31st
IASP WORLD
CONFERENCE
QNCC | 19th – 22nd October

GRAPHENE GOES TO WORK IN SWEDEN

PARALLEL SESSION 5

STPs and AIs fostering technology-driven projects

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IASP
International Association of Science Parks and Areas of Innovation

QATAR SCIENCE & TECHNOLOGY PARK
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www.iasp2014doha.com

IASP World Conference
Doha, Qatar | October 2014

Graphene Goes to Work in Sweden

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Block 1 Subtheme 1.3

1 Executive Summary (150 words)

Science Parks play an important role in bridging the knowledge gap between researchers and companies. In this paper, Johanneberg Science Park in Sweden exemplifies how a Science Park in collaboration with other stakeholders can help making the new super-material graphene a driving force in tomorrow's economy by capitalising on large existing projects such as EU's Graphene Flagship, and public innovation support.

The Swedish Graphene Strategic Innovation Programme is a multi-annual nationally funded programme aiming to make Sweden a leading country for commercial applications of graphene. Johanneberg Science Park in Gothenburg, Sweden, together with Chalmers Industrial Technology and several other industrial and academic organisations will address the knowledge gap by bringing SME's, large companies and researchers together, providing IPR and business intelligence, arranging workshops and training sessions, including entrepreneurship training, ultimately to create a Graphene Open Arena for Innovation.

2 Introduction

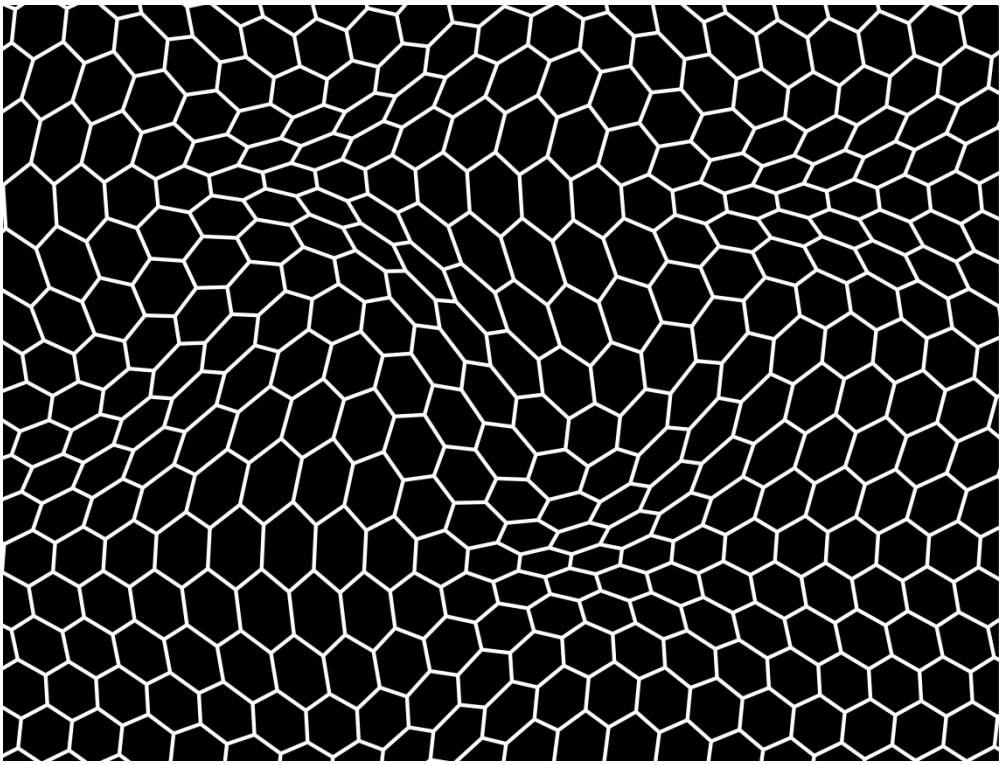


Figure 1 Hall Effect in Graphene (Image: Univ. of Manchester)

2.1 Graphene – a material of almost endless possibilities

"Graphene may be the most amazing and versatile substance available to mankind".

Graphene consists of a monolayer of carbon atoms in a hexagonal pattern (Figure 1), forming a 2-dimensional atomic crystal. Graphene is a nanomaterial with quantum physical properties promises huge benefits as a base for future disruptive technologies and industrial applications. This new material is stronger, more flexible, conducts heat and electricity better than any hitherto known material and has several unique properties that make it suitable for a number of ground-breaking

applications, including devices such as biosensors, supercapacitors, water desalinators and high-speed electronics (see Figure 2).

The major draw to science and industry in the field is graphene's unique properties, each of which seems to be superior to its rivals. This material is the first 2D atomic crystal ever known to us; the thinnest object ever obtained; the world's strongest material; its charge carriers are massless Dirac fermions; it is extremely electrically and thermally conductive; very elastic; and impermeable to any molecules… The list goes on.

2.2 The Graphene Flagship Project

In 2013, the European Commission awarded funding to the Graphene Flagship project, one of two "super-projects" that will receive EU funding over the next 10 years, with a total budget per project of EUR 1 billion! The project has as its aim to bring graphene out of the laboratories and into European society, primarily as a source of industrial and economic growth. Chalmers University of Technology in Sweden is the leader of the project that initially gathers 75 research groups from 17 countries across Europe, including several Nobel laureates. An expansion of partners will be effective during summer 2014.

Much of this work is still about advancing the Technology Readiness Level (TRL) of the graphene technologies, but a significant part of the project is devoted to Innovation. The innovation work package, tasked with engaging industry, venture capitalists and other assets that will boost Europe's innovation capacity in the graphene field, is led by Chalmers Industrial Technology (CIT), a Chalmers-based research institute.

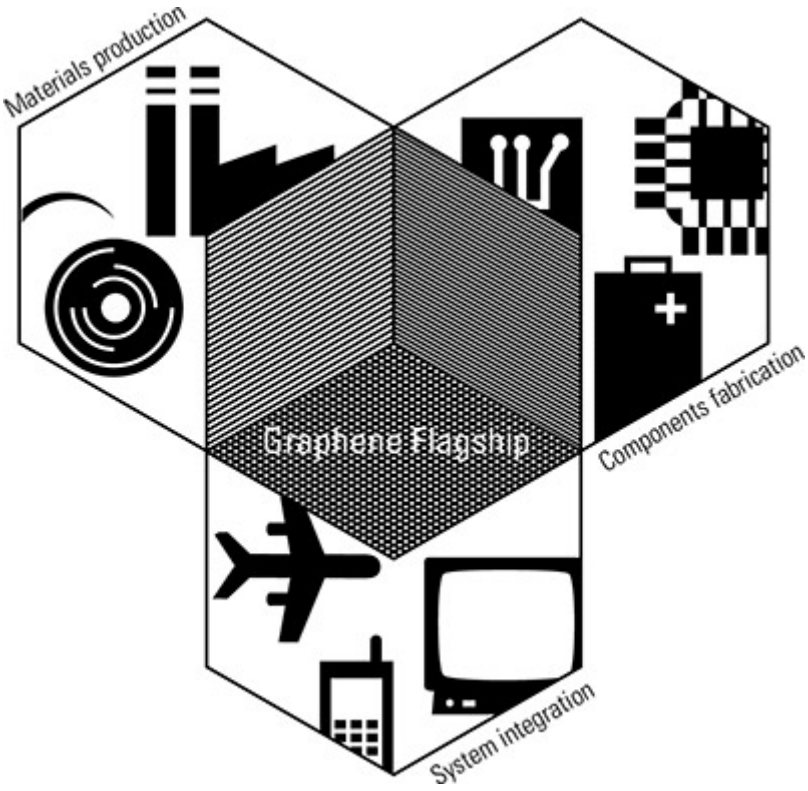


Figure 2 Innovation paths for the Graphene Flagship (Image: Graphene Flagship)

2.2.1 Involvement of Industry, SME's and Entrepreneurs

Advancements and breakthroughs in technology are by themselves not enough to create innovation, competitiveness and economic growth. Validation has an important role to play in delivering disruptive innovation that will enable entrepreneurs and engineers to put products on the market.

This is an area where Europe has been lagging behind, whether at a corporate, SME or start-up level.

There is a strong emphasis on industry engagement in the Graphene Flagship, where several work packages are being led by representatives from industry.

- To increase the collaboration with industry and especially SMEs, an industry workshop series has been initiated. The aim is to identify groups of companies and researchers with a common interest and to start formulating proposals for interesting innovation projects for those identified groups.
- To foster entrepreneurship, the Graphene Flagship will offer entrepreneurial training to the researchers active in the project, as well as promoting a culture of entrepreneurship in the scientific community. To further pave the way for innovation, the project will actively seek to attract talented entrepreneurs, and considers setting up an early stage investment fund to promote commercialisation of graphene-based ideas.

3 Chalmers Industriteknik and Johanneberg Science Park, Collaborators in the Chalmers Innovation System

3.1 Johanneberg Science Park

Johanneberg Science Park was founded in 2010 and is situated on the Johanneberg Campus of Chalmers University of Technology. The Park is co-owned by the University, the City of Gothenburg and seven industrial companies. Johanneberg Science Park's main focus areas are Urban Development, Energy and Materials/Nano science. The Park's activities mainly centre on setting up Open Arenas within these focus areas and on developing the Campus area by providing office and lab facilities in the new buildings being erected on campus. Today, there are 140 companies situated on campus with a total staff numbering about 1,000. By 2023, the number is expected to reach 5,000. Johanneberg Science Park also operates a Growth Platform for small and medium sized enterprises (SME) which offers strategy and business development support to established firms in the region.

3.2 Chalmers Industrial Technology

Chalmers Industrial Technology (CIT) is the polytechnic institute for research oriented development of Chalmers University of Technology, organized for effective R&D services to industry and society. The annual turnover is € 8 M and number of employees is approximately 80 of which 50% have a PhD degree. The activities are funded by commissions from the university, the government or industrial partners. The main activity is utilization of university knowledge for industry in projects. The number of projects per year is approximately 200. The projects include industry in all technology sectors in Sweden and internationally**.** CIT currently manages the Innovation work package in the Graphene Flagship and the newly started Strategic Innovation Programme Graphene in Sweden.

4 Graphene – A Strategic Innovation Programme

Strategic Innovation Programmes are granted and co-funded by the Swedish Agency for Innovation Systems (VINNOVA) and The Swedish Energy Agency. Strategic Innovation Programmes receive up to MSEK 50 (MEUR 6) annually. Programmes are regularly evaluated to qualify for continued funding. Currently, there are 11 Strategic Innovation Programmes active, the Graphene Programme being among the most recently awarded.

4.1 The scope of the Strategic Innovation Programme

During preparation of the Strategic Innovation Agenda (SIA), the first step towards establishing the Strategic Innovation Programme (SIP), several areas of strengths were identified where graphene can make an impact for Swedish industry in the coming years. This SIP will focus on the areas with TRL (Technology Readiness Levels) higher than 3 (Figure 4), meaning that no pure research projects

will be included in the programme. The focus will be on innovation, as well as on demonstrator projects that engage enterprises that build the value chains of the future, for benefit of the Swedish industry and society.

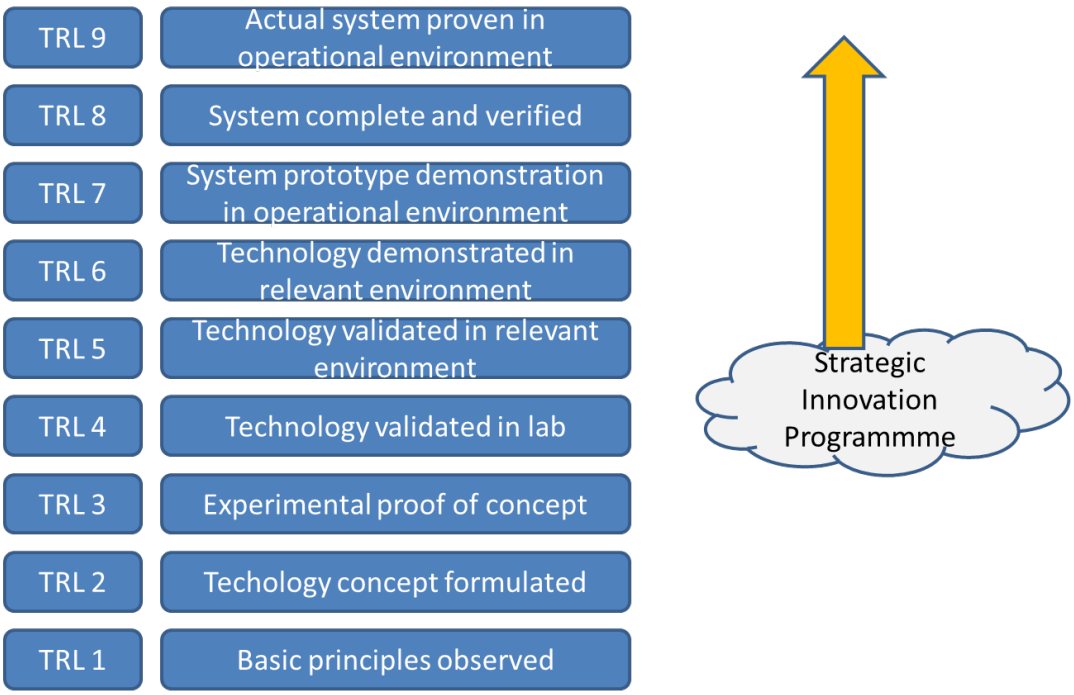


Figure 3 Technology Readiness Levels and the Graphene Strategic Innovation Programme

The identified areas of strength and the road maps for them are summarised in the SIA and are depicted in Figure 4. These should be viewed as industrial or technology platforms. These areas of strength as well as the involved actors are dynamic and are expected to change over time. As the technology readiness levels increase, additional actors are expected to adapt to the new technology and participate in joint R&D activities. The SIO will naturally grow and adapt to attract and encourage new partners to join.

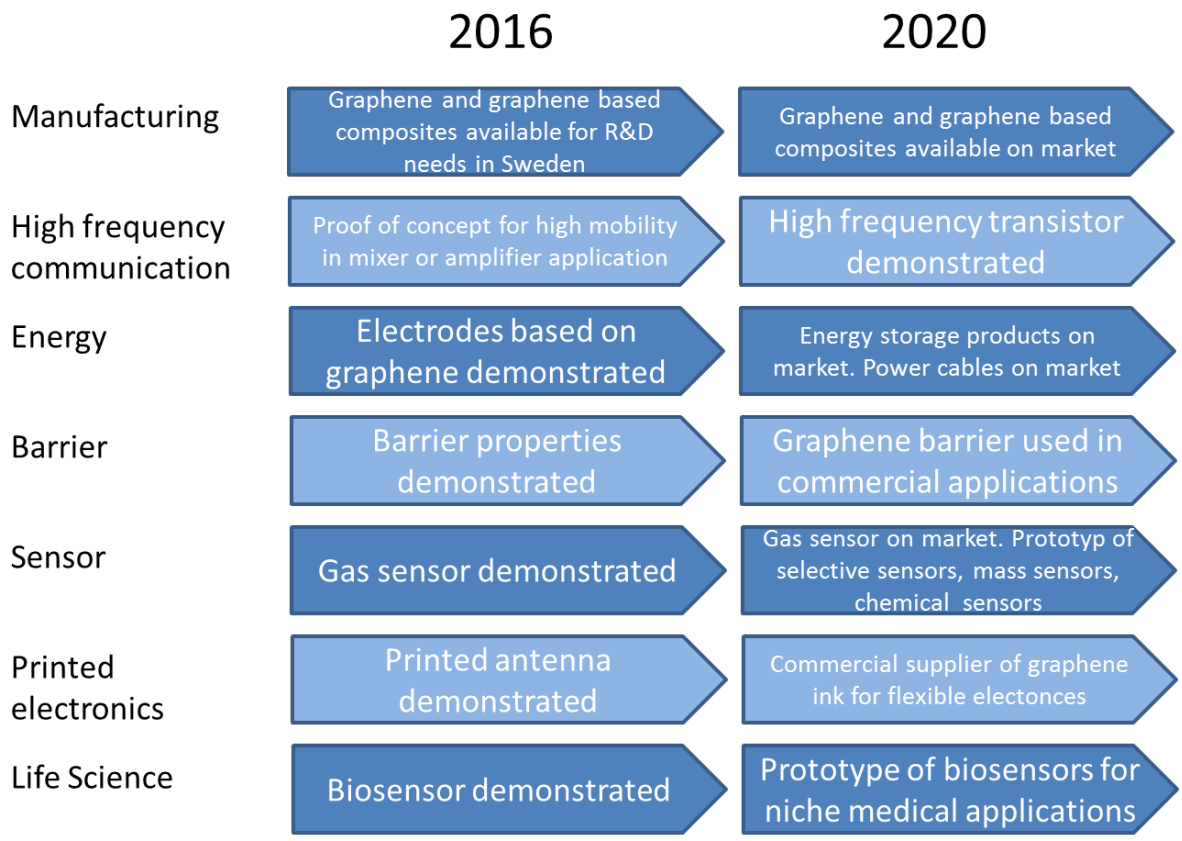


Figure 3 Key technology platforms and expected outcomes by 2020 as identified by the SIA

Research on related 2D-layered materials is advancing strongly and will be included in the graphene class of materials when appropriate. In this SIO programme, however, we focus on graphene as an enabling technology since the science is more mature and the five applications better understood. Practical graphene-based applications are expected to appear within the next few years, which make it industrially appealing. Other 2D-layered materials need additional exploration regarding fabrication routes, material properties, and device feasibility, before commercialisation is feasible However, experience with graphene will reinforce and accelerate development of other 2D-layered materials.

4.2 Needs of industry

Five needs must be fulfilled for Swedish industry to be successful in graphene-based technologies and to achieve a strong international position. These needs are the basis of the objectives of the Graphene SIP.

Need #1: Increase technology readiness

There is a multitude of technological challenges to be overcome related to application-specific and product/process-specific aspects in the areas of product development and design; and manufacturing engineering (design for manufacturing/assembly/producibility).

Need #2: Strengthen collaboration and exchange

Currently, arenas and meeting places enabling cross-industry and industry-university exchange are missing, which results in a lack of collaboration within and across value chains preventing critical mass of needs, interest, potential and momentum among actors. As a consequence, there is a limited awareness of actors active in the graphene field: who knows what, what is ongoing, what the strategies/objectives of key actors are.

Need #3: Link and define funding opportunities

Today, there is very limited participation of Swedish industrial actors in international projects for graphene R&D and innovation (for instance, in the Graphene Flagship Competitive Call in Feb 2014 only 22 of the 721 applying partners were from Sweden).

So far, Sweden lacks significant public and private funding dedicated to graphene R&D and innovation (compared to Spain, Poland, Germany, Italy or the UK). Furthermore, we lack the mechanisms to stimulate and define the volume and direction of such funding since no single actor, private or public, has a comprehensive view of and mandate over graphene-related research and innovation initiatives.

Need #4: Provide strategic guidance and a common view

No common vision is available for the future Swedish graphene-based industry and no single actor currently has the incentive for developing, updating and disseminating one.

There is limited coverage of what is ongoing in terms of scientific, technological, IP and business developments in the graphene field, in Sweden or abroad, resulting in a weaker knowledge base upon which research and technology strategies and roadmaps can be formulated. The SIO programme will from the start act as an information source for funding opportunities, and ultimately when up and running also act to influence funding organisations' future calls.

Need #5: Stimulate Swedish graphene material supply and multiple-loop industry interaction

The lack of a domestic supply of graphene materials and material characterization services results in longer lead times, fewer feedback loops between material suppliers and Swedish companies, and inhibited learning. Standards on material properties and characterization methods are missing, which further delays engineering and innovation efforts.

5 Bridging the Knowledge Gaps

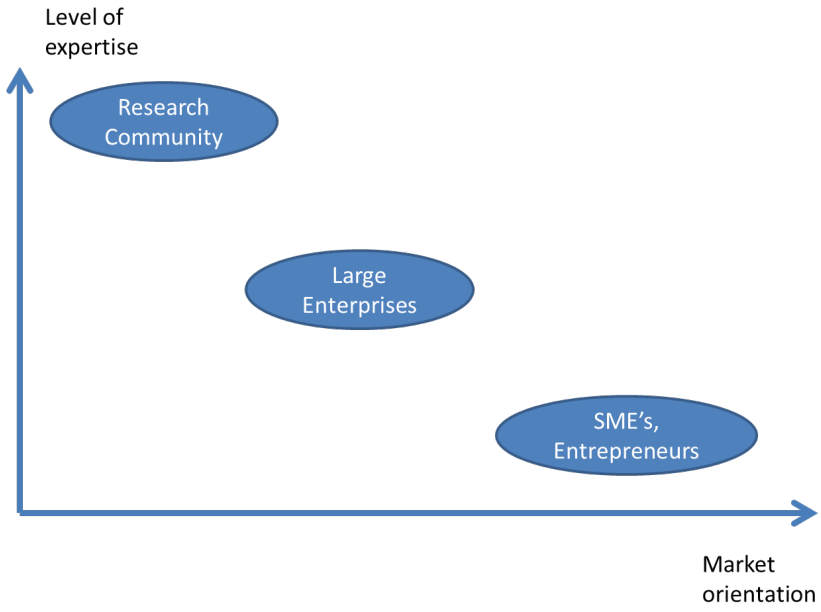


Figure 4 Knowledge gaps between graphene stakeholders

At the local level, Johanneberg Science Park, based at Chalmers, in collaboration with Chalmers Industrial Technology assumed the task of engaging the Swedish industry, including Small and Medium sized Enterprises (SME) in the graphene project. Johanneberg Science Park is developing Open Arenas in the areas of Built Environment, Energy and Materials/Nanotechnology.

The challenge of involving enterprises, particularly SME's in development around a material such as graphene lies to a great extent in the present wide knowledge gap (Figure 4) between entrepreneurs and researchers. Since graphene is a novel material, there are very few commercial applications available to date. Furthermore, with the material itself barely available it has not been possible to experiment with it outside of research labs, and knowledge is very limited.

Few straightforward innovation paths for graphene exist today, since the development will be disruptive rather than incremental. This situation poses a problem when it comes to the knowledge transfer required between scientists and entrepreneurs. Up until this moment, when researchers and companies have met to brain-storm about future applications of graphene, the type of information that the researchers are able convey is either very basic and trivial information about the material's properties and (almost limitless) possibilities, or, on the other hand, detailed information from their own research projects, which is generally very specialised and complex. Neither of these two kinds of information serves the entrepreneurs in their effort to come up with new ideas. Moreover, researchers rarely have notions concerning commercial viability and market potentials of the various applications suggested. If this situation prevails, it will delay the development of commercial applications and thus the expected economic growth based on graphene. This is clearly the kind of case where Science Parks have an important role to fulfil.

The strategic innovation program Graphene with the management of CIT and participation of Johanneberg Science Park will address these knowledge gaps to lead the way to new clusters, networks and innovation paths, creating the conditions necessary to establish Sweden as one of the leading European countries in graphene innovation. The paper describes a number of activities that will be undertaken in order to strengthen the SMEs' role in the graphene innovation system. The following objectives have been set:

- Strengthening cross-industry and industry-academia knowledge transfer
- Improving availability of graphene material to SME's
- Improving availability of experimental resources to SME's
- Stimulate idea generation of graphene-based applications
- Establish conditions for business and entrepreneurial development based on graphene

Planned activities include

- Demonstration and validation projects
- Training workshops on specific material properties of graphene and the possibilities they offer
- "Speed-dating" sessions where representatives of large companies, researchers and SME's meet
- IP, research and business intelligence
- Market analyses and user clinics
- Creation of value chains and clusters among Swedish and international companies
- The creation of a graphene "Open Arena", a neutral and easily accessible meeting place where all kinds of stakeholders (academia, industry, government and citizens) can meet to exchange ideas and knowledge, develop innovative solutions and share common resources

Stimulating collaboration between large and small enterprises will be an important part of the work, since the larger enterprises occupy the "middle ground" in the diagram of Figure 5, that is, they have more expertise and resources on their hands, concerning technology development as well as market access. Simultaneously, large corporations will benefit from interacting with the faster-moving, innovative and flexible ideas generated by SME's and entrepreneurs. Thusly, it is expected that the knowledge gap between researchers, large and small enterprises be bridged (Figure 6).

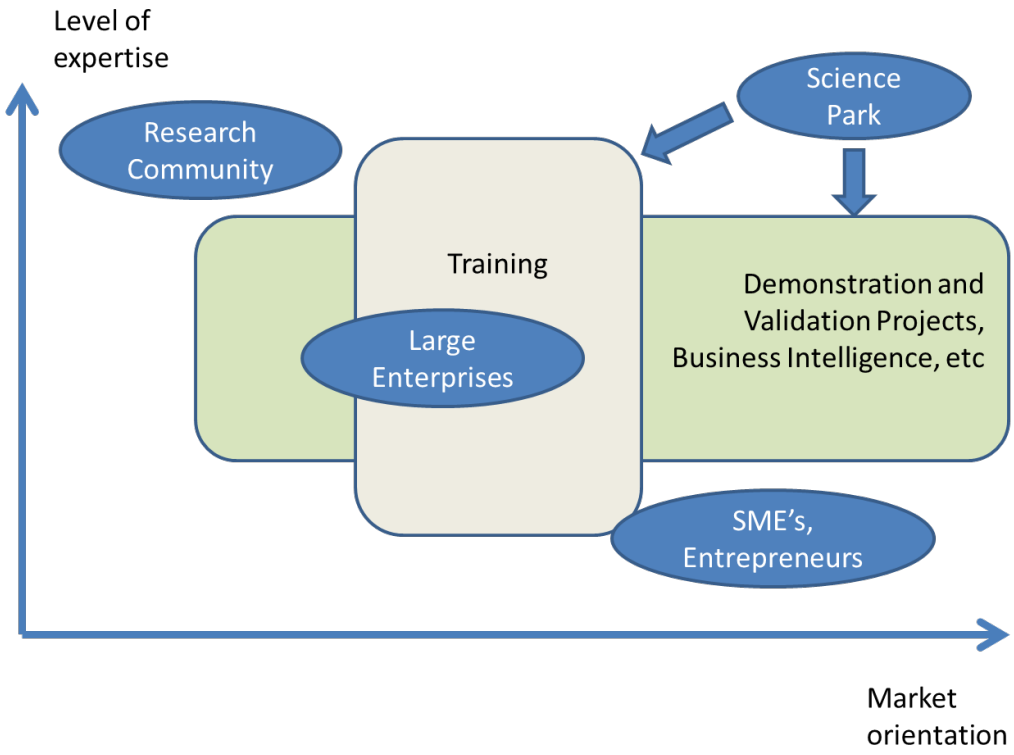


Figure 5 Bridging the knowledge gaps

Clearly, many of these activities will create synergies with other parts of the Science Park's work, particularly the creation of Open Arenas, where the Graphene Arena will form a part of the Materials/Nanotechnology Arena. Also, companies that are already part of the Science Park will be able to benefit from the new ideas, networks and clusters that are expected to be put in place.

5.1 Summary of actions and activities

The SIO programme is divided into open calls and supporting activities. These are summarised in Table 1 and described in more detailed the coming section. The open calls will be co-financed 50/50 by VINNOVA and the partners in each demonstrator project. The supporting activities will be financed by a membership fee and in kind time to co-finance the VINNOVA support.

The activities have been chosen with the objective to fulfil the SIO goals as well as the expected outcome of the VINNOVA programme in terms of strengthening sustainable growth, competitiveness and increased export, sustainable solutions for global challenges, and making Sweden an attractive country to invest and operate in.

The portfolio strategy is that each project group decide on ownership for their project outcome. Guidance can be provided from programme.

Table 1 Planned activities in the SIO Programme

Action/activity	Description	Targeted groups	Duration
Newsletter/Intelligence 2014	IPR, research and business intelligence with newsletter	Swedish actors	2014
Workshops 2014	New members, strategies, matchmaking	Swedish actors	2 in 2014
SME 2014	Hands on support	SME	2014
Demonstrator 2014	Open call	Swedish actors	Sept 2014
Demonstrator	Open call	Swedish actors	2015-2017
Manufacturing	Open call	Swedish actors	2015-2017
Newsletters/Intelligence	IPR, research and business	Swedish actors	Continuous

Action/activity	Description	Targeted groups	Duration
	intelligence with newsletter		
Workshops 2015-2017	Dissemination, strategies and matchmaking	SME/Swedish actors	2015-2017
SME	Hands on support	SME	Continuous
Entrepreneurial skills	Course and mentorship	Researchers	Continuous

6 An Open Arena for Graphene

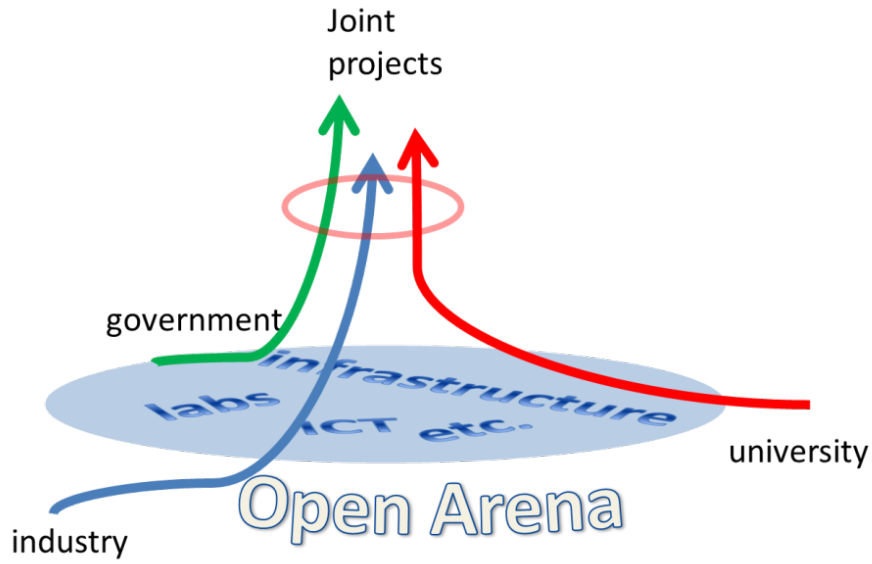
6.1 The Open Arena Concept

One of the main guiding principles for the Johanneberg Science Park has been the Open Arena concept (Figure 6). Open Arenas are, by definition, neutral meeting environments permeated by the spirit of collaboration between industry, university and society. In Open Arenas, researchers, business people, students, designers, project managers and many more meet to take advantage of the meeting spaces, test beds, labs and other infrastructures that are available.

Key attributes for the Open Arena concept are:

- Cooperation
- Neutrality
- Openness
- Application orientation

The Open Arena concept has several dimensions. One is the *physical* dimension including test beds (simulated or real environments), labs, and facilities for workshops, meetings, and conferences. Another is the *operational* dimension including thematic and more specialized arenas or programs, representing knowledge domains where different organisations co-operate in research and development. A third dimension is the *methodological* dimension where concepts such as project brokerage, open innovation, and living labs are central.



Figur 6 The Open Arena concept

An Open Arena is instrumental in accelerating the commercialisation of new technology by stimulating cross-disciplinary and Industry-Academia collaboration, providing processes and resources for project initialisation and development,

Success factors based on experience from developing the Open Arena concept:

- **Organization and infrastructure** – Science Parks as organizational bodies offering a neutral collaboration platform. Access to indoor as well as outdoor facilities and test plants, etc.
- **Strong industrial interest** – industrial partners provide market knowledge and have the ability to take commercial risks
- **Nationally and internationally prioritized focus areas** – activities in prioritized areas meets the interest from both the academia, industry and the societal spheres
- **Complementary collaboration partners** – cross-fertilization between organizations and individuals from different background and competence areas
- **Agile way of working** – flexibility and agility in management and implementation to reach the best possible results
- **Neutrality and "non-profit"** – key characteristics for successful shaping of open research and development co-operations

6.2 Open Arena for SME's in the Graphene sector – strengthening value chains

Development and manufacturing of graphene-based components has been identified as weak parts of the production value chain. Companies populating these niches are often SMEs that need particular stimuli to enter into new fields, such as graphene, since their business models are significantly impacted. To strengthen this part of the graphene value chain, activities particularly aimed towards SME's will be carried out inside of the Open Arena

6.2.1 Description

In order to attract firms to participate in the Arena, an information campaign will be directed towards identified actors – aiming at getting them involved in development projects. Additionally, hands on support with project planning, finding project team participants and resources will be provided, delivering tangible assistance in delineating new graphene based business models. This will create an arena for exchanging experiences and establish the agenda vision for new actors.

6.2.2 Expected results and effects

Within 3-5 years at least ten SMEs are presently, or have been, involved in graphene related projects (with the aim of strengthening their own business rationale). The effects are possibilities to achieve stronger and more complete value chains and higher competitiveness for Swedish SMEs. SMEs may also serve as flexible and rapid commercialisation paths for new ideas that emerge from other parts of the SIO.

7 Conclusions

The introduction of new products in the marketplace is rarely driven by technology push only. Perceived customer needs and market potential are crucial in order to justify the investments and efforts needed to develop and commercialise a new technology. However, in the case of a potentially disruptive new technology such as graphene, the knowledge gap between scientists and entrepreneurs is unusually large, and poses a significant obstacle to the early development of commercially viable applications of this new material.

In such a case, organisations such as Science Parks are uniquely positioned to act as bridges between academia and science, initiating and facilitating the flow of knowledge and information in both directions. As has been described in this paper, an ambitious programme is now being launched in Sweden in order to put the country at the forefront of an entirely new technology sector – graphene. To do so, Science Parks, research institutes and other organisations join forces to create a viable environment for knowledge transfer, value creation and commercialisation. The next five years will prove whether this effort is to be successful!