HOW TO BUILD AN INNOVATION ROADMAP FOR EMERGING TECHNOLOGIES - EXPERIENCE FROM THE GRAPHENE ROADMAP

Innovation Workshop

Exploitation of Neuromorphic Computing Technologies

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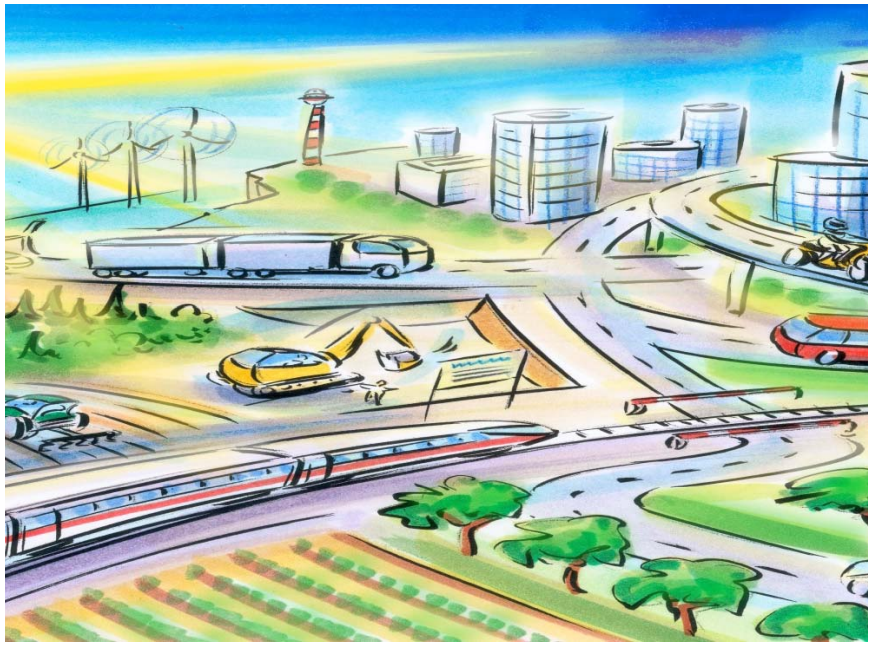

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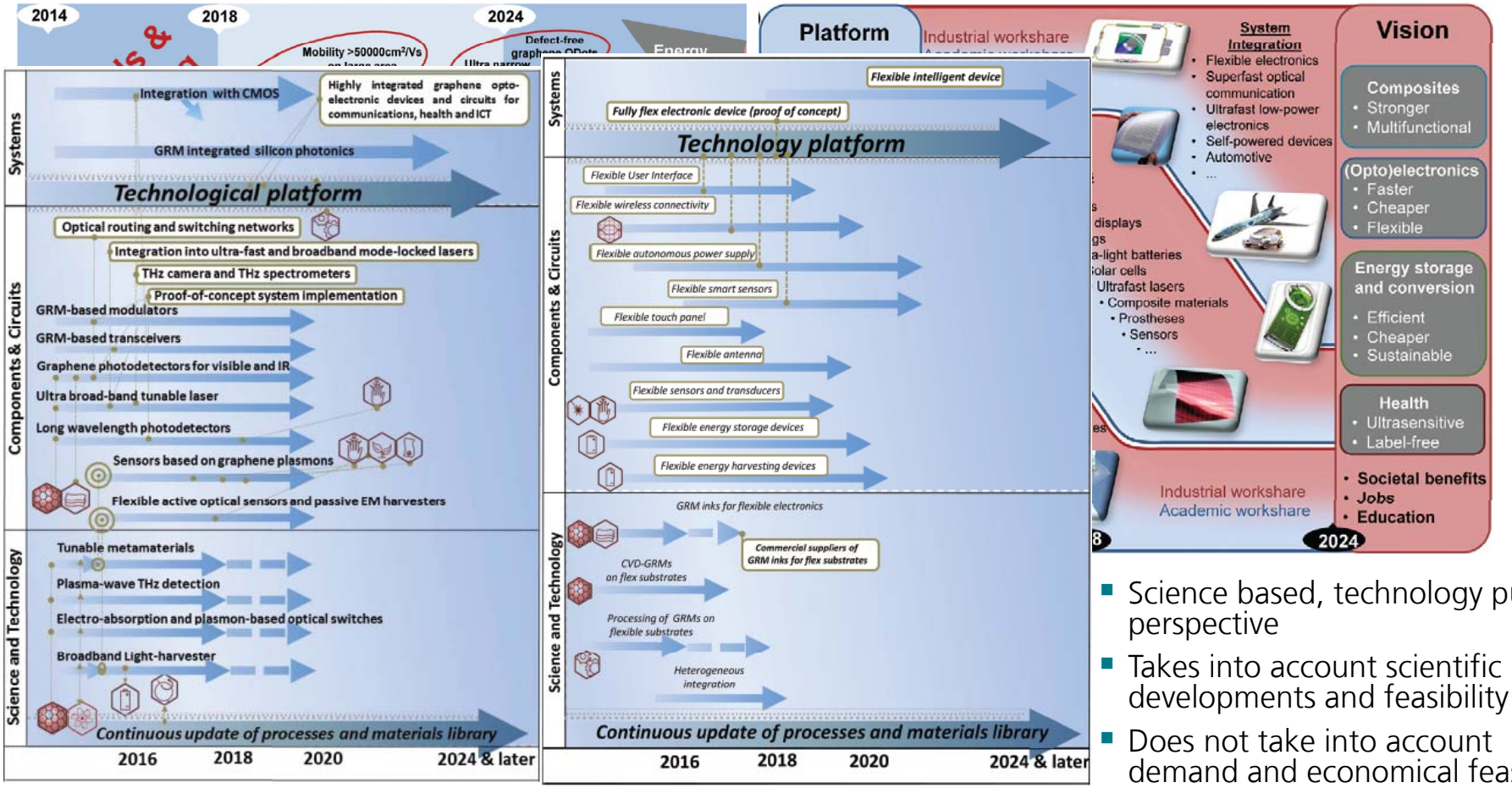
Point of departure: Existing Science and Technology Roadmap



- Science based, technology push perspective
- Takes into account scientific developments and feasibility
- Does not take into account demand and economical feasiblity

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Technology and Innovation Roadmap – Why?

- The Technology & Innovation Roadmap (TIR) should consider
  - industrial demand meeting technology supply
  - economic aspects and European added value/industrial basis
  - non-technological frame conditions

- Target groups and purpose:
  - Guide flagship research towards market demands
  - Shape the next phases of the flagship
  - Inform industry to allow uptake of flagship research results
  - Support cross-WP collaboration

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Graphene/2D Materials Science & Technology

Markets/Sectors

The approach in summary

Material

Process

Function-alisation

Formu-lation

Roadmap

Application Areas

Supply

Demand

Application Areas

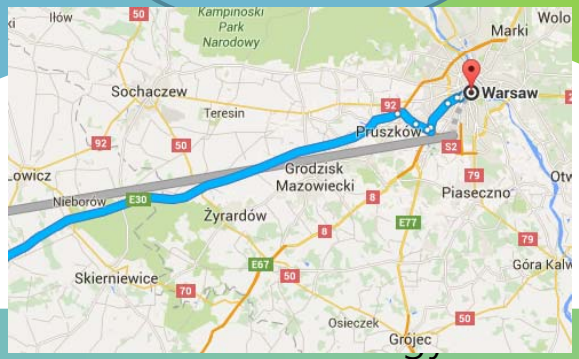
Automotive

Aerospace

Computing

Telecomm-unications

Energy



Starting point

Destination

Science Material

Component

Innovation System/Product

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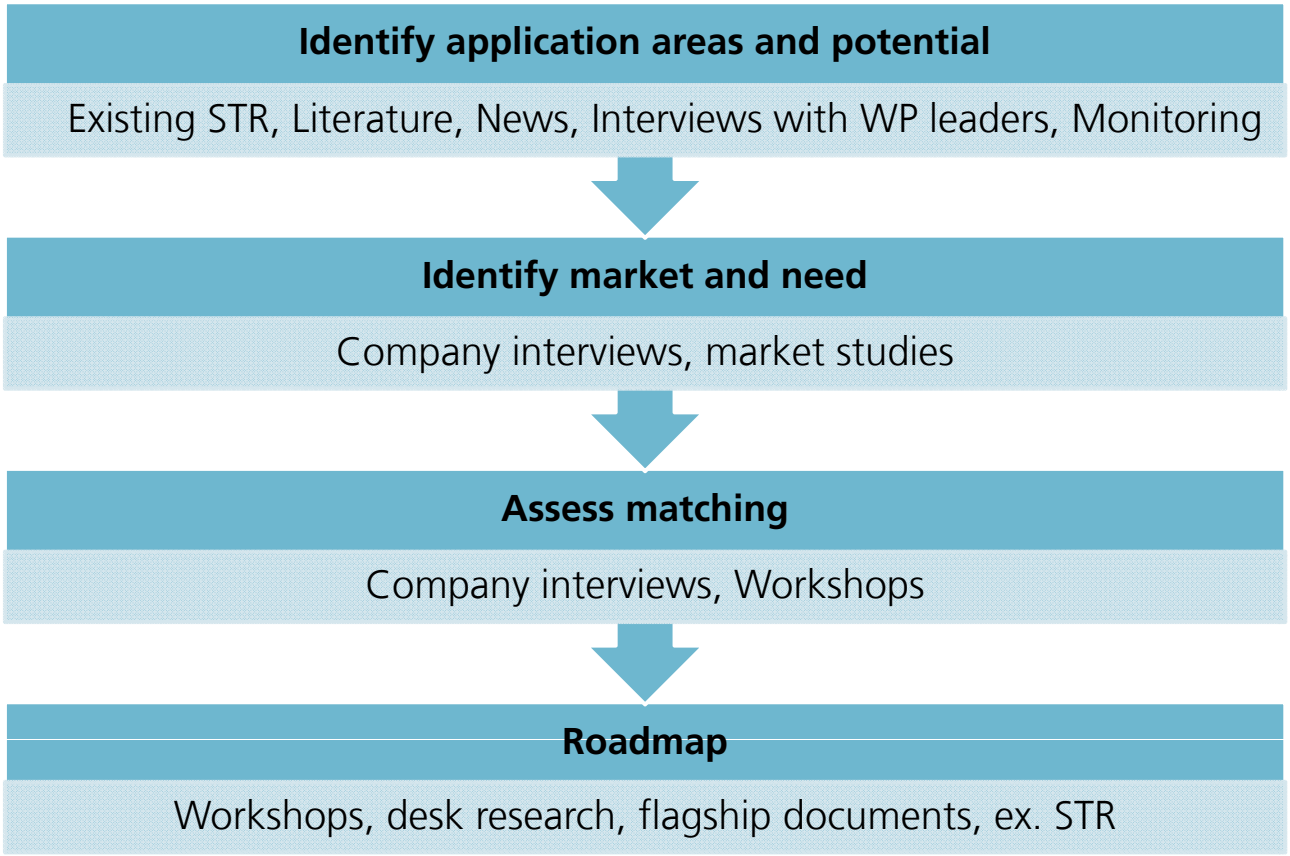
Technology and Innovation Roadmap – How? 4 steps



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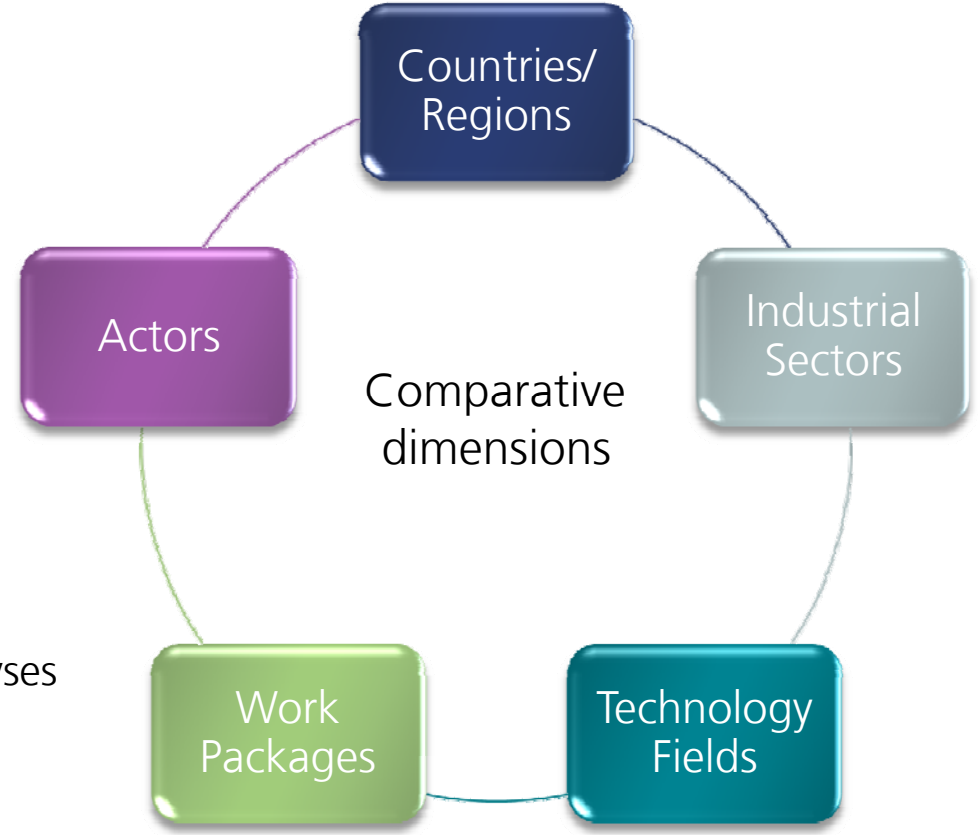
The Monitoring Tool
Assessing state of the art and competition

Comparative benchmark analysis:

- Science (bibliometry, publications)
- Technology and innovation (patents)



State of the art:

- Relative sizes and performances
- Technology field dynamics
- Co-publications and cooperation analyses
- Co-analyses with market activities
- Semantic/content-wise analyses
- Scientific focus of publications, involved disciplines, etc.

→Annual updates←

Workshops:
Structured into three sessions:

1. SWOT analysis
2. Portfolio analysis:
   - market attractiveness
   - technological attractiveness for different graphene applications
3. Roadmapping section
   - current technology readiness levels
   - timing and development path of GRM for use in application areas and related markets
   - important challenges and barriers (red brick walls).

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SWOT for use of emerging technologies in specific application

Internal factors directly controllable by emerging technology development itself:
- existing and potential technological (dis-)advantages (enabling factor,)
- non-technological (dis-)advantages production/process/implementation (dis-)advantages
- knowledge base and maturity

Advantages over others.

Strengths

Weaknesses

Disadvantage relative to others.

External **supportive aspects**

Opportunities

Threats

External hindrances/issues that could cause trouble for using graphene/2D

External factors not directly controllable by emerging technology development itself:
- markets/trends
- requirements/demands of and for applications,
- strengths/weaknesses of state of the art and competing technologies
- (EU) supply/value chains
- (EU) innovation ecosystem
- frame conditions

SWOT analysis – some aspects to consider

Technology:
Performance Today
Performance potential
Uniqueness: "USP"
Complexity: Ease of use

Production:
Scalability Today
Scalability Potential
Integratability Today
Integratability Potential
Cost for production

Applications:
Cost reduction today
Cost reduction potential
Diversity
Product value

Market:
Justified cost/function gain
Market volume
Market competitiveness

Timing:
Time to market assessment

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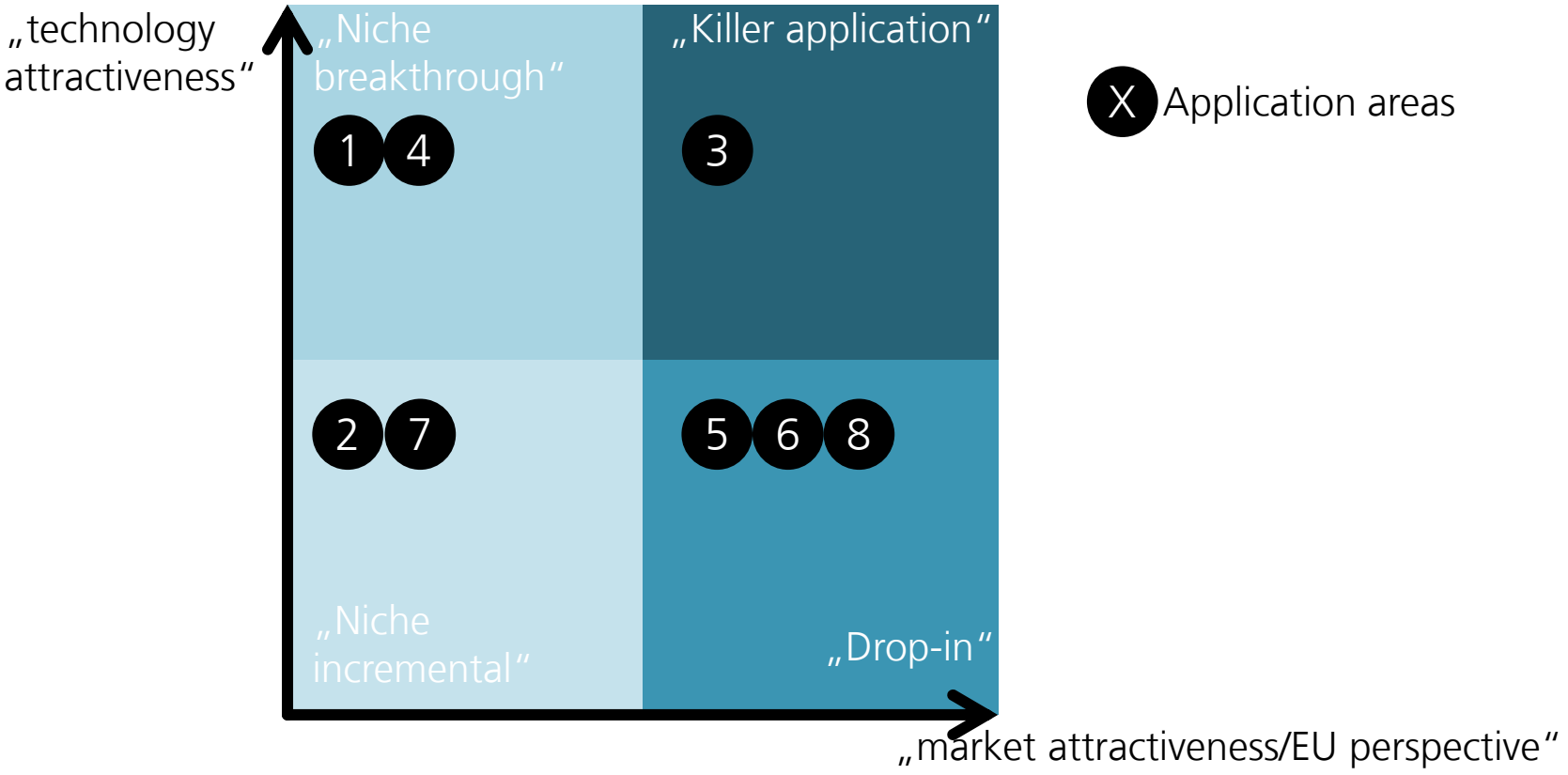
Assess matching: Portfolio analysis

- Portfolio Analyses



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Roadmapping
Key questions (1)

1. **Application with technology demonstrators TRL>3 (CRS 2)**
2. **KPIs:**
   - What are key targets?
   - Lead KPIs, lead parameters that are crucial? Numbers?
3. **RL today (range)**
   - Start with coarse scale, what are we exactly talking about (e.g. in terms of market, product)
   - Optional: Narrow down to TRL, MRL for applications/products mentioned by the participants
   - In case there is already something on the market: What is the quality, is it real?
4. **Barriers/challenges**
   - RBW: What are key barriers/challenges? Where shall one invest to solve problems? What is the critical path? How can a road look like?
   - Implications for research activites?

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Roadmapping
Key questions (2)

5. Time related aspects:

- **Window of opportunity? (Market-side time related aspects)**
- **Hierarchy of activities and actions that are executed to meet those targets**
- **Time dimension for those activities**
  - When can the target be reached?
  - When is next step reached (on coarse scale)
  - Probability?
  - Compare to other elements (what comes first?)
  - Concrete product examples
  - Early adopter? When?
  - What comes later? When are which markets addressable?
  - Are there multiple 'paths' or 'routes' to reaching that target?
  - Is there a product or application area that can be served "along the way" (e.g. Li-S batteries is the main goal, but along the way (or when those work), also standard LiB can be enhanced…

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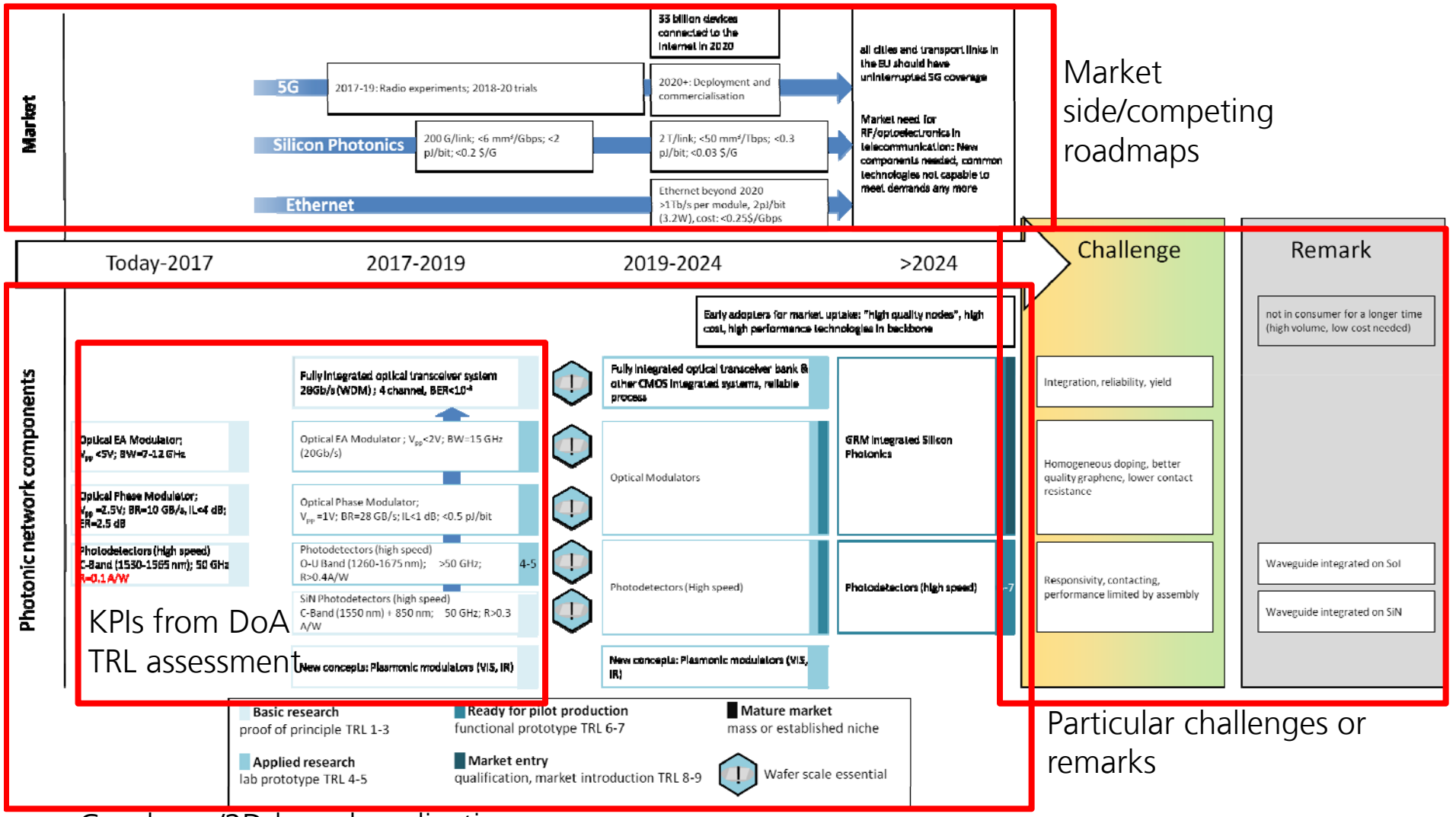
Roadmap – example from Graphene Flagship: Photonic network components



Market side/competing roadmaps

Particular challenges or remarks

Graphene/2D-based applications

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Conclusions
One possible point of view

- Qualitative assessment as guideline, based on insights
- Two possible measures for prioritization

- actual proven and foreseeable technological performance of emerging technology
- uniqueness and delineation from emerging competing technologies or SotA

- European perspective (EU companies/Industries enabled by this GRM development, macroeconomic perspective, strong integrators outside Europe, dominating industry)
- overall market potential and market need for solutions offered by GRM
- Negative assessment can point towards global value chains, where most added value will be potentially generated outside of Europe

Application sub topics	Current technological potential (USP)	Market potential (EU perspective)
Sub topic 1	- - (rather poor))	- (not good)
Sub topic 2	0 (not promising)	+ (promising)
Sub topic 3	++ (very promising)	? (undecided, not assessable, still open question)

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Innovation roadmapping for emerging technologies: success factors (1)

- Backing and commitment of project coordination and funding agencies (scientists might have other priorities than engaging in innovation and roadmapping)
- Use Roadmap as one information source affecting further funding and clearly communicate this role
- Set up interdisciplinary roadmapping team combining science, engineering, economic and societal perspectives AND methodological experience
- Interact intensively with scientific work and researchers, feedback information thereby creating commitment
- Use approach that is as transparent as possible to create broad acceptance in the project (e.g. through feedback loop and offers for involvement)

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Innovation roadmapping for emerging technologies: success factors (2)

- Expose researchers to industry expectations, challenge scientific excellence with needs and demand of industry and users: workshops
- Implement application driven way of thinking (market pull)
- Include market research
- Take into account European perspective, i.e. Industrial basis and beneficiaries of developments to enable European added value
- Take ecosystem perspective: there is no standalone, single actor mode of innovation
- Be hard in methodologies
- Develop and include an external perspective via STI monitoring

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Graphene Flagship TIR: leasons learned

- Industry engagement is crucial even at early stage or low TRL
- Don’t ask industry for interest in emerging technology, rather ask for needs, functions, cost, performance....
- Design and include roadmap into research planning at earliest possible stage
- Focus on purpose of roadmap:
  - Start with internal management and planning tool
  - Expand for dissemination
  - Don‘t do this in parallel

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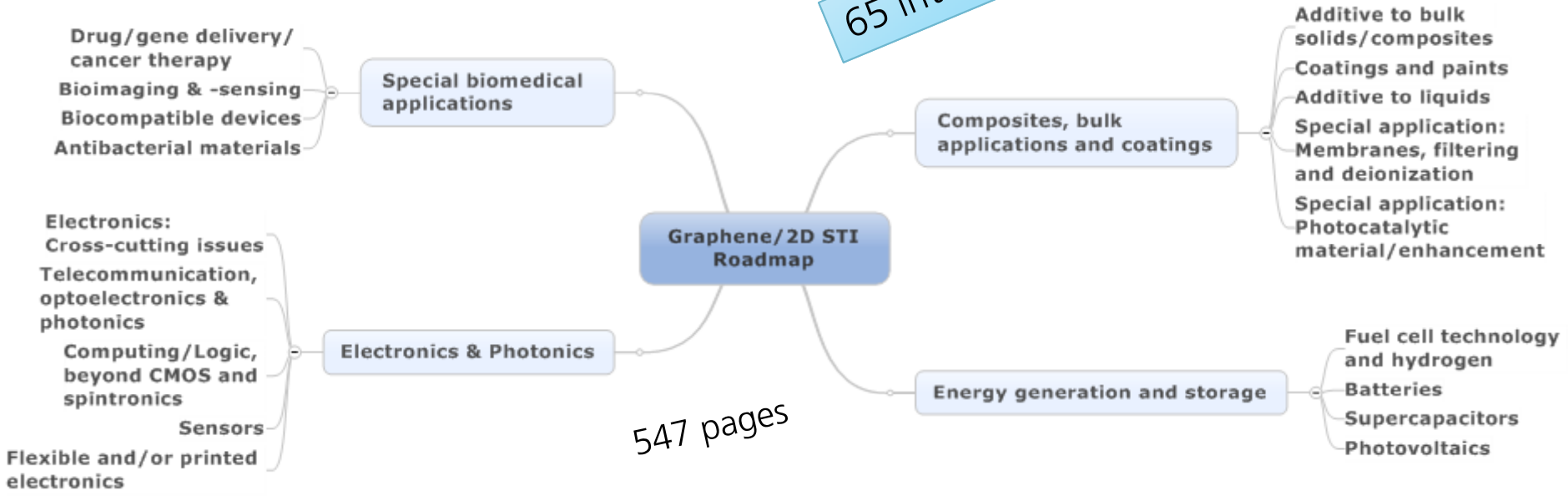
Graphene Flagship TIR: The current version

4 main topics with 18 subtopics and ~84 application areas covering nearly all industrial sectors

Existing roadmaps, market reports, strategic documents, databases (market data, patents, publications, news)

2 Workshops with 82 participants

65 interviews in total, 46 with industry



547 pages

470 pages content

92 Figures

97 Tables

31 Roadmaps

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Structure of roadmapping document

For each topic

1. Introduction
   - Delineation of topic
   - Role of graphene/2D materials
2. Market perspective (opportunities and threats)
   - Market overview
   - Opportunities and threats
3. Graphene/2D materials perspective
   - Current strengths and weaknesses
4. KPIs
5. Roadmap
   - Current maturity
   - Barriers/Challenges
   - Potential actions
   - Roadmap
6. Conclusion - Current technological potential (USP) and Market potential (EU perspective)

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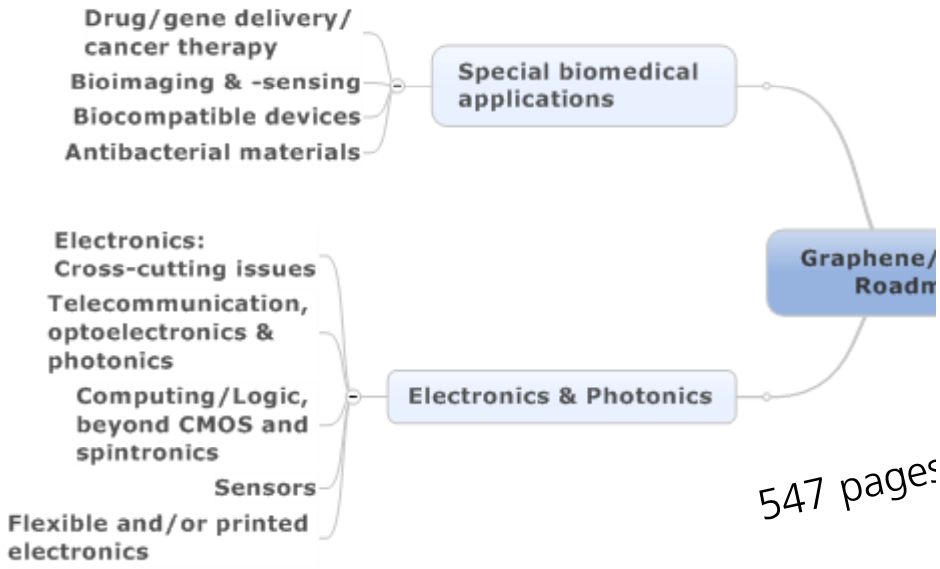

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STI Roadmap: Revised Annex 2 to deliverable 15.1

Graphene and other 2D materials

Technology and Innovation Roadmap

Version 3

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