2		27.3	0.0	5.5			17.6	0.0	0.85	50.3	139.9
2019	1.2	0.1	0.5	0.3	6.1	3.8			0.1	28.3		16.1	0.0	7.1		0.1	16.0	0.2	0.08	36.4	116.5
2020		0.1	0.0	0.0	5.1	7.7			0.1			2.0		6.3		0.1	8.9	0.3	0.07	42.1	72.9

Table 8.3 TOTAL (PV+ unallocated solar) RD&D Budget in million EUR (2021 price excluding rates)[14]

	Austria	Belgium	Czech Republic	Denmark	Estonia	Finland	France	Germany	Hungary	Ireland	Italy	Luxembourg	Netherlands	Norway	Poland	Portugal	Slovak Republic	Spain	Switzerland	Turkey	United Kingdom	Grand Total
Total	***132.6***	***73.3***	***7.0***	***112.9***	***4.5***	***87.2***	***1303.2***	***1279.4***	***0.2***	***18.2***	***556.8***	***0.0***	***492.8***	***163.3***	***63.4***	***2.7***	***16.4***	***288.5***	***421.2***	***22.2***	***368.6***	***5414.4***
2000	0.94	0.0	0.0	2.5	0.0	0.0	9.6	49.7	0.0	0.0	19.1	0.0	17.0	1.0	0.0	0.0	0.0	4.5	16.4	0.0	2.3	**123.2**
2001	1.10			5.1			10.6	37.4			19.4		21.7	1.3		0.1		3.4	16.4	0.0	3.2	**119.7**
2002	1.95						32.2	30.9		0.0	13.4		21.3	1.9		0.1		3.6	1.5	0.3	7.8	**115.0**
2003	1.82			1.5			19.7	38.4		0.1	13.4		18.0	1.8		0.01		6.5	13.5	0.0	6.8	**121.5**
2004	0.53			3.0			28.5	31.2		0.0	13.0		0.0	1.3		0.01		1.9	11.4	0.0	8.7	**99.6**
2005	1.74		0.4	3.0		0.2	43.3	53.4		0.1	12.8		16.5	1.3				2.3	11.1	0.2	13.2	**159.5**
2006	0.70		0.2	4.6		1.4	49.1	49.1		0.2	15.8		13.5	1.9		0.04		4.5	10.0	0.1	1.6	**152.6**
2007	2.04	9.6	0.2	7.7		1.5	64.8	42.4		0.5	20.2		14.4	5.2		0.1		5.9	10.6	0.1	11.9	**197.1**
2008	2.86		0.3	6.5		2.6	68.3	62.9		2.4	32.4		17.4	6.5		0.1	1.4	7.1	15.0	0.1	0.0	**225.9**
2009	6.43		0.4	5.2		7.5	87.2	55.3		2.5	22.8		31.8	0.0	5.5	0.4	1.6	15.8	15.7	0.1	22.2	**280.4**
2010	9.62		0.4	11.6		1.3	70.5	60.1		3.5	0.0		33.9	17.7	4.9	0.2	1.7	23.1	16.7	0.0	38.1	**293.3**
2011	12.45	7.1	1.6	12.1	1.1	3.0	93.0	67.0		3.8	61.3		34.1	18.0	9.2	0.0	3.0	58.4	20.5	0.0	13.9	**419.7**
2012	9.25	9.6	1.0	10.3		7.4	92.3	74.6		1.6	48.2		32.9	13.1	5.3	0.4	2.7	34.9	19.8	0.0	12.4	**375.7**
2013	13.45	8.0	0.6	10.3	0.8	22.7	91.9	63.4		0.0	52.2		27.9	11.5	3.2	0.6	3.7	13.6	21.1	0.0	13.9	**358.6**
2014	15.22	7.0	0.6	9.4	0.5	5.0	92.0	57.1		0.7	68.0		21.7	9.2	6.5	0.5	0.5	19.1	27.8	5.6	13.6	**359.9**
2015	8.80	6.8	0.03	5.4	0.5	7.2	92.3	73.1		0.8	40.3		57.6	14.0	4.0	0.3	0.0	16.3	29.1	3.3	13.8	**373.8**
2016	12.79	5.3	0.02	4.9	0.3	3.6	85.9	69.5		0.6	24.8		27.4	15.6	2.9		1.3	15.0	35.2	1.1	29.4	**335.4**
2017	8.29	1.2	0.03	3.4	0.7	5.6	72.2	90.5		0.3	25.1		23.8	17.3	3.0		0.1	8.0	35.6	1.8	22.9	**319.7**
2018	10.14	2.7	0.2	1.8	0.3	7.0	70.0	83.1		0.5	26.2		27.3	8.7	5.5		0.1	17.6	36.3	1.7	50.3	**349.6**
2019	7.80	8.3	0.5	2.9	0.3	6.1	59.7	102.3		0.4	28.3		16.1	8.0	7.1		0.1	16.0	29.7	7.7	37.9	**339.3**
2020	4.68	7.7	0.4	1.7	0.0	5.1	70.1	88.0	0.2	0.4			18.4	8.0	6.3		0.1	11.2	27.7	0.2	44.6	**294.8**

Annex 5

Exchange rates used for the conversion of Swiss Francs to Euros depending on the year

Table 8.4 Annual average exchange rates used to convert CHF to EUR

Year	CHF	
2015	0.93776	EUR
2016	0.9238	EUR
2017	0.9004	EUR
2018	0.83612	EUR
2019	0.8991	EUR
2020	0.9342	EUR
2021	0.9252	EUR
2022	0.9677	EUR