

FLAG-ERA II

Deliverable D6.5

Landscape analysis in the domain of the Graphene Flagship

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Description of content		This deliverable reports a landscape analysis in the domain of the Graphene Flagship.		
Publishable abstract		This deliverable analyses the landscape of the Graphene funding, presenting the research topics proposed for the JTC 2021 call of FLAG-ERA as well as presenting the scope of the national/regional funding ensured by the FLAG-ERA participating funding agencies.		
Keywords		Transnational projects dedicated to graphene and 2D materials; national/regional projects dedicated to graphene and 2D materials; research topics of the FLAG-ERA sub-calls dedicated to Graphene; transnational collaboration in the FLAG-ERA projects		

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1 Introduction

The landscape analysis of the Graphene domain is performed in the frame of the FLAG-ERA project. This analysis is of three types, even though all aspects are clearly linked to understand the evolutions and dynamics of the Graphene research community in Europe.

A first analysis is dedicated to understand the gaps and needs in term of topics funding. This analysis results in the evolution of the research topics proposed to the Graphene research community at each FLAG-ERA call. The topics selected for the JTC 2021 are reported in a first part of this report.

The second aspect of the landscape analysis is the understanding of the activities in the domain of Graphene performed at regional/national level. To have a vision of this part, the national/regional funding of the FLAG-Era participating agencies was analyzed in the second part of the report.

And third, a short part is dedicated to the analysis of the outreach of the FLAG-ERA graphene sub-calls in term of partners funding throughout Europe.

2 Topics definition for the JTC 2021

The FLAG-ERA JTC 2021 is the fourth thematic call dedicated to Graphene research and innovation. Already, from JTC 2017 on and to reflect the evolution in the field the graphene, the FLAG-ERA calls were split in 2 sub-calls; one dedicated to Graphene Basic Research and 1 sub-call dedicated to Graphene applied research and innovation.

The definition of the research topics proposed to the research community is prepared by consulting the FLAG-ERA participating funding agencies in the one hand and consulting the Graphene Flagship in the other hand. The goal of these consultations is to ensure that the proposed topics are filling the gaps and filling the needs of the Graphene community.

The topics proposed in the frame of the JTC 2021 graphene sub-calls are reported below:

JTC 2021 Graphene Basic Research topics:

1. Layered Magnetic Materials and Heterostructures
2. Growth and device integration of two-dimensional amorphous materials
3. Scalable growth & device integration of UltraLow Power Spin-Orbit Memories based on GRMs
4. Bacterial degradation of GRMs
5. GRM based devices and circuits for neuromorphic computing
6. Infrared+THz emission and detection with twisted GRMs
7. Functionalized GRMs for advanced multivalent metal-ion batteries (MMIBs)
8. Chemical sensing with GRMs
9. MXene foams for capacitive deionization water desalination
10. Rheological models for GRM suspensions and multiphase flows

JTC 2021 Graphene Applied Research and Innovation topics:

1. Antiviral protection with GRM-based foams and coatings
2. GRM-based Neural Interfaces for Bioelectronic Medicines
3. GRM-based spectrometer for visible and infrared
4. GRM-based, Ultra-Broadband THz-Transceiver technologies for 6G compliant wireless communication
5. Tuning the hot-carrier lifetime in layered materials heterostructures for photoresponsivity enhancement
6. GRMs for advanced metal-ion supercapacitors
7. GRM-based electrodes for redox flow batteries
8. GRM components for Self-charging and Self-powered Electronics

As a consequence, the evolution of topics from one FLAG-ERA call to the next one is directly an analysis of the scientific landscape in the Graphene domain.

Regarding the evolution of the topics, it must be stressed that the ones proposed for the JTC 2015 were broader.

Some of the topics proposed in 2021 were indirectly present in the previous calls, such as the topics 2 to 4 of the Graphene Basic sub-call, and topics 2, 4 and 6 in the Graphene applied sub-calls.

Notably, some new topics were proposed for JTC 2021; such as the 5th and the 9th in Graphene Basic (dedicated to neuromorphic computing and water desalination respectively) and topics 1 and 5 in graphene applied (dedicated to antiviral protection and tuning hot-carrier lifetime for photoresponsivity enhancement).

Besides, some topics were not proposed anymore in 2021, such as topics related to quantum technologies, which was present in JTC 2017 and 2019. This reflects the activity of the other ERA-NET dedicated to quantum technologies: QuantERA. In JTC 2017 two topics were proposed related to thermoelectrics and inks but are not present in JTC 2021, and the topics reusable templates and tissue engineering proposed in 2019 were not taken over in 2021. This removal of topics is also linked to the wish of reducing the number of proposed research topics in the call 2021.

3 National/Regional funding inventoried

a) About the data reported in this section

This section of the report has been elaborated as part of the Task 6.4 'Landscape inventory 2021 in the domain of the Graphene' and Task 6.5 'Strategic analysis 2021 in the domain of the Graphene' within the sixth Work Package of FLAG-ERA II (Communication and information dissemination).

The information reported in this section was collected in the form of 2 separate surveys, it should be kept in mind that the answers below do represent the specific FLAG-ERA partner point of view in the context of their own missions and cannot be considered as fully representative of a country position.

Disclosure statement

The country-specific information described in this report only partially reflects the national landscape in the field of graphene as it is based on the limited view of the participating NRFO’s, and their sometimes restricted missions related to funding basic, clinical and/or innovation research. It should therefore should be interpreted with caution.

b) Specific national/regional funding actions besides FLAG-ERA

General

Twenty one funding organizations distributed in eighteen countries are funding graphene research in the frame of one or more FLAG-ERA project, having participated to at least one edition of a JTC funding graphene research projects. In the ongoing call JTC 2021 a total of 18 NRFOs from 15 different countries participated. In the present inventory, the answers of 14 NRFOs from 12 different countries listed below per alphabetical order are being described (* participated to the FLAG-ERA JTC 2021 call):

- Belgium: F.R.S.-FNRS* + FWO*
- Bulgaria: BNSF*
- Estonia: ERC
- France: ANR*
- Israel: ISERD*
- Lithuania: RCL*
- Romania: UEFISCDI*
- Slovenia: MIZS*
- Slovakia: SAS*
- Spain: AEI*, IDEPA*
- Sweden: VR*
- Poland: NCBR

Funding policies and instruments of the NRFOs on graphene and 2D materials

The majority of the NRFOs fund graphene and 2D materials research through regular national (and/or regional) bottom-up open calls or programs.
Only 2 funding agencies, among the ones having answered the survey, do declare having additional specific funding action: namely NCBR in Poland and ISERD in Israel.

NRFO with national graphene funding action besides FLAG-ERA	Start and end year of the funding action	Time line of the funding action’s start	Status of the NRFO in FLAG-ERA while starting this funding action	Preparation of the national funding action	Number of projects funded / approximate associated budget
ISERD (Israel)	2014-2017 And 2019-2021	While FLAG-ERA was running	Already member of FLAG-ERA	Planned before ISERD’s participation to FLAG-ERA	3 projects, 18 participants / 8 M€
NCBR (Poland)	2012-2016	While FLAG-ERA was running	Already member of FLAG-ERA	Not planned before FLAG-ERA	12 projects / / 13 M€

Tab. 1. Overview of the reported specific national/regional programs dedicated to graphene and 2D related materials.

c) Bottom-up research funding throughout Europe

Transnational versus national funding of the NRFOs on graphene and 2D materials

All funding organizations participating to FLAG-ERA transnational support to Graphene and 2D related materials answering both surveys, did declare having national/regional projects funded in the frame of bottom-up research funding.

In total more than 1117 projects, for a global budget or more than 246 M€, were funded by for bottom-up national/regional research projects by the FLAG-ERA members beside the dedicated transnational calls. These projects are reported, for the period from 2015 to 2021,.in the FLAG-ERA II deliverable 6.4.

This national/regional bottom-up funding may be compared with the funding distribution of the FLAG-ERA calls. Over the 4 Graphene dedicated calls of FLAG-ERA, 56 projects representing a budget of 39.5 M€ were funded.

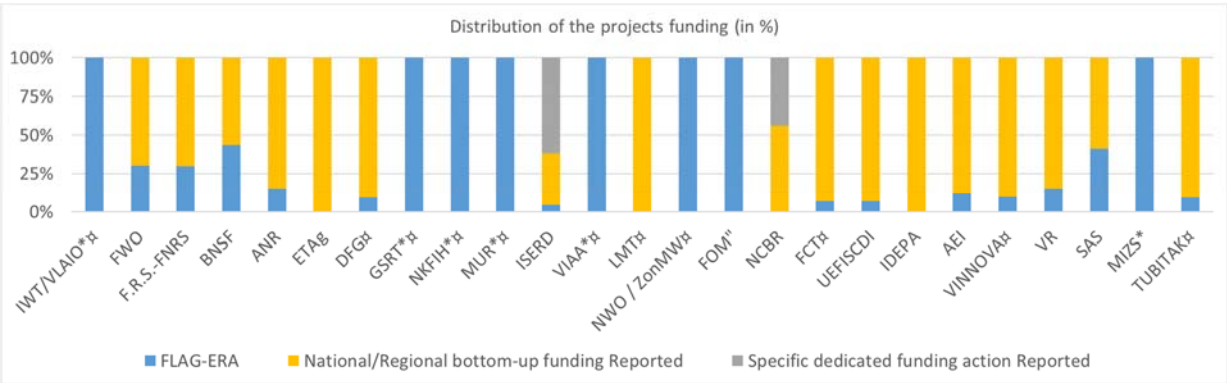


Fig. 1. *Distribution of the agencies funding, in percentage, between transnational projects, bottom-up funding and specific national actions (" : funding agency with no more activity; * : information on bottom-up projects not reported; ‡ : information on specific national/regional funding action not reported).*

Considering only the funding agencies having reported their national/regional data, it may be concluded that the funding of national/regional projects represents for them 70 to 85% of their budget dedicated to graphene and 2D materials, and thus, transnational FLAG-ERA projects represent 15 to 30% of their budget dedicated to graphene and 2D materials.

For the few countries with specific graphene dedicated funding actions, it is interesting to note that then these actions are representing a very large part of their support to graphene research.

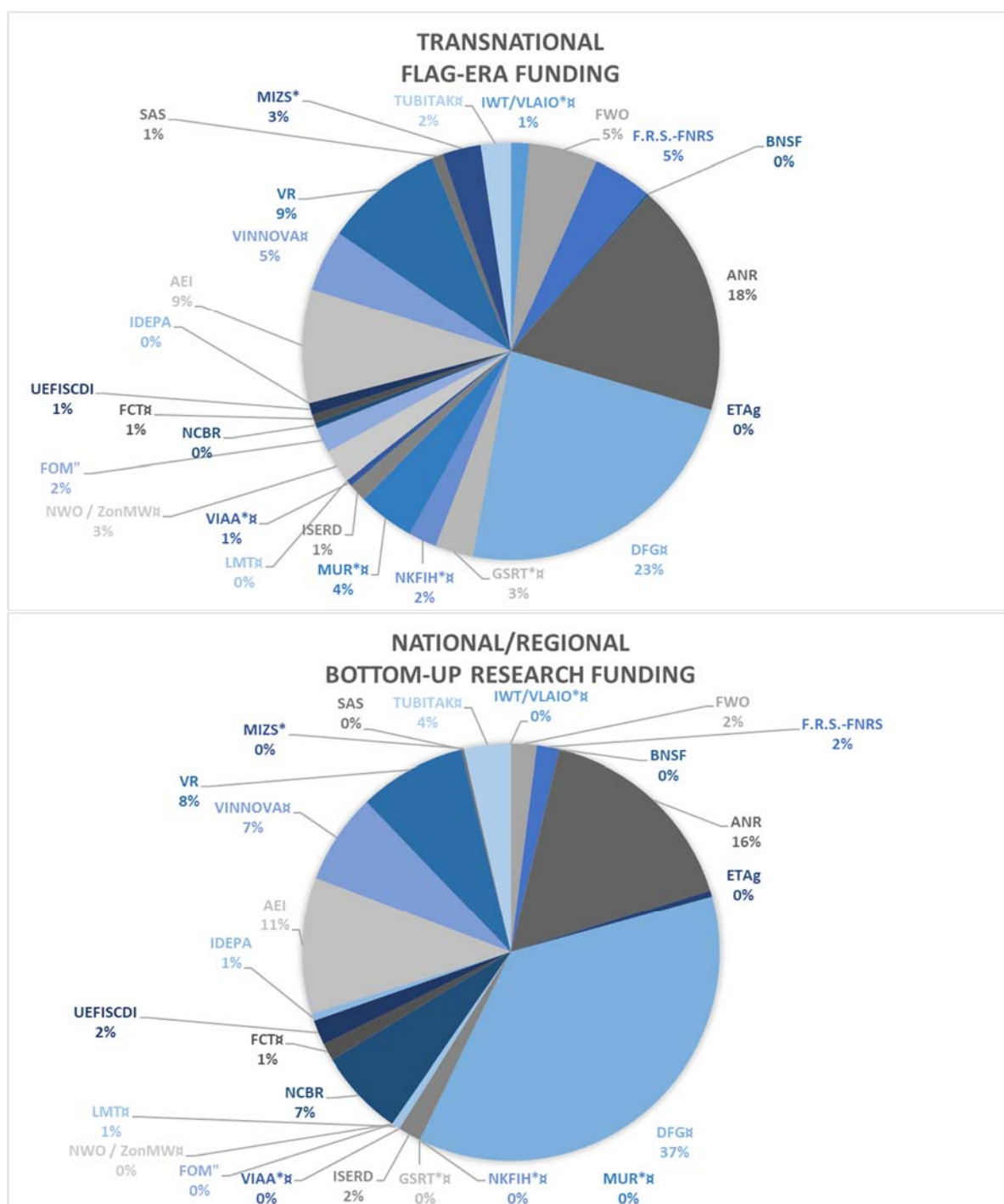


Fig.2. top: distribution of the FLAG-ERA transnational funding (% of the 39.5 M€); bottom: distribution of the national/regional funding (% of the 246 M€, from the reported information in the survey).

From Fig. 2, it may be concluded that the share of most funding agency in the funding of project remains comparable from the transnational point of view or from the national/regional point of view.

Among the organizations having reported their national/regional funding, it is interesting to observe that in Poland the graphene and 2D materials research is strongly supported, whereas NCBR is no more participating to transnational funding. On the contrary around, in Belgium (FWO+F.R.S.-FNRS, the funding of graphene and 2D related materials is stronger.

Timeline of national funding of the NRFOs on graphene and 2D materials

This shows that the starting of FLAG-ERA was concomitant to the ramp-up of national projects throughout Europe.

In order to analyse the keywords of the national/regional funded projects when available, 8 word clouds were built (see Fig. 3). When preparing the word clouds, the words “Graphene”, “materials”, “carbon” and if present “organic” and “molecular” were excluded.

Figure 1 displays eight word clouds, each representing a different project portfolio in nanotechnology. The word clouds are arranged in a 2x4 grid. The top row shows four word clouds for ANR, ISERD, SAS, and FCT. The bottom row shows four word clouds for AEI, NCBR, TUBITAK, and VR. Each word cloud contains a variety of research topics, with the size of the words indicating their frequency. The topics include electronics, photonics, quantum, nanotechnology, materials science, and various other nanotechnology-related fields.

Project Portfolio	Number of Projects	Total Budget (M€)
ANR	90	40.5
ISERD	6	4.5
SAS	10	0.5
FCT	15	3.3
AEI	207	26.1
NCBR	17	16.5
TUBITAK	134	8.7
VR	53	20.5

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4 Funding organizations distribution and collaborations in the FLAG-ERA funded projects

Distribution of the funding in the transnational FLAG-ERA Graphene sub-calls

Among the 56 projects dedicated to Graphene applied or graphene basic research funded in the frame of one of the FLAG-ERA transnational call, 19 funding organizations are represented. Most of the time, the number of project per funding organization is related to the height of the funding commitment and to the research community activity. As a result, some funding organizations fund more partners, as observed on Fig 4.



Fig. 4. Word cloud obtained on the funding organization’s name from the list of 217 partners funded in the frame of FLAG-ERA projects dedicated to graphene.

Collaboration in the FLAG-ERA Graphene projects

Graphics are reported in annex 2 regarding the transnational collaborations in the FLAG-ERA projects funded in the frame of all the Graphene sub-calls. It appears from the diagrams that, even some funding organizations are more involved, the collaborations remain well spread over the members participating.

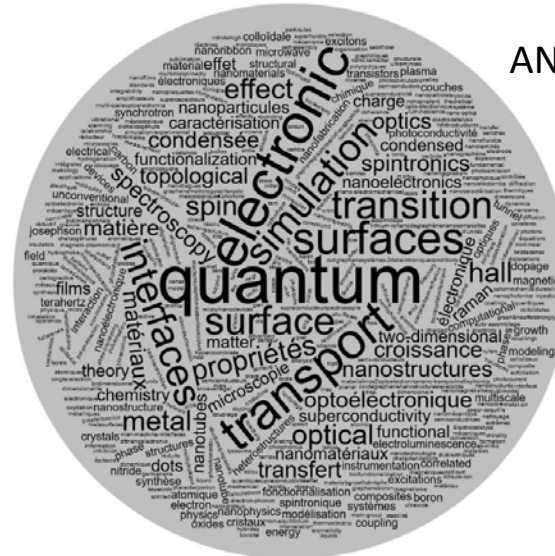
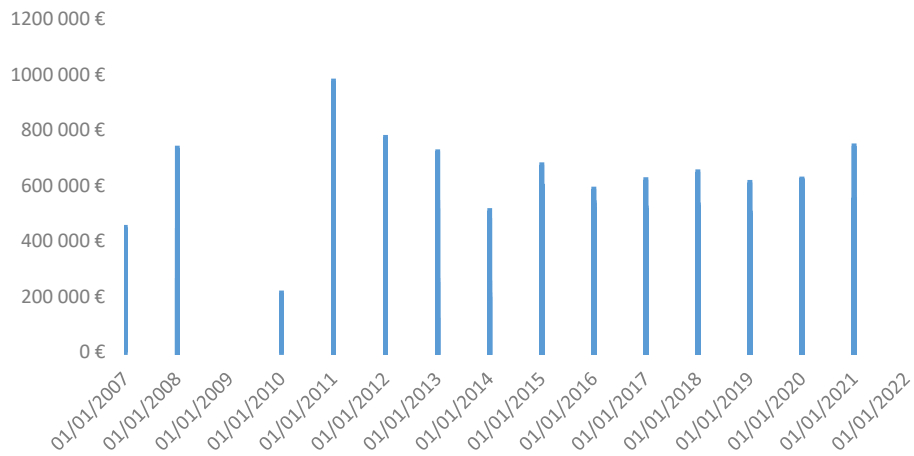
5 Conclusion

In conclusion, the FLAG-ERA graphene sub-calls are proposing research topics to the applicants that are evolving each edition in order to reflect better the dynamic of the research community and the dynamic of the Graphene Flagship. Besides, the FLAG-ERA participating funding agencies do all have bottom-up national calls where projects are funded in the domain of Graphene. There the topics addressed by the applicants are very broad and some, such as quantum technologies, are no more covered by the FLAG-ERA transnational calls as it is covered by the QuantERA calls, in which all FLAG-ERA participating funding agencies are also involved.

Regarding the FLAG-ERA transnational calls, it appears that the collaboration throughout “wide-Europe” (including Israel and Turkey) is very efficient and that despite some leading agencies, most of Europe is covered.

Annex 1 (overview on the timeline and keywords of national/regional funded projects)

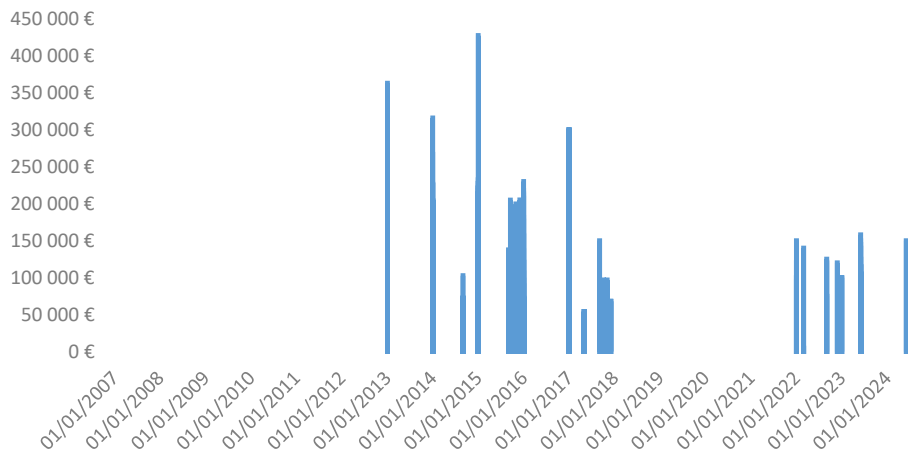
ANR ProjectFunding (Euro)



ANR: 90 projects; 40.5 M€

Excluant: graphene;
materials; carbon;
molecular; organic

AEI-MCIU ProjectFunding (Euro)

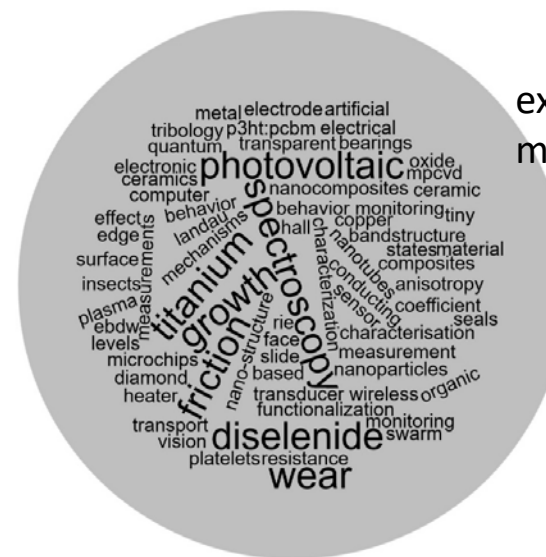
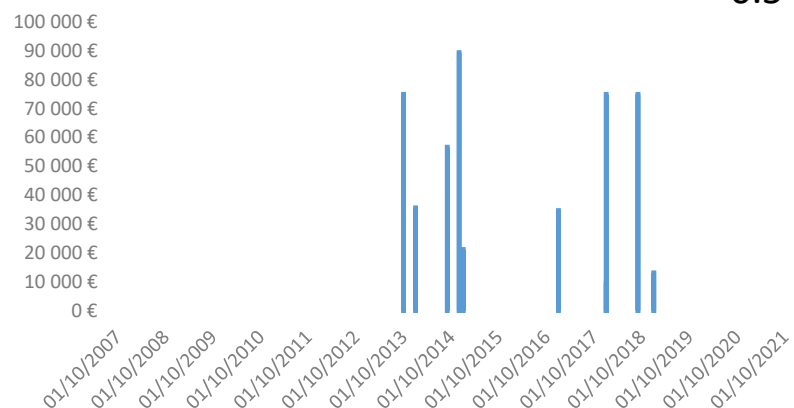


AEI: 207 projects; 26.1 M€

Excluant: graphene;
materials; carbon;
molecular; organic

SAS ProjectFunding (Euro)

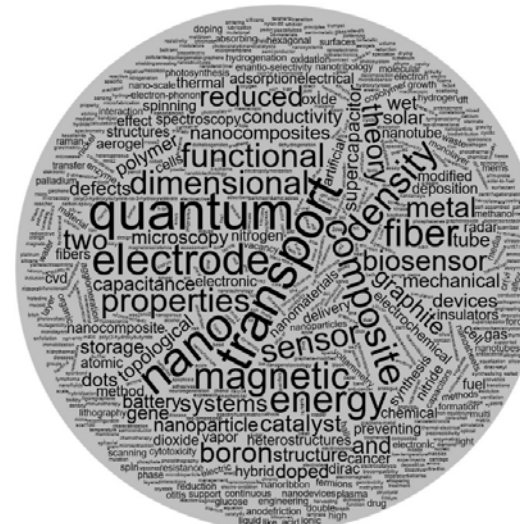
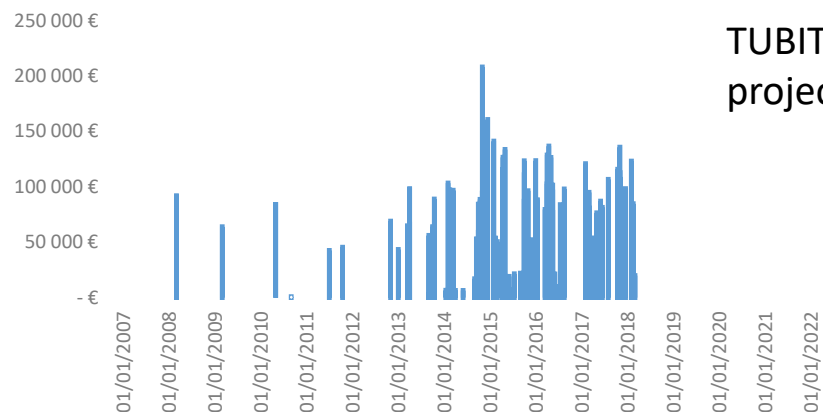
SAS: 10 projects;
0.5 M€



excluding graphene;
materials; carbon

TUBITAK ProjectFunding (Euro)

TUBITAK: 134
projects; 8.7 M€



excluding graphene;
materials; carbon

FCT: 15 projects; 3.3 M€

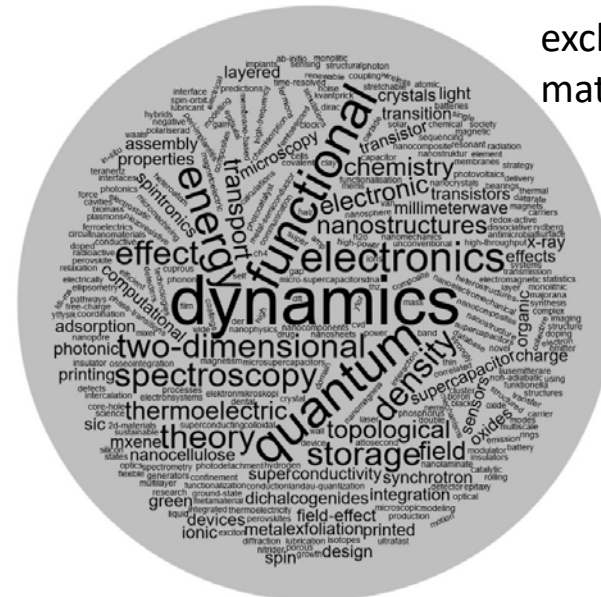
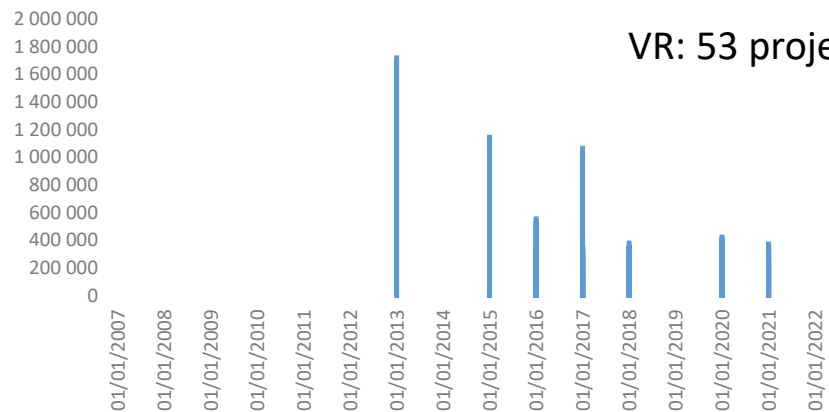
FCT ProjectFunding (Euro)



Excluant: graphene;
materials; carbon;
molecular; organic

VR ProjectFunding (Euro)

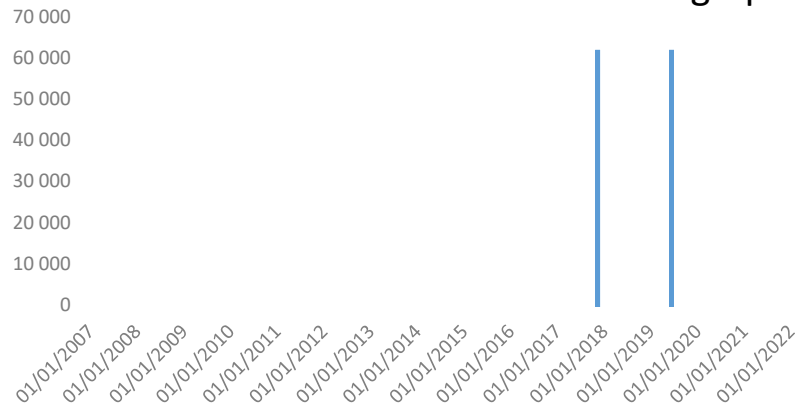
VR: 53 projects; 20.5 M€



excluding graphene;
materials; carbon

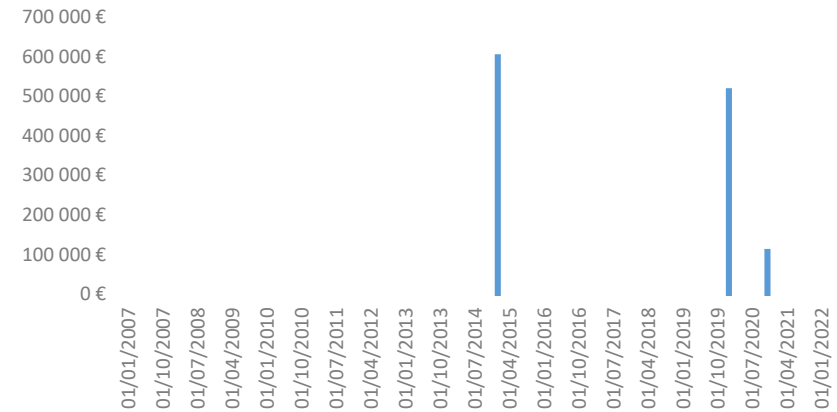
BNSF: 4 projects; 0.25 M€

BNSF ProjectFunding (Euro) BNSF: all keywords
graphene



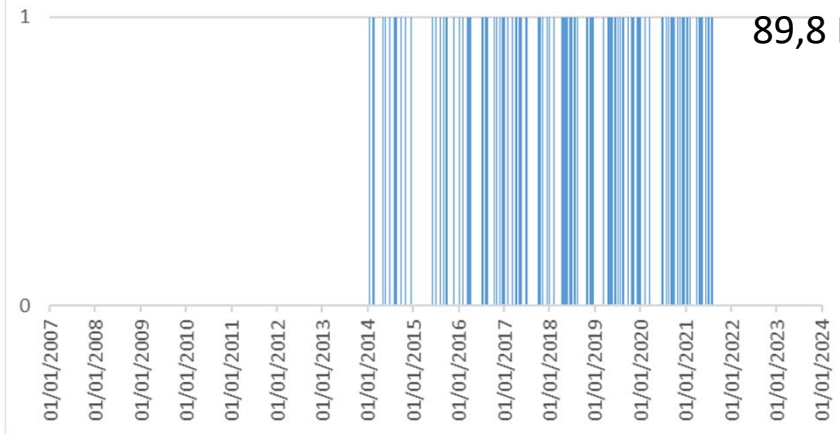
ETAg: 3 projects; 1.2 M€

ETAg ProjectFunding (Euro)

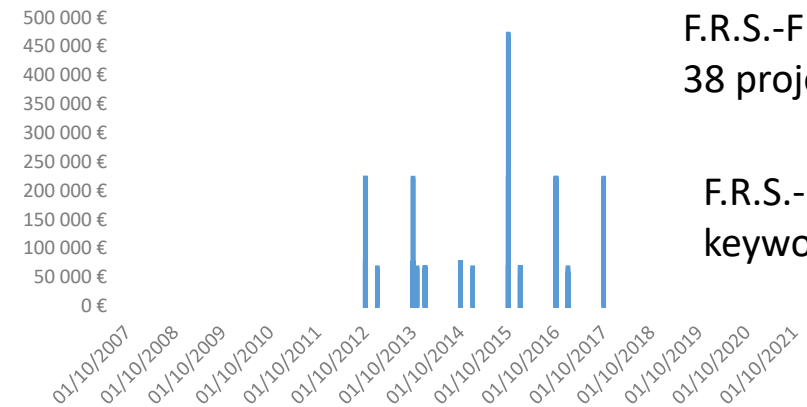


DFG:
236 projects;
89,8 M€

ProjectFunding (Number)



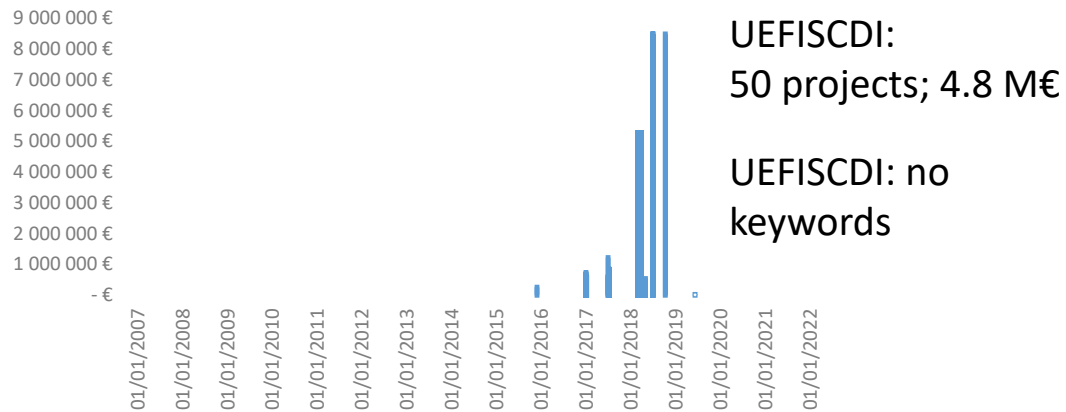
F.R.S.-FNRS ProjectFunding (Euro)



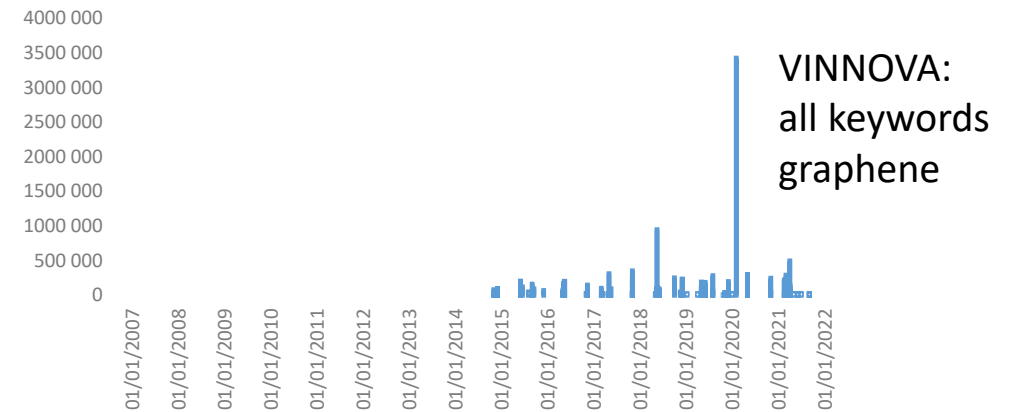
F.R.S.-FNRS:
38 projects; 4.2 M€

F.R.S.-FNRS: all
keywords graphene

UEFISCDI TotalFunding (Euro)



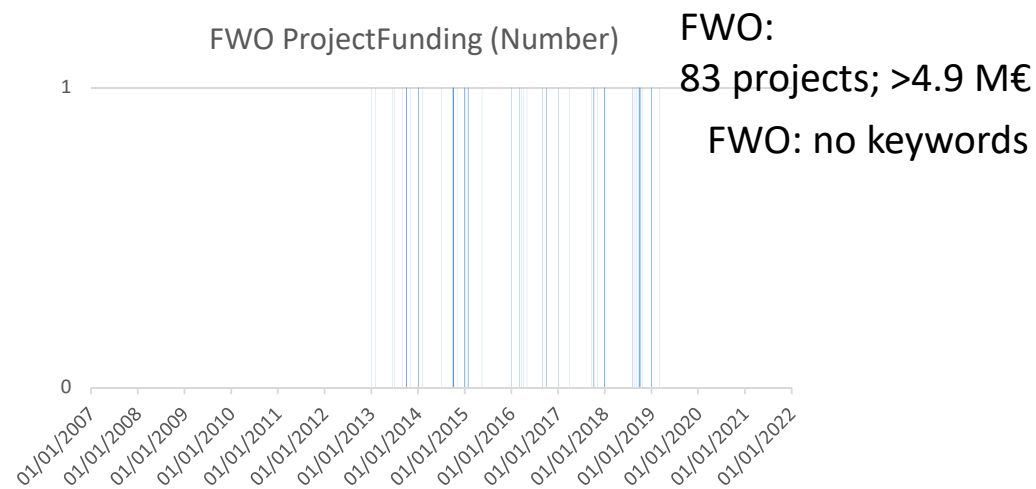
VINNOVA ProjectFunding (Euro)



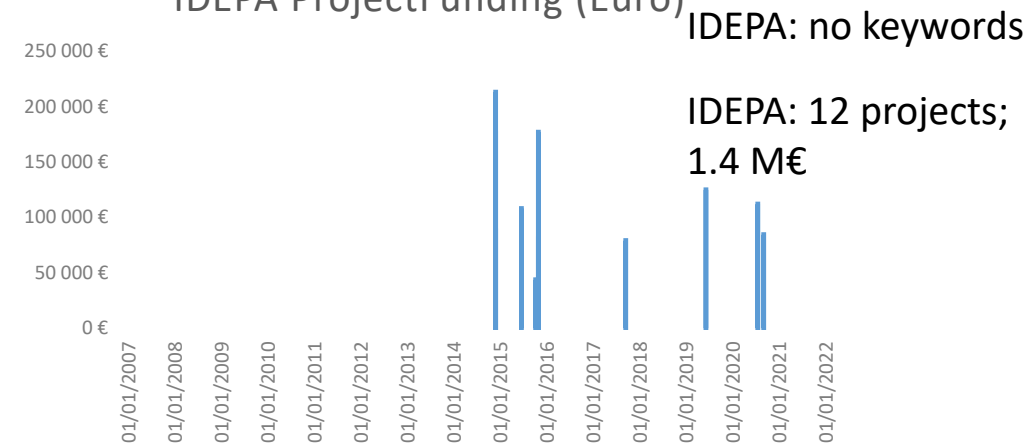
LMT: 5 projects; 1.6 M€; no dates; no keywords

NWO: 10 projects; starting dates from 2020; no keywords

FWO ProjectFunding (Number)

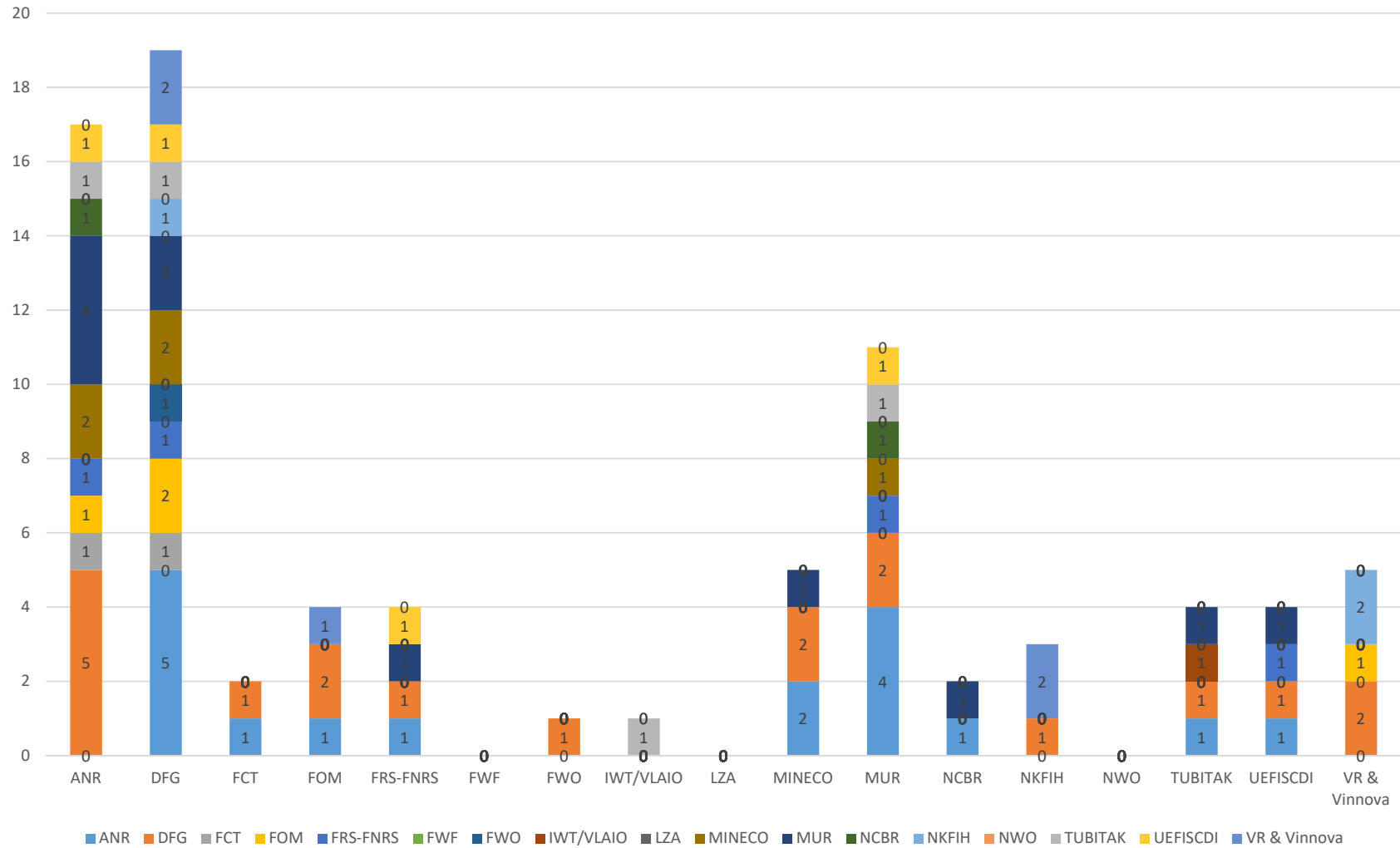


IDEPA ProjectFunding (Euro)



Annex 2 (Transnational collaboration within the FLAG-ERA projects)

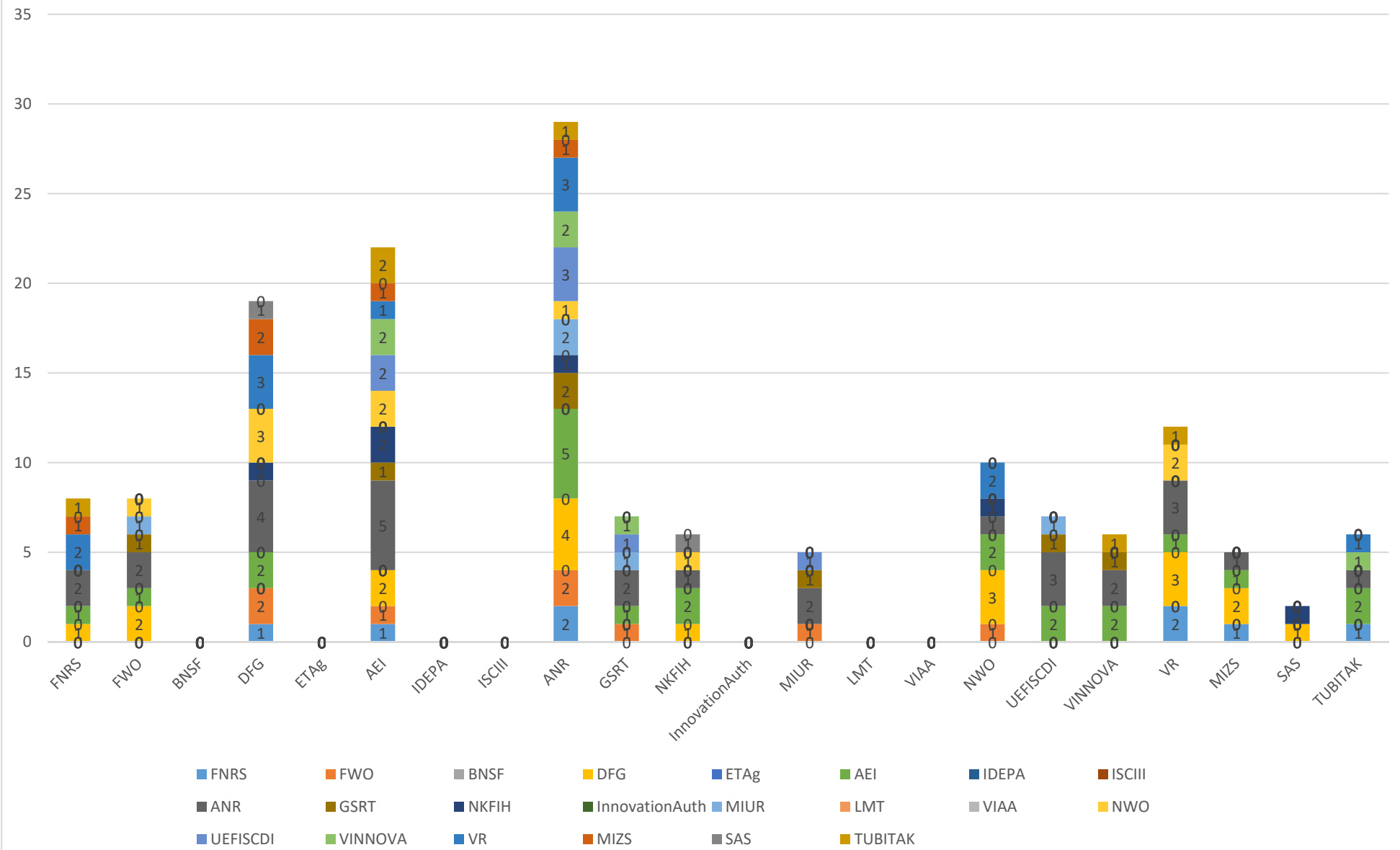
Collaborations in JTC 2015 Graphene projects



Stacked bar chart showing the number of publications per country for 20 different research institutions. The y-axis represents the number of publications (0 to 20). The x-axis lists the institutions: FNRS, FWO, BNSF, DFG, AEI, ANR, GSRT, NKFH, MIUR, LMT, VIAA, NWO, NCBR, UEFISCDI, VINNOVA, VR, MIZS, SAS, and TUBITAK. Each bar is composed of segments representing different countries, with the country name and publication count labeled on each segment.

Institution	Country	Count
FNRS	FR	1
	BE	1
	IT	1
	US	1
FWO	BE	2
	FR	1
	US	1
BNSF	FR	0
DFG	DE	1
	FR	2
	IT	0
	US	2
	UK	4
	JP	3
AEI	DE	1
	FR	0
	IT	1
	US	2
	UK	2
ANR	FR	2
	IT	1
	US	4
	UK	2
	JP	3
GSRT	FR	0
	IT	1
	US	2
	UK	1
NKFH	FR	0
	US	1
MIUR	IT	0
	US	1
LMT	FR	0
VIAA	FR	0
NWO	FR	0
	IT	1
	US	3
	UK	2
	JP	2
NCBR	FR	0
UEFISCDI	FR	0
	IT	1
VINNOVA	FR	0
	US	2
	UK	1
VR	FR	2
	US	3
	UK	1
	JP	2
MIZS	FR	1
	US	2
	UK	1
SAS	FR	0
	US	1
TUBITAK	FR	0
	US	1
	UK	2
	JP	1

Collaborations in JTC 2019 Graphene projects



Collaborations in JTC 2021 Graphene projects

