GRAPHENE FLAGSHIP

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CHALMERS

*"FET Flagships are ambitious large-scale, **science-driven**, research initiatives that aim to achieve a visionary goal.*
*The scientific advance should provide a strong and broad basis for future **technological innovation** and economic exploitation in a variety of areas, as well as novel benefits for society."*

Scale: 10 year project period,
1 B€ project cost (500 M€ from EC)
Coordinated by Chalmers University of Technology

Ramp-up phase: Oct., 2013 – March, 2016
142 partners, 54 M€ EC funding
Core 1 project: April, 2016 – March, 2018
154 partners, 89 M€ EC funding
Core 2 project: April, 2018 – March, 2020, 88 M€ EC funding
Further Core project(s) after 2020, budget(s) undecided.

Funding by member states, and other EU programs (in 2014)
MS: over 47 M€ plus investments in research infrastructures
EU: about 54 M€ (ERC, Marie Curie, collaborative projects in addition to the flagship funding)

EC-funded part of the flagship today and in H2020

- Today:
  - 142 partners in 23 countries
  - 11 S&T work packages
  - 240 full-time equivalent persons, about 500 individuals
- H2020:
  - 154 partners in 23 countries; about 1/3 industry, 1/2 academia and 1/6 other
  - 15 S&T work packages
  - 450 full-time equivalent persons

- Progress along the value chain materials-components-systems towards higher technology readiness levels

Evolution of the Flagship 2013-2015

Year	Partners	Academic	Industrial	Other	Budget/yr
2013	75	48	16	8	18 M€
2014	142	76	41	25	24 M€
2015	154	75	54	25	45 M€

Clear trend towards more industrial involvement, as planned

Involve new partners as needs arise and resources become available (Expression of Interest mechanism)

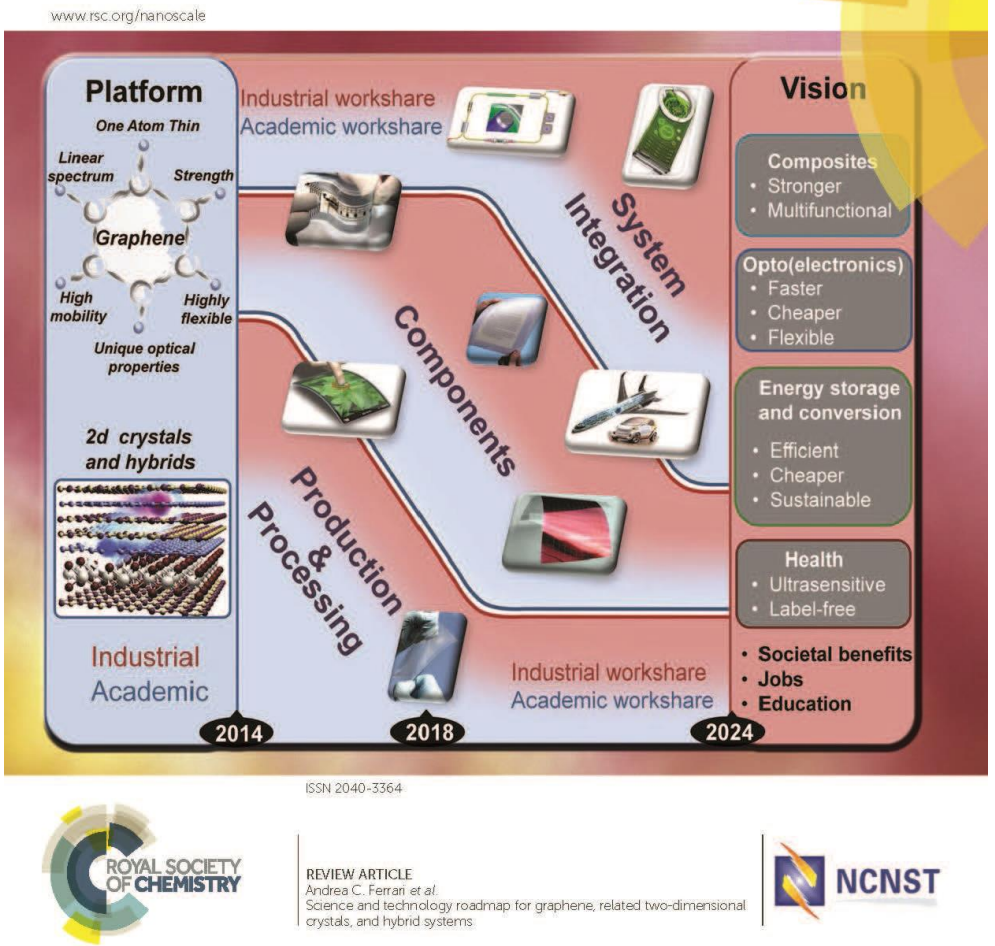
Summary of Year 1:

- 324 articles published
- 577 talks and other dissemination activities
- 17 patent applications (confidentiality!), 21 invention disclosures (confidentiality!!) [data 9/2015]
- About 240 full time equivalent people, some 500 individuals
- Funding used during year 1, about 15 M€ or 3% of the total EC contribution

Some highlights from the first 18 months: S&T roadmap

Published in January 2015 as A.C. Ferrari, [abt. 50 other authors] and J.M. Kinaret, Nanoscale **7**, 4598-4810 (2015) (*open access*).

Technology and Innovation Roadmap is being updated in a process led by Fraunhofer Institute, 1st edition expected to be issued in 2016



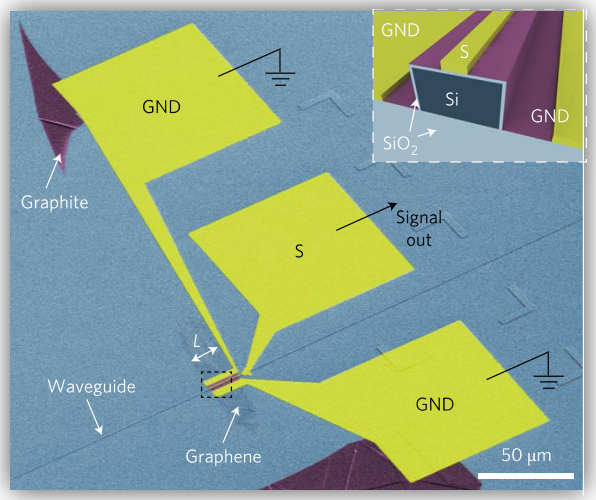
Some highlights from the first 18 months: shear exfoliation

Jonathan Colema *et al*, Trinity College Dublin

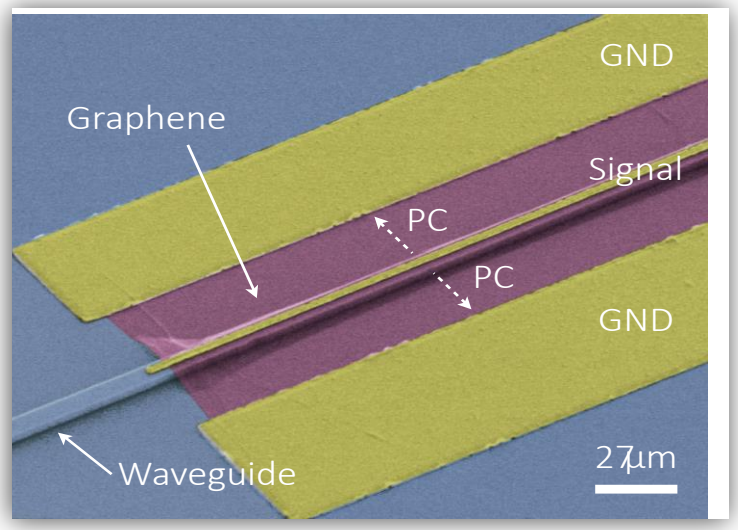
300 liters
30% SLG
Suitable for other 2d materials
Licensed

In collaboration with Thomas Swan & Co. Ltd. that is commercializing the technique.

Some highlights from the first 18 months: fast optical communication

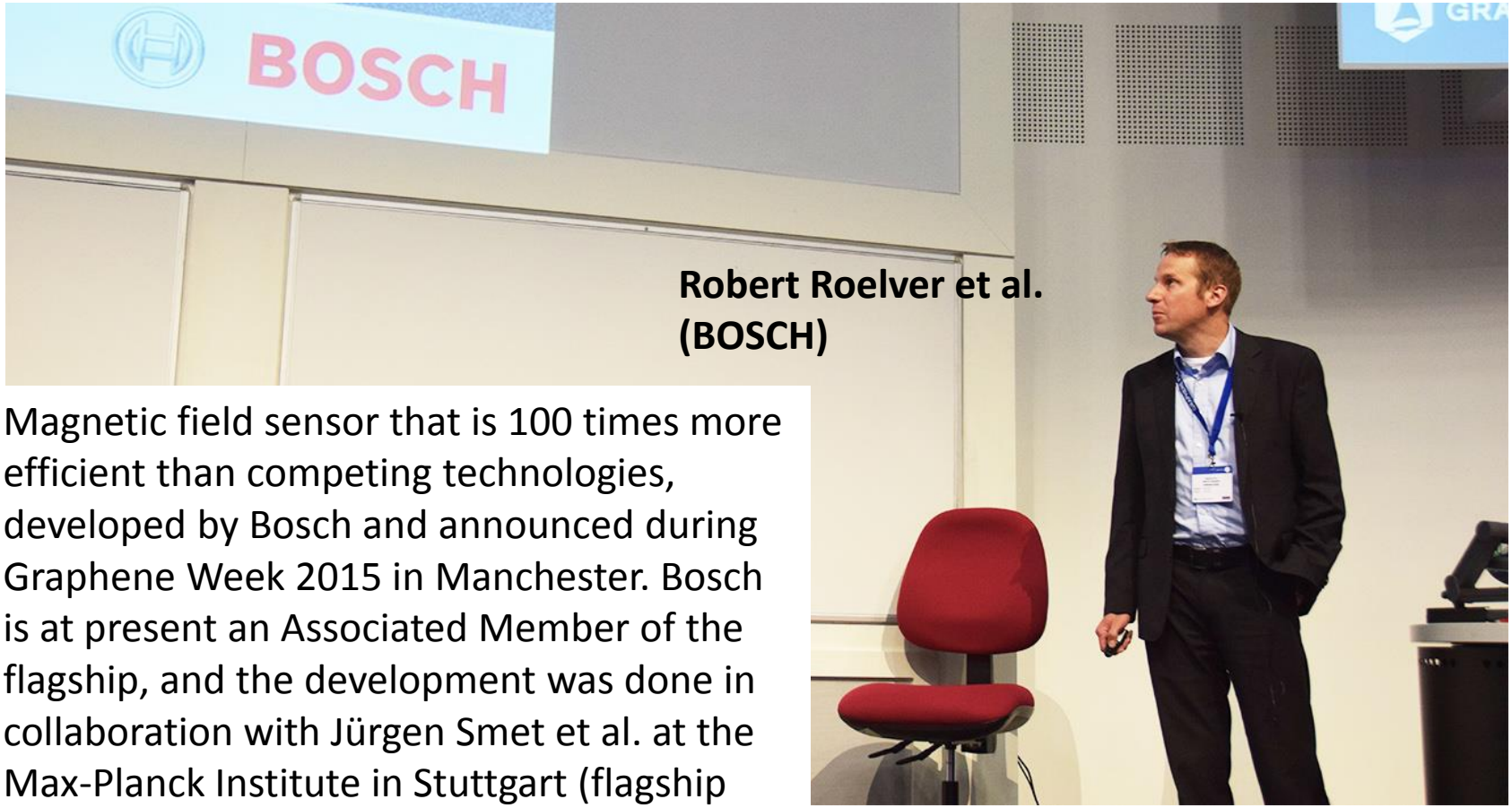


Daniel Neumaier (AMO GmbH), Wolfgang Templ (Alcatel-Lucent) *et al*.



(1) Ultra-wideband operation. In principle from UV to THz.
(2) High-speed operation. >50GHz (in principle >200 GHz)
(3) Low energy consumption. < 1J/bit
(4) Small device footprint. <50µm^2
(5) Compatibility with CMOS and other technologies.
(6) Simplicity and low cost.

Some highlights from the first 18 months: graphene sensor



Robert Roelver et al. (BOSCH)

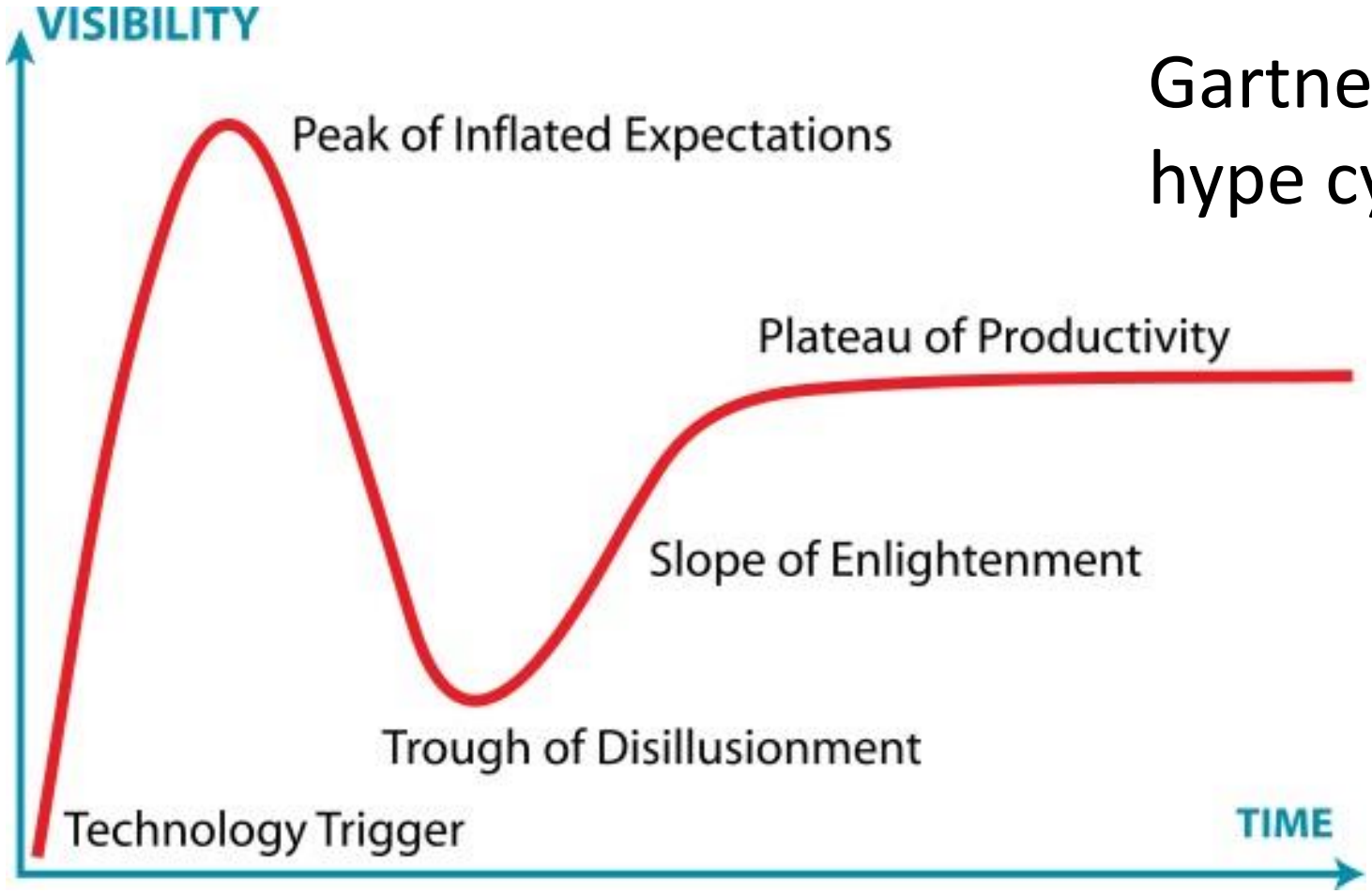
Magnetic field sensor that is 100 times more efficient than competing technologies, developed by Bosch and announced during Graphene Week 2015 in Manchester. Bosch is at present an Associated Member of the flagship, and the development was done in collaboration with Jürgen Smet et al. at the Max-Planck Institute in Stuttgart (flagship partner)

Estimated technology readiness levels

	Materials	Electronics	Optoel. & photonics	Sensors	Flexible	Energy	Composites & Membranes	Production
TRL 9							Sports equipment	Chemical exfoliation CVD
TRL 8								R2R CVD
TRL 7			Touch screen	Magnetic field	Packaging?			
TRL 6				Humidity, pressure		Supercaps, batteries		
TRL 5								
TRL 4		Freq. multiplier, amplifier			Flexible screen		Anti-corrosive coatings	Other LMs
TRL 3	Other LMs		Data transmission					
TRL 2								
TRL 1								

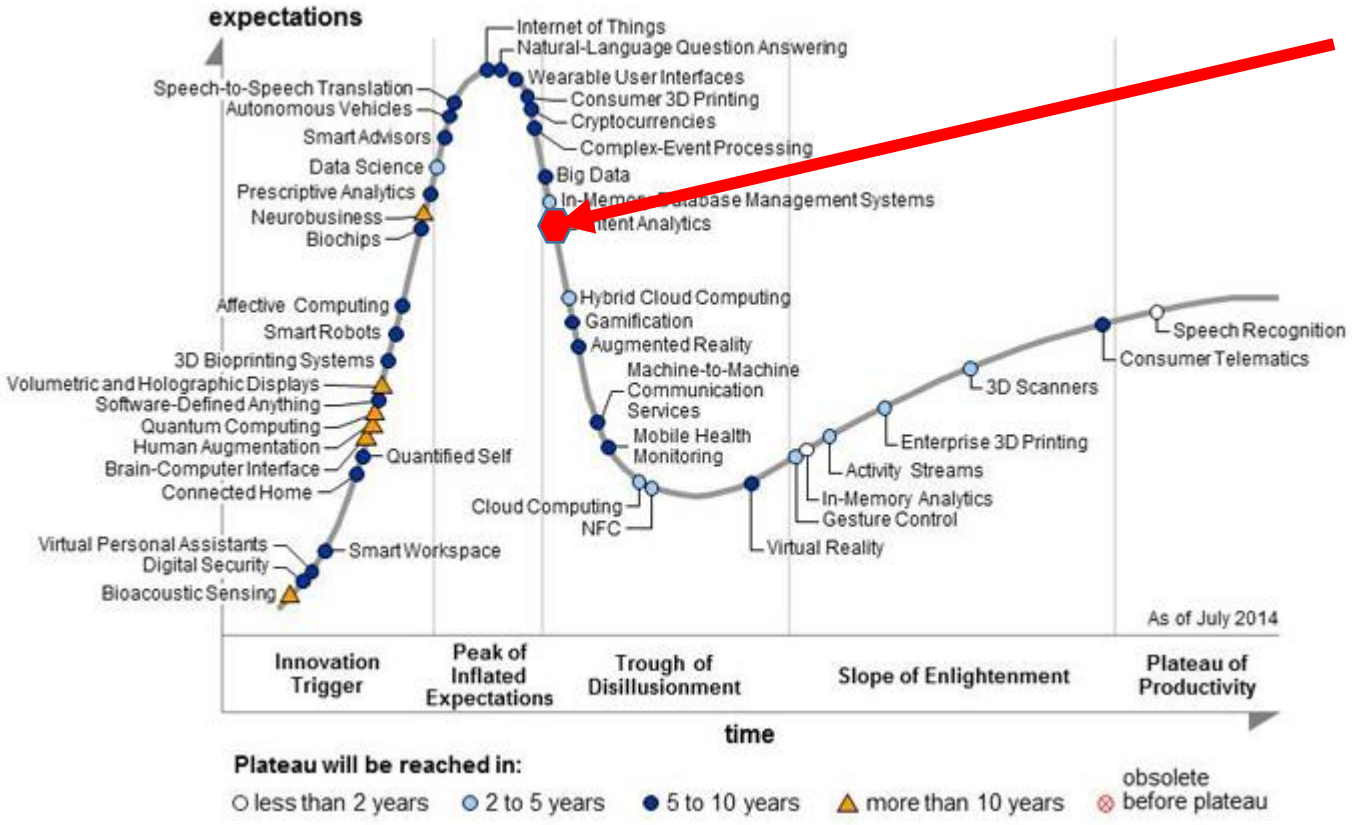
Emerging areas: nanofluidics, medical technologies

Future considerations: disruptive technologies evolution

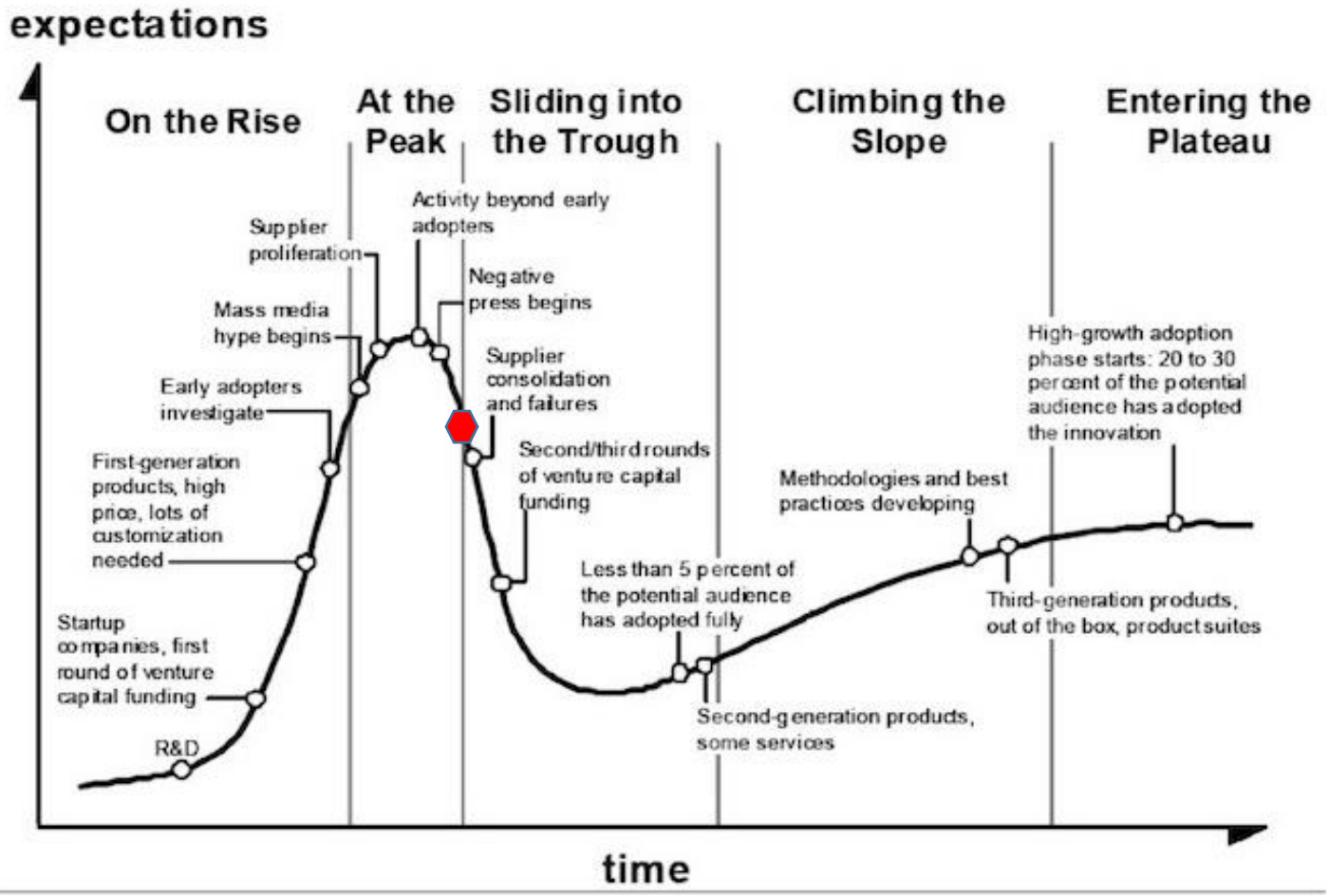


Gartner hype cycle

Future considerations: disruptive technologies evolution



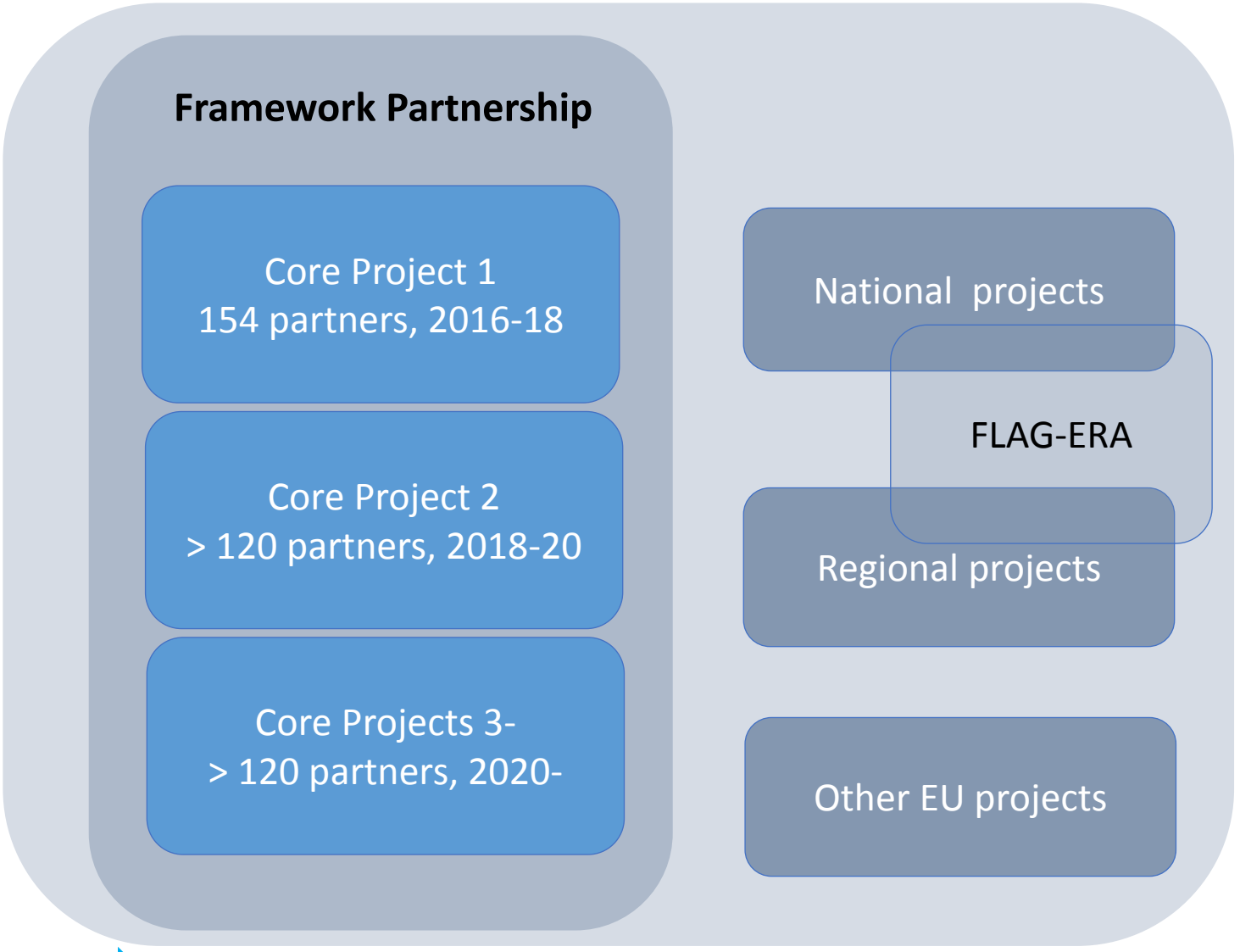
Future considerations: disruptive technologies evolution



Source: Gartner

Waves will get bigger

Future considerations: flagship evolution and *focusing*



Waves will get bigger still

Input to focusing

- Internal yearly review of WPs
- Commission yearly review of the Core Project
- Technology and Innovation Roadmap produced by the Core Project (technology push vs. market pull)
- Science and Technology Forum of the Core Project (WP leaders and deputies, strategic advisory council)

Description of a new Core Project

Identifying future priorities and gaps:

The current Graphene Flagship project has in place mechanisms for identifying future needs and priorities and identifying gaps by:

- **Providing input on topics for the FLAG-ERA Joint Transnational Call:**

⇨ successfully implemented for the first JTC ⇨ mostly basic research

- **Identifying new Associated Members**

⇨ 10 currently accepted, mostly companies

- **Publishing Expressions of Interest**

⇨ 12 new consortium partners added to Core 1, mostly companies

- **The Science and Technology Forum**

⇨ Meets once per year to plan Core Project work plans and activities, identify synergies between WPs and gaps.

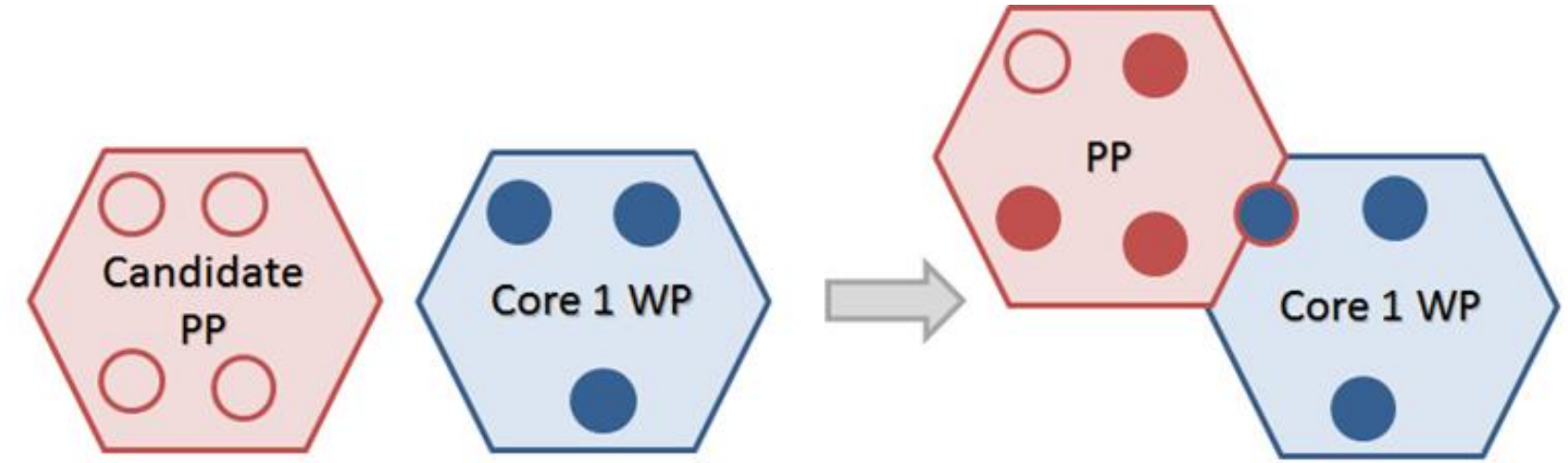
Association mechanisms

- In FP7: Associated Members (AMs), at present (Sept 4, 2015) 10 associated members
- In H2020: Partnering Projects and Associated Members
  - Participants in Partnering Projects are expected to become Associated Members
  - First PPs are expected to emerge from the FLAG-ERA Joint Transnational Call (13 projects), resulting in 20-30 new AMs
- AMs have the same rights as partners except
  - Access to EC financing is limited to core project partners
  - Non-disclosure agreements between the affected parties can be used to give access to confidential information
  - Balance between ease of association and rights

Considerations for Core Project *vs*. PPs

- Advantage/Need of a large, comprehensive project is unclear for projects that are on a very low technology readiness level (fundamental research):
  Very low TRLs are suitable for PPs
- Mutual competition may become problem in a large consortium for projects that are very close to market
  High TRLs are suitable for PPs
- Member state funding systems may be able to react faster than the core project (at least 18 month planning cycle, e.g. Nov. 2014 – April 2016):
  Emerging hot topics may be suitable for PPs
- Core projects are not exhaustive even in the topics they cover (e.g. sensors):
  Need collaboration with MS's and Core projects

Association mechanism

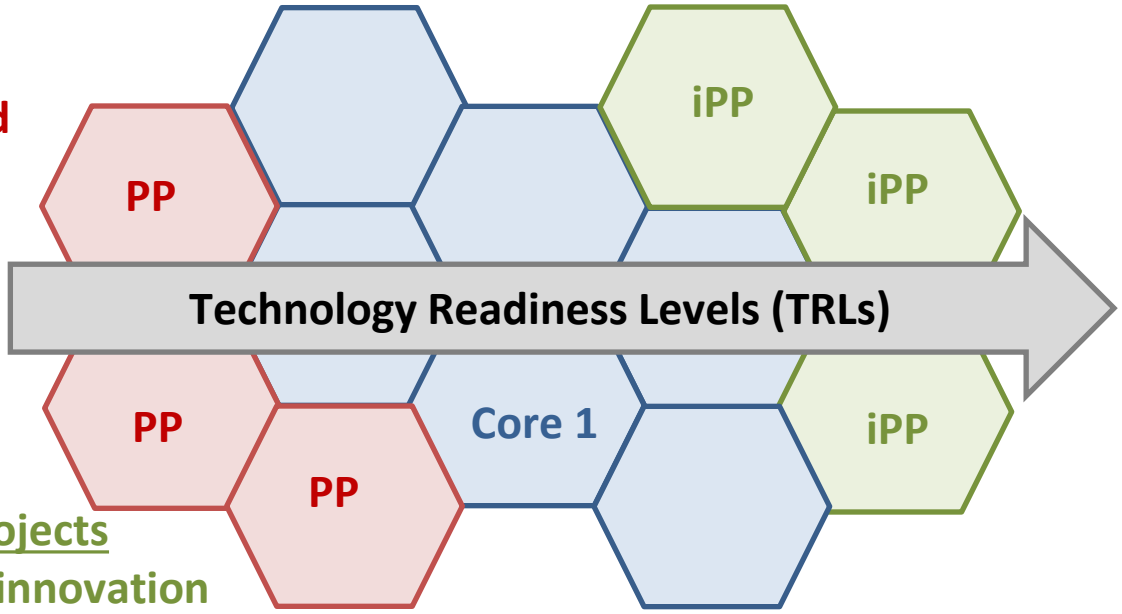


Alignment of PPs with respect to TRLs

Partnering Projects
Bottom-up, basic/applied
ERC, FLAG-ERA, national funding

Core Project WPs
Strategic research
EC FET funding

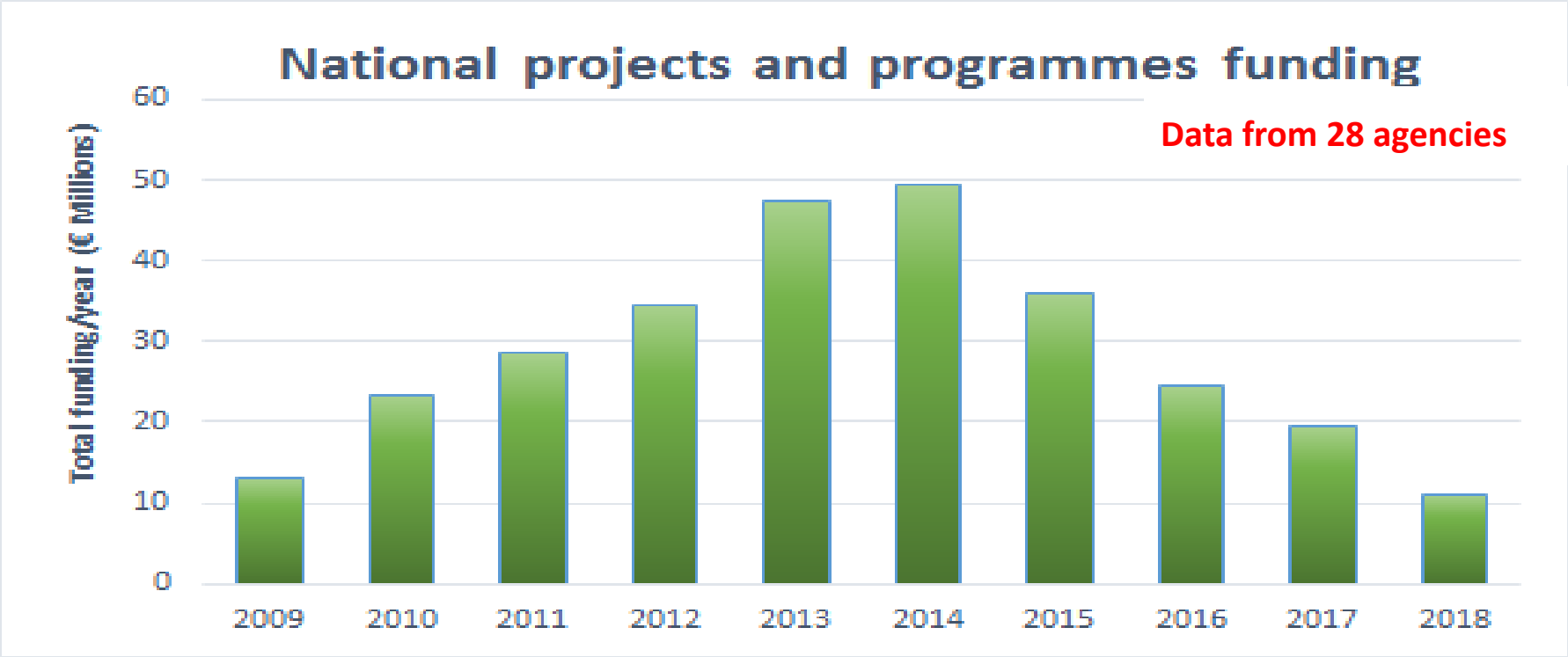
Innovation Partnering Projects
Technology transfer and innovation
SMEs, national, regional, EC, private funding



Examples of expected PPs

- EC-funded: PolyGraph and Gladiator, industrially oriented
- MS funded:
  - Outcome of the recent JTC, 13 projects, mostly on very low TRLs
  - Other existing national projects, *e.g.* from GrafTech (Poland), DFG Priority Program (Germany), or SIO-Grafen (Sweden) programs
- In the future, we would like to see more applied PPs in line with the overall evolution of the flagship
- Probably best to limit the number of PPs to a few dozen, otherwise the benefits will get diluted and the system becomes unmanageable
- New (trans-national) programs needed

Survey to Research Funding Organisations

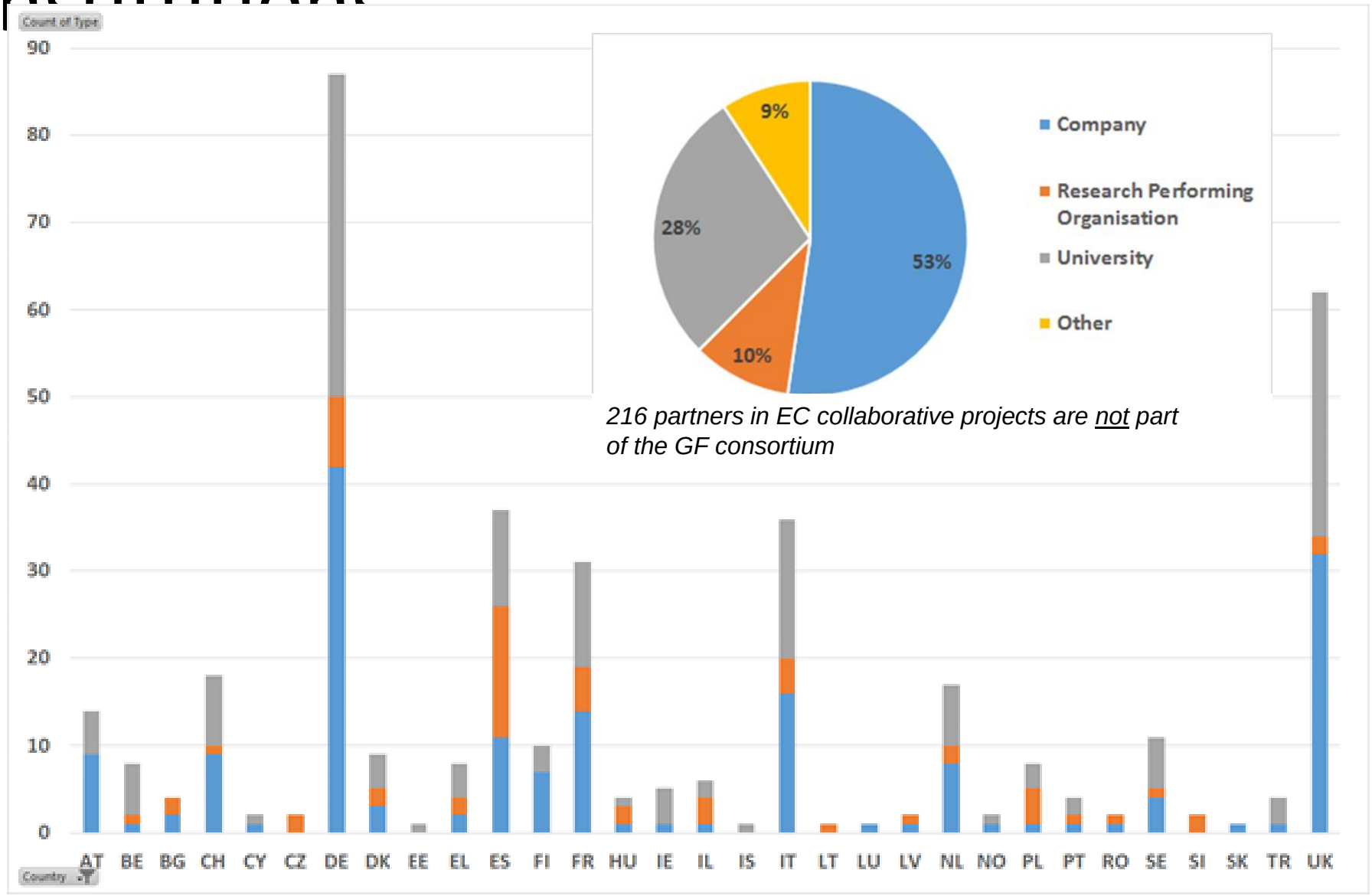


Challenges

➡ Need for more transparency and proactive sharing of data on public national research funding and priorities in order devise a proper accounting system, monitor funding trends and prepare future plans

➡ Need for long term/strategic planning at the national level (priority programmes, centres of excellence, infrastructures)

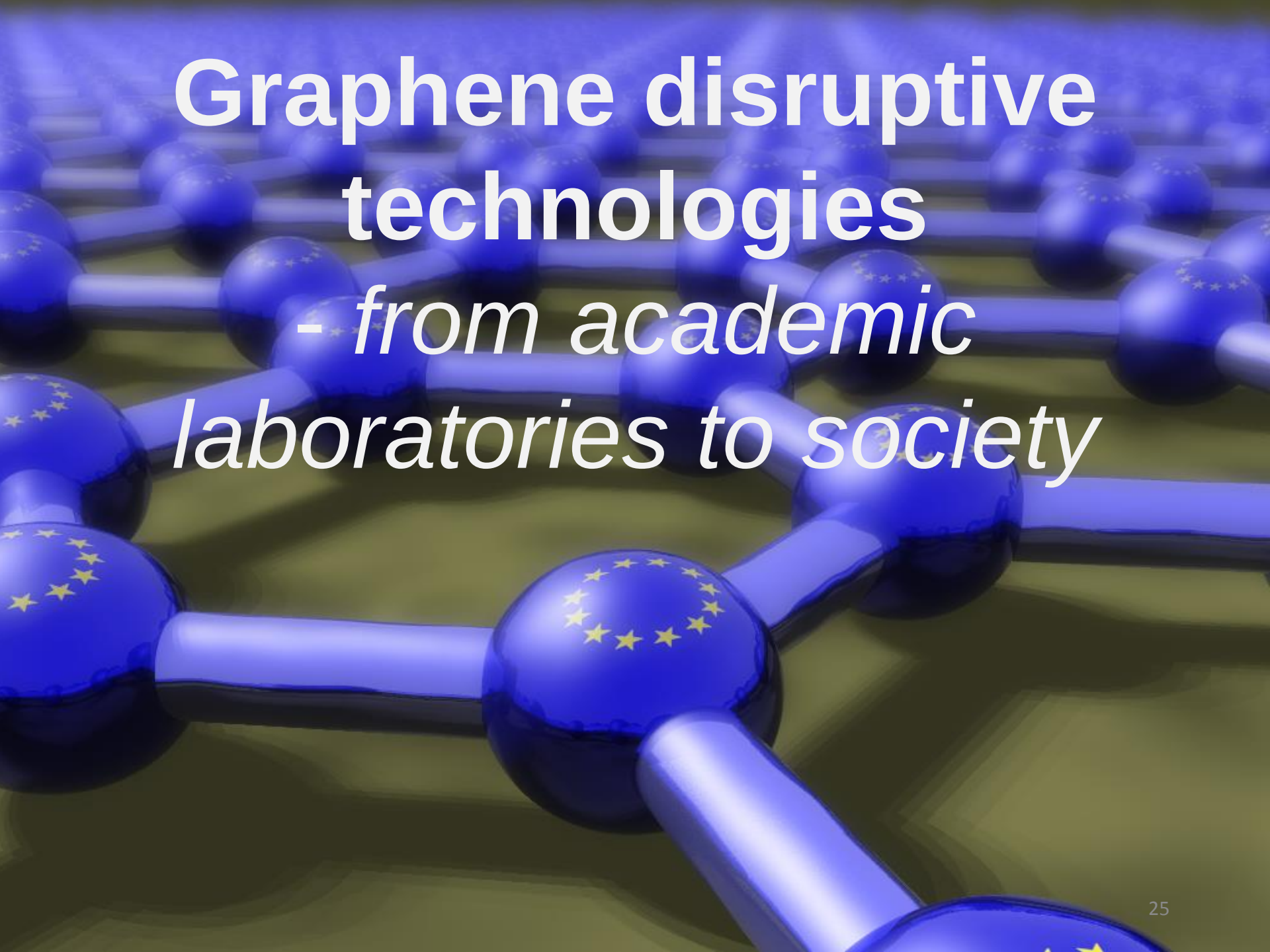
European Projects mapping- institutions



216 partners in EC collaborative projects are <u>not</u> part of the GF consortium

Key messages:

- The Graphene Flagship was built on the basis of significant investments at the national level that have been identified already in the Pilot phase. These include research projects, priority programmes, infrastructure etc.
- There is need for sustained (and increased) funding of GRM research at the level of MS over the duration of the for Flagship to succeed in achieving its objectives
- There is need to diversify funding sources to include strategic national, regional, private and innovation funding as the Flagship will move towards delivering market-oriented applications
- Graphene Flagship Core 1 partners represent between 20-30 % of the overall GRM research community in Europe
- Coordination of activities at the national level greatly facilitates alignment between national initiatives and the Core Project.


Graphene disruptive technologies
- from academic laboratories to society

Partnering Projects and Associated Members Integration – the process

What	Who
1. Identification and nomination of candidate Partnering Projects	1. National/Regional Funding Organisations, European Commission, Core Project, Spontaneous Applications (for PPs)
2. Application to become PP/AM	2. Partnering Project Leader or Coordinator
3. Approval/nomination of the PP/AM	3. Core Project Management Panel
4. Signature of the *Expression of Intent*	4. Representatives of the Core Project and Partnering Project

Documents and guidelines are currently being prepared – to be ready by the end of 2015.

Core 1 work packages

- Administrative
  - Management (J.Kinaret)
  - Research management (K. Boustedt)
  - Innovation (***TBD***)
  - Dissemination (M. Fogelström)
  - Alignment (A. Helman)
- Division 1
  - Enabling technologies (V. Fal'ko)
  - Enabling materials (M. Garcia Hernandez)
  - Spintronics (B. van Wees)
- Division 2
  - Health & environment (M. Prato)
  - ***Biomedical technologies (K. Kostarelos)***
  - Sensors (H. van der Zant)
- Division 3
  - Electric devices (D. Neumaier)
  - Optoelectronics (F. Koppens)
  - Flexible elelctronics (S. Borini)
  - ***Wafer-scale system integration (M. Romagnoli)***
- Division 4
  - ***Energy storage (V. Pellegrini)***
  - ***Energy generation (E. Quesnel)***
  - ***Polymer composites (V. Palermo)***
  - ***Coatings & foams (X.-L. Feng)***
  - Production (K. Teo)
- Division 5
  - External (N.N.)