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The contribution of the Framework Programmes to Major Innovations

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EUROPEAN COMMISSION

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The contribution of the Framework Programmes to Major Innovations

Final Report, July 2015

Written by Joint Institute for Innovation Policy (JIIP)

Directorate-General for Research and Innovation
2016 7th EU Framework Programme (2007-2013) EN

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Luxembourg: Publications Office of the European Union, 2016.

PDF ISBN 978-92-79-51532-3 doi: 10.2777/425267 KI-02-16-068-EN-N

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Executive summary

This report presents the overall findings of the Study on Contribution of the Framework Programmes to Major Innovations (N° RTD-Major Innovations-2013-A5). The aim of the project is to evaluate the contribution of the European research programmes (FP5, FP6 and FP7) to the development of a selected number of Major Innovations. The focus of the study is on the identification of the key elements explaining the factors and conditions that brought the respective Major Innovation about, and the contribution of the EU funded research. The results of the study are targeted for supporting the policy evaluation and understanding of the areas for further improvement.

The study has analysed different cases and their wider context in detail. The main conclusions drawn for the analysis can be summarised as follows:

1. Research and Development, although important, is one of many drivers for major innovations and despite the fact that the FP's have not directly contributed to breakthroughs in the Major Innovations, they have significantly contributed to the relevant innovative capacity of firms, fostering the wider innovation environment (e.g. clusters and value chains), and to related incremental innovations.
2. Major Innovations usually consist of so-called families of innovations, which together are a necessary condition to make the innovation happen. Each of the innovation families has a different "ownership", pace and timing to be mature enough to enter the market. (The recent extension to "closer to market" activities in Horizon 2020 offers opportunities for further synchronization).
3. The exploratory and excellence driven nature of FP5 to FP7 aimed at pre-competitive research (TRL 1-4), whereas 8 out of 10 Major Innovations passed TRL9. This implies that much of the results of the FP's may contribute to the Major Innovations through networking, aligning agendas, knowledge creation and diffusion in relevant families of innovations and to understanding the more general framework conditions for an innovation.
4. Major Innovations strongly depend on a high impact of policies and regulations outside of the specific R&D&I domain (for instance the telecom liberalization, energy policies or the GPS Dual use policy). The FPs have helped to create conditions and potential pathways to leverage such policies into Major Innovations.

Selected case studies

The study departed from an initial list of thirty innovations considered to fulfil the conditions of being a major one. With the help of Expert Panels, the initial list was narrowed down to a final list of ten bearing in mind the objective of the study and the European relevance of the Major Innovations. A balance was sought between EU and non-EU originating Major Innovations, the age of the Major Innovations, and the different characteristics (in terms of policy, technology field and market). The finally selected Major Innovations are[1]:

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[1] These should not be considered as THE ten Major Innovations, but an educated selection based on criteria that were in

- Car navigation systems
- Light-emitting diode (LED) lighting
- Linux / Open source development
- Mobile phones
- New generation 'Super Jumbo Jet' (cf. Airbus A380)
- Optical fibres
- Personalised medicine
- Photovoltaic solar panels
- Smart grids
- Stem cells treatment

The case study analysis follows the logic of non-linear chain-linked model of innovation, which embraces the concept of an innovation as a context-dependent, cumulative learning process characterised by continuous interactions and dynamic feedback loops.

The case studies thus scrutinise the Major Innovations on (i) the contextual framework consisting of drivers, resources and capabilities, such as market demand, societal challenges, regulations and various policies, and (ii) the role of Framework Programmes (possibly) reinforcing this development.

The case studies utilised various information sources and approaches for building up the "story of a Major Innovation", including intensive desk research of existing information sources (web searches, interrogation of journal databases, as well as searches involving material published by companies), a series of expert interviews, descriptive analysis of Framework Programmes based on FP project data and an online survey targeted to the main stakeholders of each Major Innovation.

Concept of Major Innovations

For the purpose of this study, a Major Innovation is defined as creating net benefits to the users and the socio-economic system at large in a way that deserves the adjective 'major'. Major Innovations usually do not occur in isolation, but emerge and co-evolve with others in what may be termed a 'family' of innovations. Rather than one-off stand-alone innovations, what we observe in the real world are (sub)sets of interrelated innovations, some of which may be major. This interrelated character of certain innovations, usually a combination of different types of innovations, can also take the form of interdependencies and co-evolution of innovations. This family of innovations phenomenon is what underlies the systemic and pervasive nature of most Major Innovations, as illustrated by the figure below:

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line with the purpose of the study

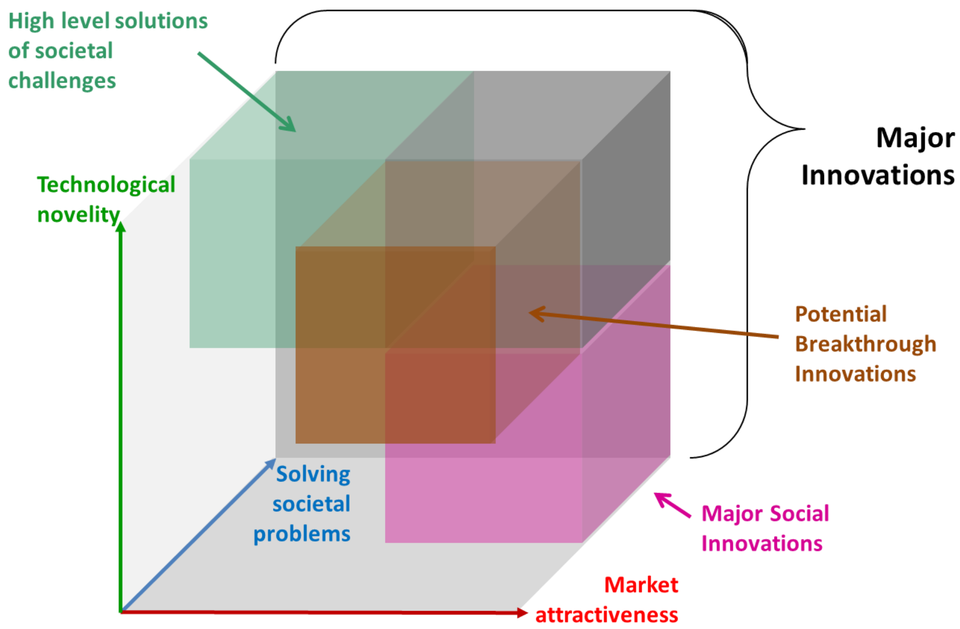


Figure 1: Dimensions of Major Innovations, Source: JIIP

Hence, the concept of Major Innovations includes those of 'Breakthrough Innovations' as well as 'Major Societal Innovations'.

Overall characteristics of Major Innovations

The selected Major Innovations should be understood as "major" from (i) their technological novelty (ii) their market attractiveness, (iii) their impact on solving societal problems.

(i) Technological novelty

All the ten Major Innovation cases studied can be traced back to technological breakthroughs. Most technologies, which are incorporated by the selected Major Innovations are not new, in the sense that they have not been developed specifically for the Major Innovation in question. As a general pattern, technological novelty/newness of most of the Major Innovations selected is based on new "combinations" or advancements of already established technologies, knowledge and processes. Therefore, the Major Innovations predominantly can be seen as an achievement of an integration process of different already existing innovations and technologies.

As an innovation is described as a product or service that has been introduced in the market, eight of the ten cases have passed Technology Readiness Level (TRL) 9, only personalised medicine and stem cells are still in lower TRLs. The Major Innovations case studies are in different evolution phases as shown by the figure below:

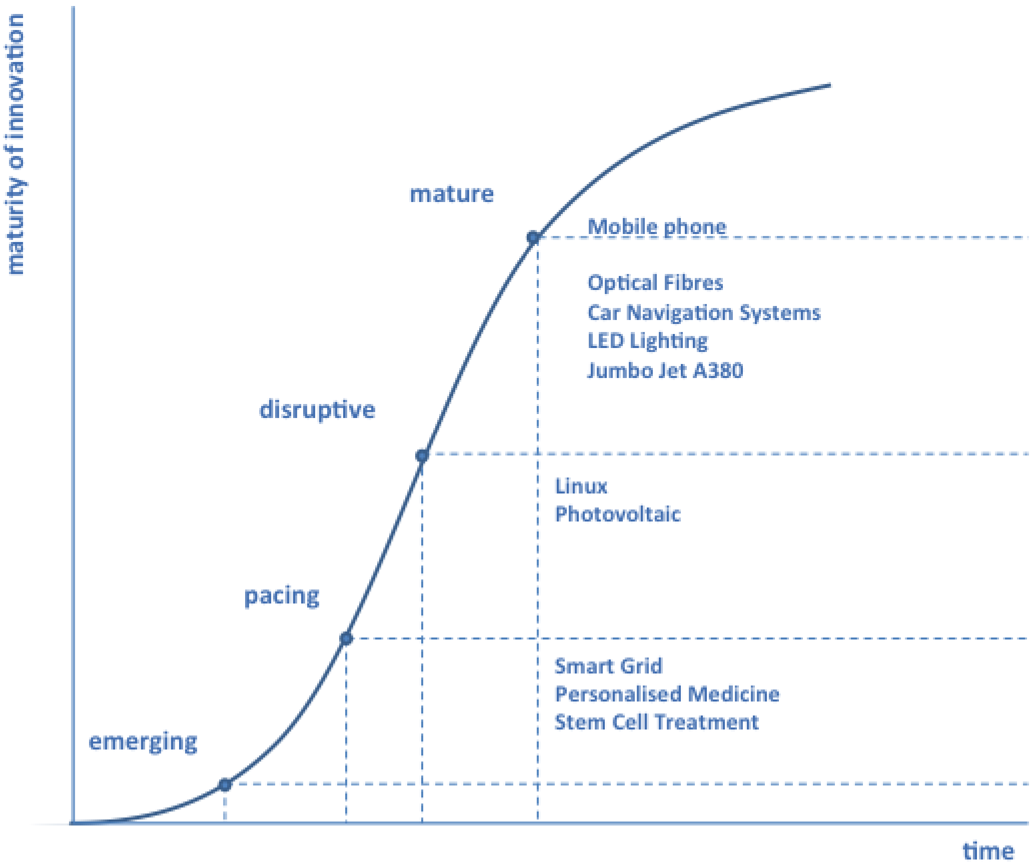


Figure 2: Innovation maturity

Car navigation systems, mobile phones, optical fibres and LED lighting are truly disruptive innovations that can be considered to have reached a global level of diffusion already. The Super Jumbo Jet, photovoltaics and the Linux operating system have a considerable importance in their respective markets but are still expected to have some important growth potential in future. Smart grids, personalised medicine and stem cell treatment are Major Innovations, which have major potential for economic and societal impact but in large parts this potential is still to be realised.

(ii) Market attractiveness

In all ten Major Innovations, new knowledge and competences have been created which also show impacts going beyond the respective technology field. Depending on their level of embedding in different value chains, the Major Innovations show different paths leading to their economic impact. The Major Innovations observed also showed impacts on industrial structural change. Each Major Innovation impacted the industries either by triggering industry change, by creating a completely new industry sector or by pushing industry diffusion forward. Only in the case of stem cell treatments, those impacts cannot yet be evidentially seen. However, it is expected that the development of stem cell treatments will cause considerable changes in the medical industry.

All the Major Innovations studied are global in terms of both the innovation value chains and end-users. However in some case studies, in particular photovoltaics and LED, global value chains have changed along the evolution of the Major Innovations and a shift in the location of knowledge creation, innovation, manufacturing and markets can be observed.

(iii) Addressing societal challenges

The Major Innovations observed also showed societal and environmental impacts, with differences between the case studies. For nearly all the Major Innovations, the full extent of the societal but also economic and market impact cannot yet be estimated. This is especially the case for emerging and advancing innovations. This should be taken into account when comparing the currently evident economic impact and potential future impact.

Drivers for Major Innovations

The study assessed the main drivers for the major innovations looking at R&D drivers, policy drivers, market-based drivers and societal drivers.

(i) R&D related drivers for major innovations

All studied Major Innovations are characterised by **technological novelty** or a combination of novelties. Some cases of the Major Innovations are clearly based on outstanding scientific progress and technological breakthrough, but these were not the majorty of the cases. Equally, regulation or standards played an important role as drivers. However, it is important to note that **most Major Innovations commonly build on existing inventions and scientific and technological imputs from different fields**. In these Major Innovations the creation of interfaces between different disciplines commonly played an important role as a driver of innvation.

The following overview shows the relevance of different R&D and technology related drivers of the ten Major Innovations observed.

Table 1: Relevance of different R&D and technology-related drivers of the ten Major Innovations

R&D related drivers of innovation ✓✓ distinct driver ✓ contingent driver × no significant driver	Car Navi-gation Systems	LED Light-ing	Linux Oper-ating System	Mobile Phones (MP)	Super Jumbo Jet (A380)	Opti-cal Fibres (OF)	Personal. Medicine (PM)	Photo -voltaic (PV)	Smart Grids (SG)	Stem Cell Treat-ment (SCT)
Outstanding scientific knowledge	×	✓	×	×	×	×	✓✓	✓	×	✓✓
Technological breakthrough	×	✓✓	×	×	×	✓✓	✓✓	×	×	✓✓
Technological novelty/newness based on (re-) combination	✓✓	×	✓✓	✓✓	✓✓	×	✓✓	✓	✓✓	✓✓
Existing standards (e.g., procedures, protocols, etc.)	✓✓	×	✓✓	✓✓	✓✓	×	×	×	✓✓	×

Creation of interfaces between different disciplines	✓✓	×	✓✓	✓✓	✓✓	✓	✓✓	×	✓✓	✓✓
Co-creation	×	×	×	×	✓	✓	✓✓	✓✓	✓✓	✓✓
Data availability / management (data collection, data preparation)	✓✓	×	✓✓	✓✓	×	✓✓	✓✓	×	✓✓	✓✓
Single hotspots and players driving technology development significantly	✓✓	✓✓	×	✓✓	✓✓	✓	✓	✓✓	×	✓
Fragmented international community driving technology development	×	✓	✓✓	✓		✓✓	✓✓	×	✓✓	✓✓

Figure 3 shows four dominant patterns among the ten selected Major Innovations.

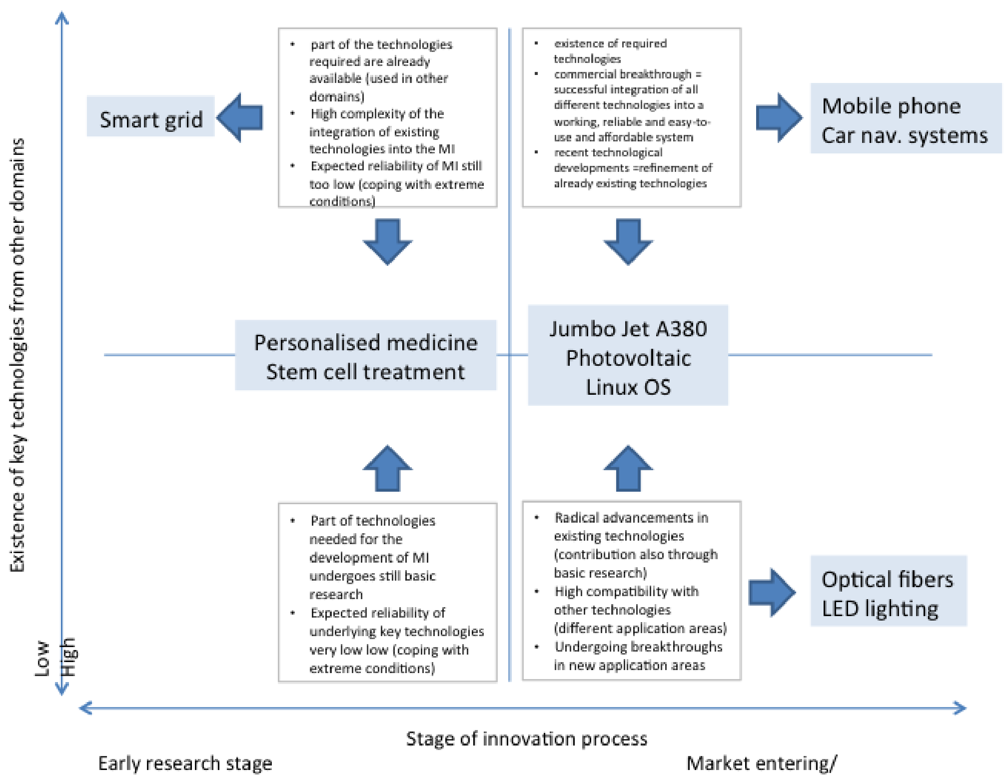


Figure 3: Major Innovations in connection with existing key technologies and their stage of innovation process Source: Case studies

(ii) Policy drivers and framework conditions for major innovations

A survey-based expert assessment of the relevance of different policy drivers for major innovations shows that for most Major Innovations governmental intervention in some form was among the major drivers. Existing regulatory and legal frameworks, standards and IPR also play an important role for the development and improvement of Major Innovations. Policy and regulation can also support the legitimacy of an innovation, when a product regulation ensures the safe use, it will be accepted (as in the case of stem cells), and equally if policy reflects societal values (such as sustainability) the uptake of the innovations will be positively affected. R&D incentives and funding stood out as being important for all of the analysed Major Innovations. Depending on the stage of development, the existance of well-functioning capital markets providing private funding (eg venture capital, seed capital) are also improtant for the majority of cases, while in other cases subsidies for consumers to foster the take-up of a technology did play a role.

Table 2 shows the survey-based expert assessment of the relevance of different policy drivers and framework conditions.

Table 2: Policy drivers

Policy drivers ✓✓ distinct driver ✓ contingent driver × no significant driver	Car Navigation Systems	LED Light-ing	Linux Oper-ating System	Mobile Phone (MP)	Super Jumbo Jet (A380)	Optical Fibres (OF)	Personal. Medicine (PM)	Photo-voltaic (PV)	Smart Grids (SG)	Stem Cell Treat-ment (SCT)
Political commitment (governmental intervention)	×	✓✓	×	×	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Existing regulatory and legal framework	×	✓✓	×	×	✓✓	✓✓	✓	✓✓	✓	✓
R&D incentives and funding	✓	✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Private funding (e.g., venture capital, seed capital, etc.)	✓✓	✓	✓	✓✓	×	✓✓	✓✓	×	×	✓✓
Subsidies for end consumer	×	✓✓	×	×	×	✓	×	✓✓	✓✓	×

(iii) Market-related drivers for major innovations

Private and public demand and demand in emerging economies and changes in end user and industrial behaviour drive the development and improvements of the Major Innovations.

Table 3: Market-related drivers

Market related drivers ✓✓ distinct driver ✓ contingent driver × no significant driver	Car Navigation Systems	LED Lighting	Linux Oper-ating System	Mobile Phone (MP)	Super Jumbo Jet (A380)	Optical Fibres (OF)	Personal. Medicine (PM)	Photo volt-aic (PV)	Smart Grids (SG)	Stem Cell Treatment (SCT)
Open up a market niche	×	✓✓	✓✓	×	✓✓	×	×	✓✓	×	×
Market readiness	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	×	✓✓	×	×
Responses to market trends	✓✓	×	×	✓✓	×	×	×	×	×	×
Strong public demand	✓	✓✓	×	✓✓	×	✓✓	✓	✓✓	✓✓	✓
Strong private demand	✓✓	✓	✓✓	✓✓	✓✓	✓✓	✓	✓	✓	✓
Change of industrial behaviour	✓✓	✓✓	✓	✓✓	✓	✓✓	✓	✓✓	✓	✓
Changes in end user behaviour	✓✓	×	✓✓	✓✓	✓	×	×	✓✓	✓	×
Demand in emerging economies	✓	✓	✓	✓✓	✓✓	✓✓	✓	✓✓	✓	✓✓
Becoming an industry standard	✓✓	✓	✓✓	✓✓	✓	✓✓	✓	✓	✓	×
Ease of use & functionality	✓✓	✓✓	✓✓	✓✓	×	×	×	×	×	×
Creation of common eco-system	×	×	×	✓✓	×	✓✓	✓	✓✓	✓	×
Provision of necessary infrastructure	✓✓	×	×	✓✓	✓	✓✓	✓	✓✓	✓	✓
Affordability (price cuts)	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	×	✓✓	×

The market structure and dominating business models associated with the selected cases differs substantially. Furthermore, it has to be considered that Major Innovations emerge and co-evolve in a family of innovations. In most cases, Major Innovations cannot solely be associated with one market. For example, the car navigation market consists of three sub-markets or market segments, namely the 'in-dash' GPS navigation system market; the GPS-based Portable Navigation Devices market and the app-enabled GPS navigation market. Another example is the stem cell treatment market, which consists of the following sub-markets: (1) clinical stem cell treatment, (2) drug development and disease modelling; (3) (re)-programming of tissue cells and (4) identification/treatment of cancer stem cells.

In the long term, the markets associated with Major Innovations are becoming blurred with the rise of new applications, business models and changing user patterns (e.g., the car navigation systems market is strongly related to service-based markets due to the rise of in-car entertainment; the personalised medicine market will become strongly related to the nutrition market).

The Major Innovations that we analysed, most often lead to changes in previous business models. Major Innovations generally motivate new business ideas and attract new entrants to the market. In many cases, these are start-ups or SMEs trying to make use the potential of the technological novelty/newness of the Major Innovations. They are threatening the top tier of companies in the market by their willingness to take considerably higher risks.

(iv) Societal and environmental drivers for major innovations

Demographic changes as well as socio-economic challenges in their various forms commonly played a driving role for the majority of the Major Innovations analysed. In the same vein, environmental concerns were a strong driver for some. While broader societal contexts were important for almost all, direct public comittment and public perception were crucial only for half of the Major Innovations, while for the other half the usability for the end-user was the decisive context. Across the board, the growing presence of ICT applications in everyday life was identified as an important driver both from the demand and diffusion side.

Table 4: Driving role of different societal challenges

Societal, environmental and other drivers ✓✓ distinct driver ✓ contingent driver × no significant driver	Car Navigation Systems	LED Light-ing	Linux Oper-ating System	Mobile Phone (MP)	Super Jumbo Jet (A380)	Optical Fibres (OF)	Personal. Medicine (PM)	Photo-voltaic (PV)	Smart Grids (SG)	Stem Cell Treat-ment (SCT)
Societal commitment / public perception	×	✓✓	×	×	×	×	✓✓	✓✓	✓✓	✓✓
Changes in the social fabric (due to new needs, socio-economic challenges (ageing society), etc.)	✓✓	✓✓	×	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Demographics (e.g., rise in migration; tourism; but also human characteristics influenced by their geographical location, etc.)	✓✓	×	×	✓✓	✓✓	✓✓	✓✓	×	✓✓	✓✓
Facilitation (Usability) for the end user	✓✓	×	✓✓	✓✓	✓✓	✓	×	×	×	×
Growing presence of ICT in every-day life	✓✓	✓	✓✓	✓✓	×	✓✓	×	×	✓✓	×
Reduction of the environmental burden (e.g., energy efficiency)	✓✓	✓✓	×	×	✓✓	✓✓	×	✓✓	✓✓	×

Overall conclusions on the drivers for Major Innovations

R&I incentives and funding, demand (private, public and in emerging economies) and changes in industrial behaviour are the most important overall drivers for Major Innovations, as they were found in all case studies.

When looking more specifically at the individual case studies, it emerges that the regulatory framework also plays an important role. Personalised medicine, stem cell research, smart grids, photovoltaic panels as well as LED lighting are Major Innovations addressing societal and ecological challenges, which received policymakers' broad attention and support, both via funding and privileging regulations. Regulatory measures or indirect subsidies favoured or at least encouraged LED lighting, photovoltaic and smart grids. Regulations are seen as an important accelerator of the diffusion of those technologies. Similar findings could also be seen in the case of personalised medicine and stem cell treatment[2] (e.g., the clear political commitments regarding iPS cells in Japan).

The car navigation systems, mobile phones, the Super Jumbo Jet, optical fibres and Linux as Major Innovations, have also been driven by private research/innovation efforts, entrepreneurial spirit and smart marketing. However, this does not mean that public policy was irrelevant. There is clear historical evidence that in car navigation systems and mobile phones, key policy events boosted the entry of the Major Innovations into the mass market (car navigation system: opening up of the GPS–NAVSTAR satellite system for civilian use in 2000; mobile phones: liberalisation of the European telecom markets). Overall, it seems that – by various means – governments were able to create (or at least to help to create) markets which were the basis for the breakthrough of these Major Innovations.

Contribution of the Framework Programmes to the Major Innovations

When assessing the contribution of the Framework Programmes, a few important starting points have to be taken into account:

1) The **timeline** of the Major Innovations: The first applications of many Major Innovations (and therefore the development of technologies and innovations underlying them) had already been achieved by early/mid 1990s, before FP5 started in 1998. So FP5-7 could not impact their birth and first applications. Taking into account for instance the average time lag between R&D activities and commercial success, the ICT sectors shows relatively short innovation cycles (6 to 9 months) for individual innovations while other sectors like the energy sector or pharmaceutical sector show quite long innovation cycles (far more than 15 years). The development of a family leading to a major innovation can take even longer.
2) The **complexity** of the Major Innovations: as we demonstrate, most of the MIs are based on a variety (family) of innovations that do not happen simultaneously. These innovations may not have the same 'breakthrough value' in the process, but are still essential for the Major Innovations. This means that FPs can contribute at different levels to the Major Innovations at different points in time. Usually funding schemes support individual innovations among the family of a major innovation.
3) The **aims of the FPs**. The exploratory nature of FP5 to FP7 aiming at pre-competitive research (TRL 1-4), whereas 8 out of 10 Major Innovations passed TRL9. This implies that much of the results of the FP's may contribute to the Major Innovations through

[2] However, it has to be mentioned here, that regarding the development of stem cell research the EU intentionally adopted a 'wait and see' position regarding its clear political commitment. The reasons therefore are on the one hand ethical aspects regarding the human embryonic stem cells and on the other hand, high safety concerns regarding stem cell treatments.

networking, aligning agendas, knowledge creation and diffusion and less in directly applicable innovation outcomes.

Role of FPs for Major Innovations using the TIS approach

The concept of an 'innovation system' stresses that the flow of technology and information among people, enterprises and institutions is key to innovative processes. It stresses the interactions between actors which are needed in order to turn an idea into a successful process, product or service in the marketplace. The concept of 'technology innovation system (TIS)' specifically provides an innovation system analysis on the level of several functions associated with the development of specific technologies and innovations.

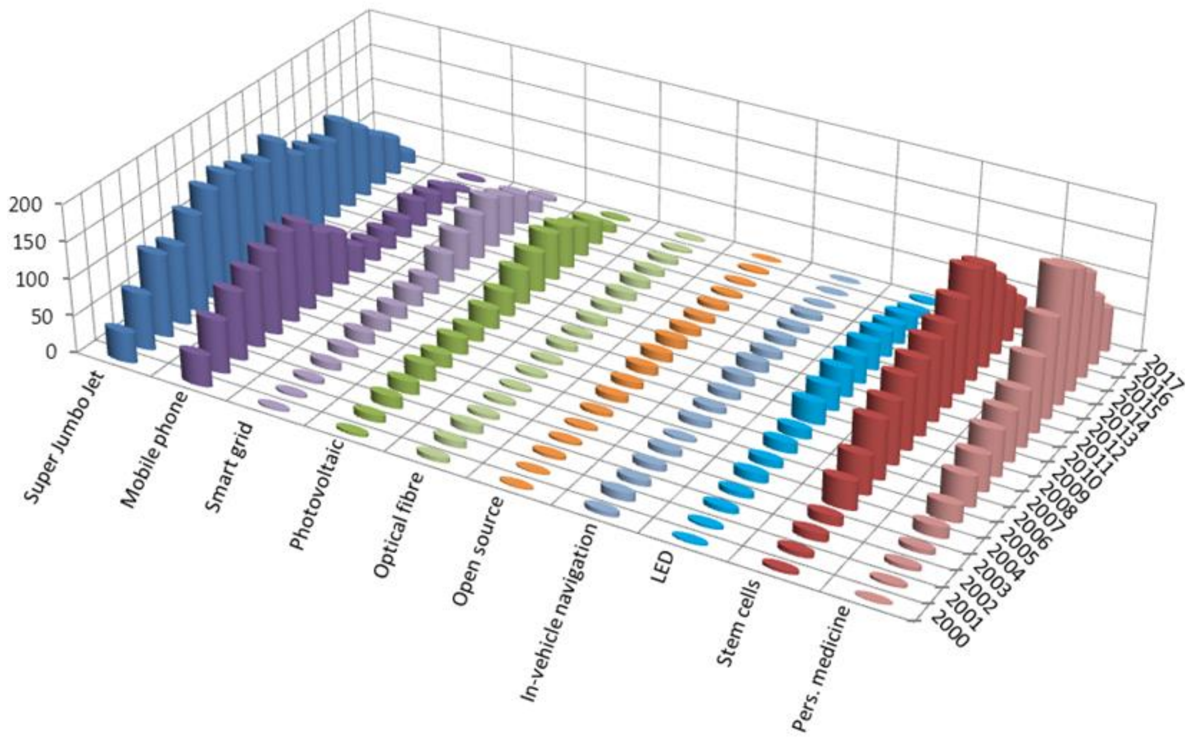
When applying the TIS framework to assess the role of FPs in the innovation system, it becomes apparent that both FPs and the regulatory framework can play a key role in supporting the seven functions of innovations, as illustrated by the table below:

TIS Function	Role EU policy and FP's
Entrepreneurial activities	•Regulation plays a role here, to remove barriers, allow easy entry to the market. •The FP's as such play a complementary role
Knowledge development	•A key role for the FP's •Also policy as a driver (energy policy for instance)
Knowledge diffusion	•A key role for the FP's •networking and diffusion of knowledge have been a key pillar in the FP's
Guidance of the search	•A key role for the FP's •in particular in the programming phase where strategic directions are chosen
Formation of markets	•A complementary role for the FP's •in particular in the programming phase where strategic directions are chosen
Mobilization of resources	•A key role for the FP's, especially in generating a sufficiently large pool of knowledge resources. •Financial resources and facilitation of access to finance are important factor
Creating legitimacy	•A complementary role for the FP's, mainly through including all stakeholders in different phases of development; A key role in managing the policy process and engaging stakeholders also in regulation and policy

Table 5: TIS framework and roles of EU policies and FP's

Funding of FPs to major Innovations case studies

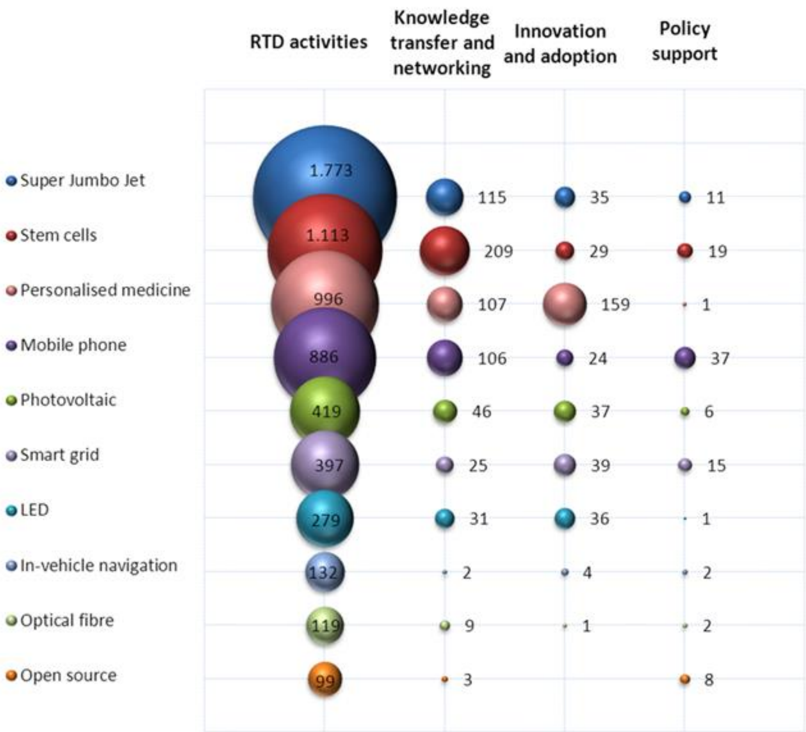
The total contribution of FPs to R&D activities increased over time. The figure below shows the annual EC financial contribution to the selected ten Major Innovations through the Framework Programmes from FP5 until FP7 (from the first FP5 projects starting in 2000 until the last FP7 projects that will finalise in 2017).



It emerges that the EC contribution to the development of personalised medicine rises significantly in the recent past and towards 2017 (based on currently available FP financial data[3]). It claims the overall first place, followed by stem cell treatment and the Super Jumbo Jet (which over the entire period received most funding). The EC contribution to mobile phone technologies declined from FP5 and 6 towards FP7. Smart grids and Photovoltaics show a gradual increase. The other four Major Innovations received stable support at lower levels.

Looking at the various instruments to support the MIs (research and technology, knowledge transfer, innovation and policy support), the EU contributions to the ten Major Innovations looks as follows:

[3] The data available include funding allocated until end 2014, which explains the perceived declining trend from 2016 onwards. Future funding will be additional to what is presented in this graph.



Detailed analysis of FP contributions to Major Innovations

The FPs can contribute to the Major Innovations in different ways. The study has focussed on gathering evidence on seven different types of contributions of FPs5-7 to Major Innovations:

Evidence for the contribution of several FPs to the Major Innovations Source: JIIP

✓✓ evidences ✓ weak evidences × no evidence		Car Navi-gation Systems	LED Light-ing	Linux Oper-ating System	Mobile Phones (MP)	Super Jumbo Jet (A380)	Opti-cal Fibres (OF)	Personal. Medicine (PM)	Photo -voltaic (PV)	Smart Grids (SG)	Stem Cell Treat ment (SCT)
Contribution to the initiation and emergence (origin)	FP5 FP6 FP7	× × ×	× × ×	× × ×	× × ×	× × ×	× × ×	× × ×	× × ×	× × ×	× × ×
Contribution to the development and introduction of one of the major successes	FP5 FP6 FP7	× × ×	× × ×	× × ×	× × ×	× × ×	× × ×	× × ×	× × ×	× × ×	× × ×
Contribution to the conceptual basis for regulatory development, policy development and standardisation (focus on externalities and synergies)	FP5 FP6 FP7	× ✓ ✓✓	× × ×	× × ×	✓ × ×	✓ × ✓	✓ × ✓	✓ ✓✓ ✓✓	× ✓ ✓	× ✓✓ ✓✓	✓ ✓✓ ✓✓
Contribution to broad explorations of new	FP5 FP6	✓ ✓	✓ ✓	✓✓ ✓	✓ ✓✓	✓ ✓✓	✓ ×	✓ ✓✓	✓ ✓✓	✓ ✓	× ✓

technological possibilities	FP7	✓✓	✓✓	×	✓✓	✓✓	✓	✓✓	✓✓	✓	✓✓
Contribution to the broader diffusion and downstream application of Major Innovations (focus on spill overs, transfer from frontrunners to followers)	FP5 FP6 FP7	× ✓ ✓✓	✓ ✓ ✓✓	× × ×	✓ ✓ ✓✓	✓ ✓✓ ✓✓	✓✓ ✓ ✓	× × ×	× × ×	× × ×	× × ×
Contribution networking and collaborating, exchange of ideas and open innovation (possible focus on next generation innovation)	FP5 FP6 FP7	✓ ✓✓ ✓✓	✓✓ ✓✓ ✓✓	✓ ✓ ✓	✓✓ ✓✓ ✓	✓ ✓✓ ✓✓	× ✓ ✓	✓ ✓✓ ✓✓	✓ ✓✓ ✓✓	✓✓ ✓✓ ✓✓	✓ ✓✓ ✓✓
Contribution to capacity building and strengthening technology competence or sectoral systems piggyback to (light house effects of) Major Innovations	FP5 FP6 FP7	× ✓ ✓✓	✓ ✓ ✓✓	× × ×	✓✓ ✓ ×	✓ ✓✓ ✓✓	✓ ✓ ×	✓ ✓✓ ✓✓	✓ ✓✓ ✓✓	✓ ✓ ✓	✓ ✓✓ ✓✓

When looking at individual FPs, one can conclude that:

1. **FP5** has contributed most through capacity and network building, finding partners for joint research and innovation. It did not provide a strong contribution for standard-setting and regulation. FP5 did not contribute to the initiation or core development of the selected Major Innovations, due to the exploratory nature and the timeframe of FP5.
2. Similarly to FP5, the FP6 funded projects did not contribute to the core development of breakthroughs among the Major Innovations. Although FP6 made contributions to incremental technological improvement (e.g., in the case of the Super Jumbo Jet), it cannot be causally linked to important steps of development of the selected Major Innovations. On the other hand, FP6 made considerable contributions to the broader diffusion and downstream application of the selected Major Innovations. Except in the photovoltaics case, FP6 was considered to contribute significantly to the identification of new partners, networking and collaborating, exchange of ideas and open innovation. FP6 funding also contributed to a greater extent to more incremental and/or peripheral but profitable technological innovations in the fields of LED lighting, mobile phone and photovoltaics. In the case of stem cells (where FP6 had committed itself with all due caution) as well as in the case of personalised medicine, FP6 contributed much more strongly to the conceptual basis for regulatory development and standardisation, e.g., the set-up of common databases funded by FP6, which had been identified as a relevant factor for both personalised medicine and stem cells.
3. **FP7** contributed more directly to development of downstream applications (e.g., in the Jumbo Jet and car navigation). FP7 also contributed much more strongly to developing new technological possibilities compared to FP6. The foundation of the European Research Council might lay the ground for future technological breakthroughs. Joint Technology Initiatives, other

‘multi-lateral activities’[4] together with European Technology Platforms, support the coordination of innovation topics at the European level and between the European and national levels. During FP7, European technology platforms relevant for the Major Innovations have been established, e.g., the European Photovoltaic platform – EU PV TP, the Smart Grids or the Platform, Advisory Council for Aviation Research and Innovation in Europe – ACARE. In mobile phones, a Private Public Partnership (PPP) in Advanced 5G networks for the Future Internet (5G) was launched. Among others, photovoltaic energy is covered by the KIC (Knowledge and Innovation Community) for sustainable energy. FP7 also started cooperating with the European Investment Bank, to provide follow-up investment for projects. That can be of importance to take research results towards applications, also in Major Innovations.

Overall messages on the FP contribution to Major Innovations

Most experts in the online survey for this study indicate that the FPs were important to their innovations. Indeed, 626 experts took part in FP projects contributing to Major Innovations, of whom 433 respond that the FP was important for their innovation, and 312 that their progress would not even have been possible at all without the FP. Overall, the FPs have contributed (to various extents) to developing already existing innovations further, on top of the already existing core developments in the Major Innovations.

For several Major Innovations, the fragmented international research community had to be brought together. This meets the core elements of FP project funding. Referring to the cases investigated, it can be said that FPs contributed to **networking and collaboration** as well as to the exchange of ideas in the case of all Major Innovations. Except for LED and Linux, experts interviewed emphasised the significance of the combination of technologies and interdisciplinary cooperation, and in the cases of personalised medicine, photovoltaics, smart grids and stem cells, joint creation with specific partners.

Regarding the beneficial effects of networking, it is evident that contacts extend well beyond the lifetime of a project, often leading to follow-up projects; the value of networks is intangible and difficult to measure, however. Considering the frame and practice in different sectors, this also included elements of open innovation (personalised medicine, stem cell treatment, photovoltaic panels, car navigation systems and mobile phones). In the cases of car navigation systems, LED lighting, optical fibres and photovoltaic panels, FP participants indicated positive impacts of the FPs concerning improvements of user-producer relations.

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[4] Future & Emerging Technologies(FET) Flagship Initiatives support collaborative Research Projects addressing high risk-ideas as the basis for radically new technologies;

Joint technology Initiatives (JTIs) support large-scale multinational research activities.

Public Private Partnerships (PPPs) coordinate research agenda in fields of strategic importance for European industry or society and launch open calls in FPs.

The European Institute of Technology (EIT) is the first EU initiative to integrate the technology and innovation agenda of all three sides of the Knowledge Triangle (higher education, research and business) by way of so-called Knowledge and Innovation Communities (KICs).

Elements of **entrepreneurship and financing follow-up** steps turn out to be crucial (maybe in combination with open innovations), but they were not in the (pre-competitive) range of FP 5 and 6 projects. In FP7, steps have been taken in that direction.

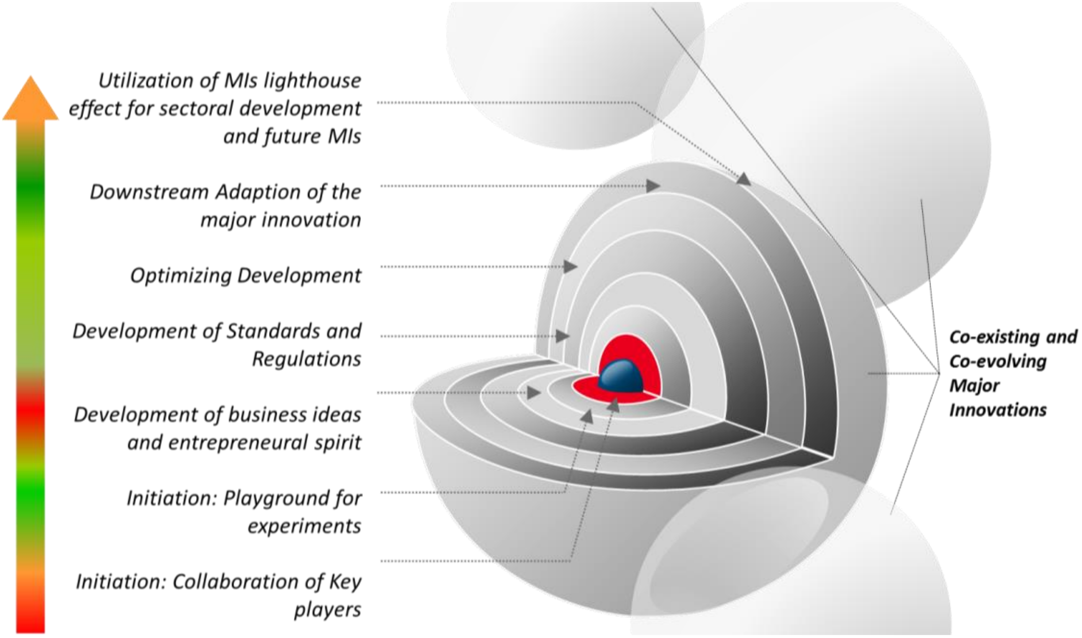
The case study analyses confirm that for all Major Innovations (except for Linux and smart grids), single hotspots and players drove technology development significantly. Thus, the involvement of the **key players** in a (potential) Major Innovation is an issue for FPs. Some publications stress the risk that FPs could be dominated by large companies in oligopolistic settings. However, the absence of key players would raise the opposite risk of the FP projects being side-tracked. We found that FP7 was rather more successful in involving them than the previous FPs.

FP6 and FP7 set much more emphasis on **coordination** of R&D and innovation policy in Member States. This might have been an outcome of the FP accompanying ERA activities or simply favoured by the fact that the all investigated Major Innovations and key players had already been broadly recognised at that time. This broad bundle of multilateral ERA activities helped coordinate strategic research agendas in Europe.

The majority of the experts in the survey noted that the FPs helped to bring Major Innovations more to the **core of the firms' activities**. This was the case for personalised medicine and stem cell treatment, where FP funding was accompanied by awareness and community building activities. It also seemed to work for mobile phones and the upcoming area of mobile applications, and for the optical fibres, photovoltaics and smart grids where new technologies needed to be adapted and taken up in procurement strategies.

As indicated by firms in the cases of mobile phones and personalised medicine (in FP6), as well as to a certain extent by firms in the car navigation case (in FP7), the Framework Programmes increasingly contributed to definitions of common technical **standards**. Furthermore, FP6 and FP7 projects also contributed to conceptual bases for regulatory development, for instance concerning the use of embryonic stem cells or the requirements for advanced medicines. These issues might not have been important for the emergence of all Major Innovations, but were key for a quick development of policy and governance approaches. Overall, projects focusing on standardisation or regulatory development amount to a small fraction of the total funding of the FPs, but these elements are important to include all stakeholders and interests in the area of Major Innovations.

Finally, Major Innovations can have a **lighthouse effect** in the sense that they attract other policies and organisations lining them up towards a joint challenge (see figure below). In terms of capacity building and strengthening technology competence or sectoral systems, lining them up towards a joint challenge, FP7 made the biggest contribution to this aspect.



Messages for H2020 and beyond

It should be noted that many of the new instruments and policies in H2020 go in the direction of our recommendations. We cannot yet assess how effective the new instruments are, and the recommendations below are based on the findings of the analysis of FPs 5-7 in the current and other related studies[5]. Activities prior to FP5 could not be taken into account.

Based on the findings of the Major Innovation cases, it should be stated that due to the complexity of innovation processes, individual FP projects or even FPs cannot bring forward Major Innovations by themselves. Major Innovations are triggered by a multitude of economic and societal factors and Horizon 2020 is just one part of a much bigger puzzle.

To make the puzzle of public policy that stimulates (major) innovations, three aspects matter:

- Getting the framework conditions right;
- Coordination of multilevel governance;
- Respect sector differences and foster sectoral linkages and cross sector elements.

Getting the framework conditions right: other parts of public policy do matter for the incubation and maturation of Major Innovations. At the EU level, this includes both specific policies and framework conditions. Examples are standardisation and intellectual property policies, as well as lead market initiatives, innovative public procurement, education policy stimulating the supply of qualified workers, the common and open trade policy with third countries, the common currency, and a strong European single market, both for goods and services. But also other sectoral policies matter, like energy (driving LED and photovoltaics), market liberalisation (driving mobile phones),

[5] For example: R.Fisher, W.Polt, N. Vonortas: The impact of publicly funded research on innovation- An analysis of European Framework Programmes for Research and Development; 2009;
R.Fisher, W.Polt, N. Vonortas Economies of scale and scope at the research project level, 2011
F.Malerba,. N.Vonortas, R.Fisher: ICT network impact, 2012

health (driving personalised medicin and stem cells) and combinations of policies (like transport and energy drinving smart grids). Support to research and innovation is thus a part of the broader public policy-mix, which should be approached in a coherent manner. This puts high demands on the coordination and dialogue between research and innovation, and other policies of the EC.

Coordination of multilevel governance: the full public policy puzzle is even more complex. It not only includes the EU level but also the national and the regional policy levels. Cluster policies at the national and regional levels, inspired by smart specialisation strategies, help to boost and nourish Major Innovations. A pro-active integrated and coherent strategy should encourage and accompany the development and market uptake of Major Innovations. Creating and nourishing a viable and conducive eco-system in which Major Innovations can emerge and prosper, requires therefore much more than Framework Programme policies alone. Stronger interaction and co-ordination is not only required at the EU level, but also between the EU and the national and regional levels, to be able to reap the benefits of complementarities and to avoid duplication. Here, important steps towards reinforcing the European Research Area have already been taken by joint programming activities, joint schemes for mobility of researchers and transnational cooperation in research infrastructures, to mention a few. Systemic strategic forward-looking thinking and systematically defining the policy steps needed at each level is part and parcel of a public policy that fosters Major Innovations.

Finally, sector differences have to be taken into account. Requirements and conditions for the emergence of Major Innovations (be they infrastructure, technology, capital, knowledge, skills, regulation, or standardisation) as well as their innovation cycles, value chains and eco systems differ significantly per sector: bringing a new product or service to the market is an entirely different process in aerospace than it is in pharma, energy or ICT. The global competition landscape equally differs significantly per sector, and for instance competition policy can have a major impact on the success in innovation and the return on investment as is, for instance, demonstrated by the photovoltaic case. Next to sectoral differences, there are also sector inter-linkages and cross-sector elements that are crucial to innovation. The development of an innovative car will require not only innovations in materials, ICT, energy, sensors, but also infrastructural innovations, regulations, and many other technology, sector and policy areas. Recent policy developments at EU level, such as H2020 with its mission and challenge orientation and the Key Enabling Technologies (and in particular the focus on cross cutting KETs and multi KETs involving for instance DG CONNECT, RTD and GROW), are promising steps towards cross domain and more systemic approaches.

Messages on policy evaluation

Key elements for measuring the broader picture of innovation impact are:

1) *The measurements of impacts should take place at all levels*: at participant, project, sector, cross sector or programme: innovations and especially large or Major Innovations are complex processes, and cases of a one-to-one relationship between a single FP project and an innovation will rarely happen;
2) *What exactly is measured as outcomes or outputs:* While not disputing the relevance of patents as such, measuring patents as an indicators of outcomes of the FPs is useful but insufficient as other methods of protecting project results are often preferred and protection is sector dependent;

3) *Assess instruments together*: not just grants, but also the instruments introduced to coordinate ERA (e.g., ETP, JTI, JPI, KICs, PPPs, etc.) are relevant for Major Innovations, and should be taken into account in coherent evaluations;
4) Include framework conditions, such as multi or cross-domain regulation and standardisation, access to capital, and capacity: non-technological drivers or barriers play a major role in the success or failure of Major Innovations. The impact of regulation, standardisation and other (non R&D&I) policies, both inside and outside the EU, should be taken into account when measuring ex post impacts, not just at the ex ante stage (where this is more often the practice) but also in the ex post evaluations;
5) Take long time frames: a major obstacle for measuring impact on innovation from FPs is the elapsed time between a project, or set of projects and the occurrence of an innovation, this can vary between several months and decades, largely depending on the sector (ICT applications are usually closer to the market, while drug development can take 15 years or more); three types of evaluative actions are recommended (in addition to the standard practice):
    a. foresight and contextual analysis on a regular basis and embedded in a consistent approach over longer periods of time;
    b. long term monitoring of impacts, taking an object-oriented approach (the (major) innovation itself), rather than the more standard subject orientation;
    c. reflective monitoring as a learning process engaging all stakeholders.

We note that Major Innovations do not happen at the project level. It takes many projects and smaller innovations to feed into and to arrive at Major Innovations. Thus, we can make only a few recommendations for the evaluation and review of projects (specifically those at higher TRL levels) that can contribute to propensity of innovation and subsequently to potentially feed and contribute to Major Innovations:

1) the real motivations of a project determining its outcome, therefore early stage realistic assessment of the real motivations of a project on the dissemination and exploitation of the results is needed as well as ensuring capability for such assessment in the evaluator teams;
2) Many projects may have excellent outcomes from a scientific or technological point of view, but at the same time do not deliver a financeable result. Therefore employing expertise in venture capital, private equity and other types of investments is needed at the evaluation stage;
3) Framework conditions such as regulation, standardisation, policies outside the specific domain, can be critical for the success or failure of an innovation, as demonstrated in this study. Insight in the implications of these must be ensured at the proposal evaluation stage;
4) Potential exploitation outside a specific domain and relevant developments outside that domain, have to be taken into account, stimulated and evaluated where appropriate in order to establish the cross fertilisation needed to foster Major Innovations;
5) Finally, we would like to underline that the innovation process is one frequently marked with high risk and failure. The FPs and their set up should take care to allow for that. Instruments that allow for a ‘Try fast fail fast’ approach in certain domains, with short review cycles and clear exit procedures would benefit highly innovative projects.

1 Introduction

At the time of public budget constraints, major demographic changes and increasing global competition, Europe's competitiveness, the capacity to create millions of new jobs to replace those lost in the crisis and, overall, the future standard of living depends on the ability to drive innovation in products, services, business and social processes and models. This is why innovation has been placed at the heart of the Europe 2020 strategy. Innovation is the best means of successfully tackling major societal challenges, such as climate change, energy and resource scarcity, health and ageing, which are becoming more urgent by day. Examples of Major Innovations in this context are electric cars, large-scale wind turbines, bio-based materials, smart grids and personalised medicine.

Europe has no shortage of potential. There are world-leading researchers, entrepreneurs and companies. Europe made great strides in creating the largest home market in the world. European enterprises and civil society are actively engaged in emerging and developing economies around the world. Many world-changing innovations can be traced back to Europe, like the iPod. Core-elements are the electronic storage method and the data compression format MP3, both developed in Europe but commercialised in the USA.

R&D and innovation have undoubtedly become a significant cornerstone for growth in the rather unstable economic times of today. With the ever-evolving complexity of R&D processes becoming intertwined with strategy, new product development and foresight, it comes as no surprise that the key question linked to all R&D/innovation efforts is profitability. In the past, R&D was viewed more as a symbol of scientific excellence being embedded in a product; it has now become an essential vehicle for growth that is expected to produce results in a rather convoluted global marketplace that is becoming asymmetric in nature day by day.

The regular evaluation of programmes and activities is one of the main tools to provide a systematic evidence base in support of policy and decision-making. It is used by the European Commission to assess the extent to which EU interventions reach the set policy objectives and how their performance can be improved, as called for in the Commission's Communication on Evaluation in 2007.

Therefore, this study on Major Innovations sought to understand the relationship between research, technological advancement, innovation and economic performance in the context of collaborative RTD projects, funded by the European Framework Programmes, in order to make these projects and programmes more useful to foster innovation and boost economic performance among the participants.

2 Approach and Methodology

The overall study objective is to evaluate the contribution of the research programmes and projects financed by the Framework Programmes to the development of a selected number of Major Innovations. Particularly, the study departs from a list of Major Innovations and then traces back the factors, including the FPs, that brought about the Major Innovation. Particularly, the project looks at the role of FP projects during the period of Fifth, Sixth and Seventh Framework Programmes[6]. The study is not a report on success stories, in the sense of a few interesting successful cases selected on the basis of a 'good story', but it aims in the course of the different tasks (Task 1: Conceptual basis; Task 2: Selection of the number of Major Innovations for the further analysis; Task 3: Case studies; Task 4: Workshop with practitioners) to develop a robust methodology for selecting and analysing 'the' Major Innovations.

Finally, in Task 5, the study aims via a cross-case analysis to capture the commonalities and differences among the cases (Chapter 4), especially from the perspective of the role of the FP activities. The idea is not only to report the best practice but also the lessons learnt from the cases where FPs were not critical success factors for the Major Innovation as well as the lessons that permit improving the policy. The results of the study should help the European Commission further understand the effectiveness and efficiency of the Framework Programmes and to support the design of new programmes.

Figure 4 summarises the main sources and dimensions of the study. It shows that through the first two tasks – namely the development of the conceptual basis and selection of a number of Major Innovations for the further analysis – definitions for the purpose of the study could be identified, questions and categories raised, on which the ten case studies as well as the cross-case analysis relies.

The conceptual underpinnings of the study were defined through the review of theoretical foundations and methodological approaches relevant for the purposes of the study. The concept definitions together with the methodological approach for evaluating the contribution of multiple generations of EU research programmes to the selected Major Innovations form the backbone of the study (Task 1). The conceptual framework laid the foundation for the comprehensive selection procedure of the Major Innovations conducted in Task 2. In Task 3 – the core of the evaluation – in-depth analyses for each of the selected case were carried out based on the methodological approach developed in Task 1. Typical for case studies, the analysis included complementary elements of qualitative and quantitative research (e.g., desk research, qualitative expert interviews, online surveys) and provided indication of the projects financed by the Framework Programmes relevant to the development of Major Innovations.

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[6] The time period between laying the foundation of inventions and the actual Major Innovation, which by definition is an innovation that has already led to important economic or societal impact, would actually favour an even longer time perspective, i.e., inclusion of FPs prior to FP4, but due to data and informant availability, the study is limited to FP5-FP7.

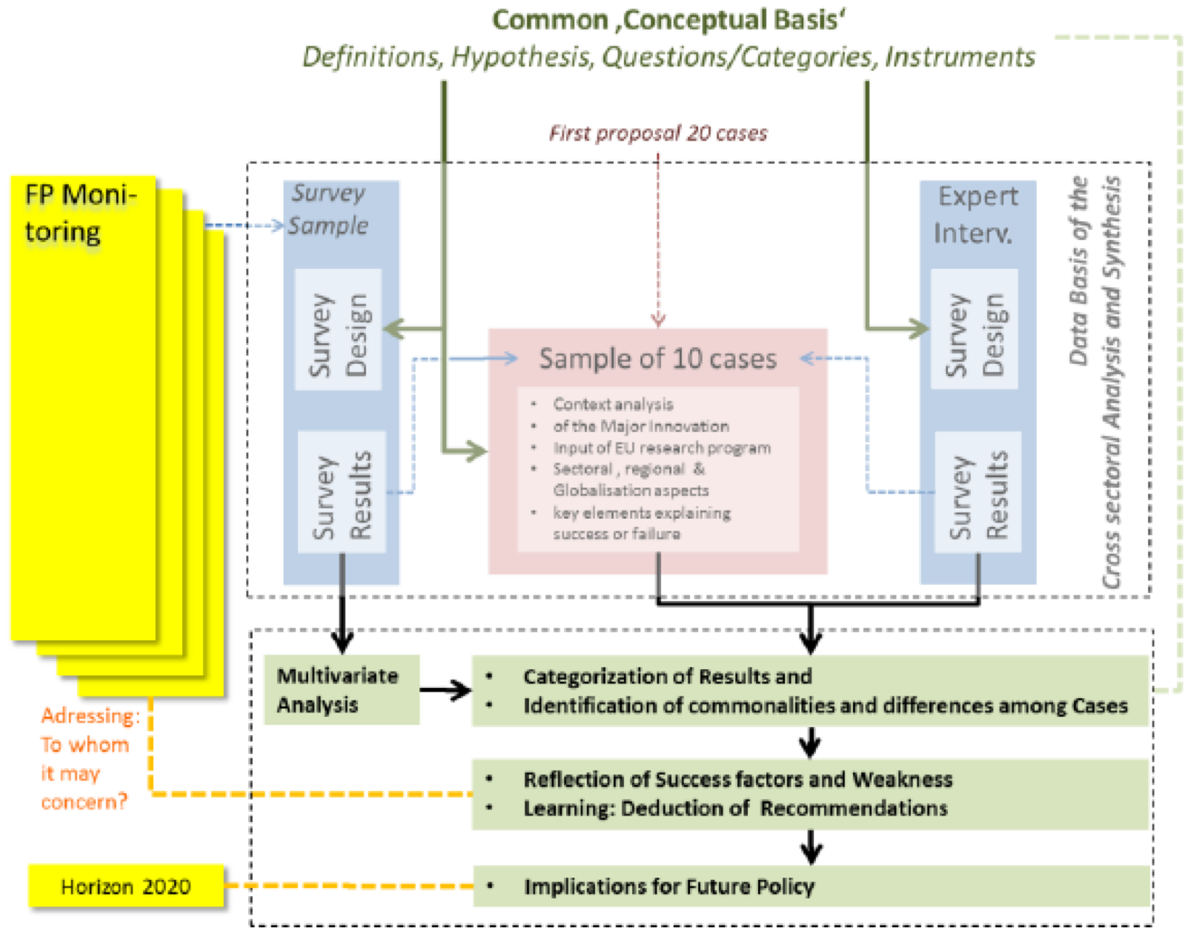

Figure 4: Approach to the study on Major Innovations Source: JIIP

In the final step – Task 5 Cross-Case Analysis and Synthesis, Conclusions and Policy Recommendations – all cases are reflected against this common set of analytical questions and categories, which had previously been integrated in the main analysis, methods and throughout all the tasks of the study. The cross-case analysis aims to identify and discuss the commonalities and differences of the characteristics determining the ten Major Innovations. Especially, the objective is to analyse the differences in the role of the Framework Programme in initiating and supporting the development of the Major Innovations.

2.1 Overview of the methodology

2.1.1 Conceptual and analytical framework of ten Major Innovations

An important motivation in the MI project is that sophisticated and evidence-based RTDI policy strategy and policy-making requires a profound understanding of empirical processes and dynamics of innovation. The analysis of ten Major Innovations follows the logic of non-linear chain-linked model of innovation by Kline-Rosenberg (Figure 1) which consists of essential elements, dimensions and dynamics with feedback loops.

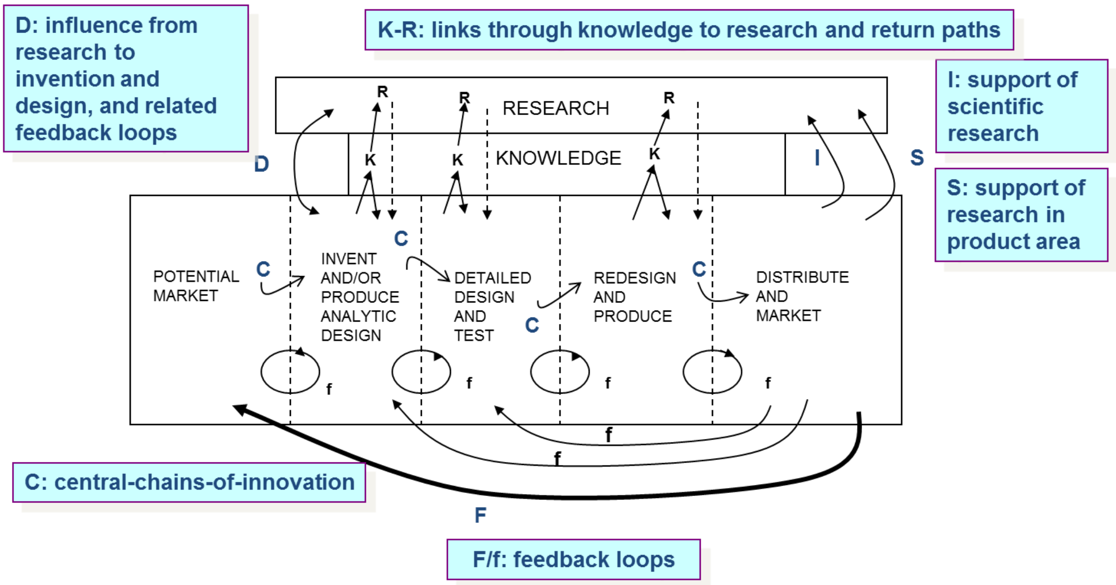

Figure 5: Kline-Rosenberg model of innovation process (Kline and Rosenberg 1986)

In the MI project, ten Major Innovations are analysed in the contextual framework consisting of drivers, resources and capabilities, such as market demand, social challenges, regulations and various policies, including RTDI policies and FPs of the European Commission (Figure 3).

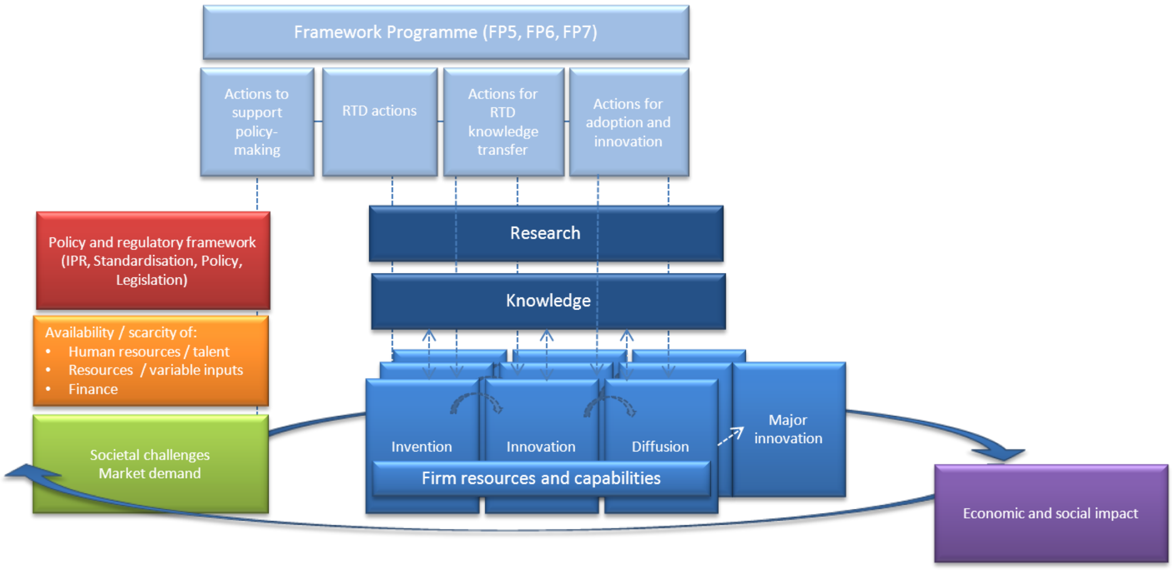

Figure 6: Contextual framework of innovation process

The key interests areas of the MI project are (1) the identification and understanding of “Major” characteristics of innovations in scientific and technological terms (radical, breakthrough, etc.); (2) the identification and understanding of the required combined processes and dynamics of successful research, innovation and business management creating and accomplishing Major Innovations; (3) the identification and understanding of the “Major” characteristics in terms of business, economy and market impacts enhancing the competitiveness of the European industries in worldwide markets; (4) the identification and understanding of “Major” characteristics in terms of societal, economic and ecological impacts emerging from Major Innovations; and (5) the identification and understanding of roles and ways by which the European Commission can contribute to creation, generation and accomplishment in different development stages of Major Innovations, supporting ultimately the legitimacy of RTDI investments by the European Commission.

Figure 4 concludes the framework, structure and criteria, given above, in the analysis and drawing conclusions on a basis of ten Major Innovation case studies and for making implications and recommendations of the various roles and contributions of the DG RTD of the European Commission to MIs.

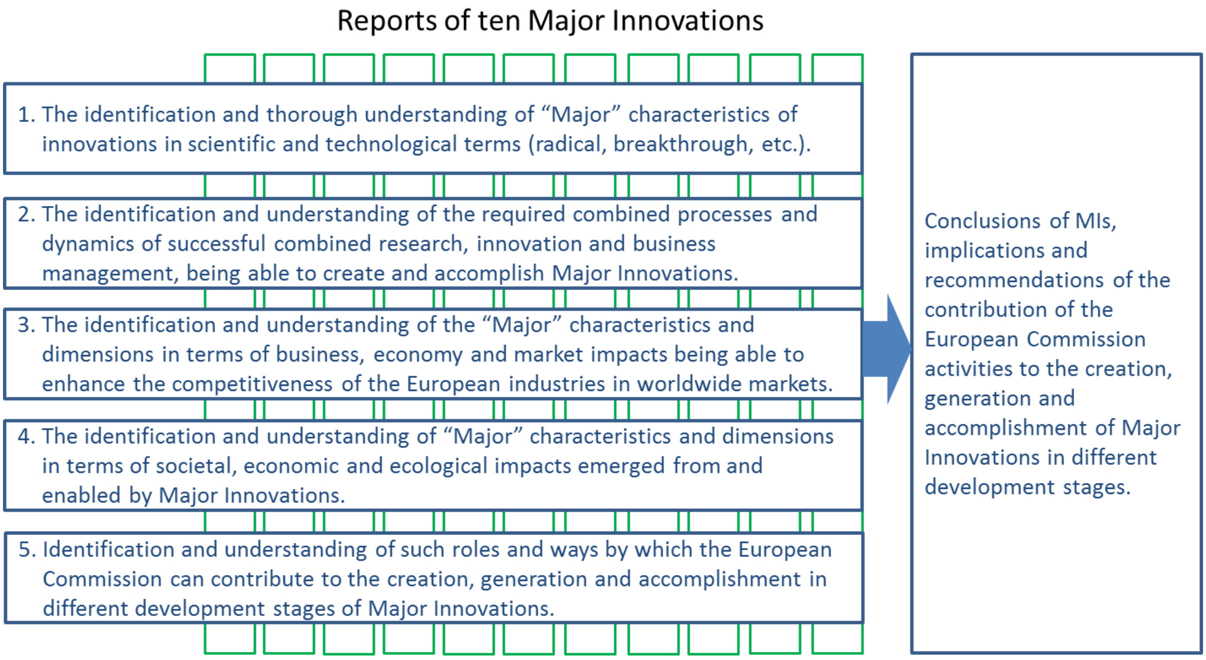

Figure 7: The framework, structure and criteria for the analysis and for drawing conclusions of the ten Major Innovation cases

In the analysis of ten Major Innovations, items 1-4 are related to various "Major" characteristics of MIs aimed at increasing the understanding of the nature and dynamics in of MI emergence, and Item 5, about the roles and contribution of the EC RTDI and other policies on MIs, which are also of importance for future development of RTDI activities of the European Commission.

2.1.2 The selection of ten Cases of Major Innovations

The selection of the ten cases of Major Innovations was based on the operational definition of Task 1. Following this operational definition, a starting list of 30 Major Innovations was created. The Knowledge@Wharton list – which includes a number of European-based/originated innovations such as MP3, fibre optics and the WWW – gave the right entry point for the level and type of Major Innovations we were looking for in the current project. The Knowledge@Wharton list gave a first direction and offered a head start for the required list of twenty Major Innovations for further analysis and evaluation in the current project. In order to arrive at a well-balanced list of Major Innovations in conformity with the tender specifications, additionally a number of issues had to be taken into account:

- Right balance in terms of innovation types (product, process, marketing, organisational; tangible/intangible);

- Right balance in terms of global impact and disruptive/radical nature;
- Geographical base/origin - European-based (linked to the European Framework Programme and hence degree of involvement of European R&D and industry);
- Time period (reference period covering FP5 (1994-2000), FP6 (2000-2006), FP7 (2007-2013)).

Taking those indicators into account and with further funnelling and selecting, 30 innovations could be presented to a selection panel consisting of and involving high-level business and innovation experts. The panel was deployed to arrive at a shortlist of 20 innovations of which 10 were eventually analysed in depth.

To give the panel a better overview of the first twenty selected Major Innovations, for each case a fiche with the basis of the information gathered was created. On the basis of those fiches, the panel was asked to make a second final selection. In this final selection, additional criteria – on top of the criteria already used (see above) – have been applied. Considerations taken on board in this final selection have been such criteria as:

- Number of FP projects identified;
- Type of FP projects granted;
- Available evaluations and impact assessments of the projects/programme parts;
- EU FP funding;
- Other funding sources;
- Global value chain / third country partnering aspects;
- Cross-over / cross-fertilisation aspects;
- Relevant cluster and/or ecosystem[7] aspects;
- Innovation cycles / 'lead' times from idea to innovation.

Like in the first selection of 20 out of 30 Major Innovations, the ultimate selection of the panel in this second selection round was supported by a short evaluation report including the main argumentation for selection, to be drawn up by the panel. The selection was proposed by the Contractor to the European Commission services, and followed by a meeting at the European Commission premises in which the representative of the Contractor and the chairperson of the panel explained the selection.

A short description of the ten selected Major Innovations is given below:

Table 6: Description of the ten selected Major Innovations

	Short description of the ten selected Major Innovations
Car Navigation Systems	The development of GPS-based in-vehicle navigation started with Japanese firms and European initiatives followed afterwards with the start of TomTom in 1991 In-vehicle navigation is an integrated system that consists of a combination of different technologies.

[7] The ecosystem model originally depicted by James Moore (1993) involves a group of firms coming together to exploit a market opportunity based on an explicit innovation architecture/platform that is defined and shaped by a dominant firm, or the keystone player.

LED Lighting	A light-emitting diode (LED) is a two-lead semiconductor that generates light when electric current is passed through it. LED produces light by combining positive and negative charges inside a chip, which consists of semiconductor material. The discovery and production of high-brightness blue and white LEDs is a product innovation and represent a major scientific and technological advancement that has transformed lighting and the lighting industry.
Linux Operating System	Linux is a Unix-like and mostly POSIX-compliant computer operating system assembled under the model of free and open source software development and distribution. The defining component of Linux is the Linux kernel. The development of Linux is one of the most significant examples of free and open source software collaboration.
Mobile Phone (MP)	Mobile phone (cellular phone, cellphone) is a wireless handheld device that allows users to make calls and send text messages among other features. Mobile phones, packed with many additional features such as Web browsers, games, cameras, video players and navigational systems, are called smart phones. Mobile phone is a part of complex telecommunication system in which data transmits between cellular networks via radio waves.
Super Jumbo Jet (A380)	The Airbus A380 is presently the world's largest wide bodied jet airliner that is characterised by a double-decker and four-engine jet airliner, it is aimed at the long-haul market following a model of big airplanes connecting major hubs. Most of the structural components of the A380 have been built in France, Germany, Spain and the United Kingdom.
Optical Fibres (OF)	Fibre optics consists of the contained transmission of light through long fibre rods made of either glass or plastics. Fibre optic cables are used for transmitting voice, images and other data at close to the speed of light. Current broadband (high-bandwidth) access is mostly related to optical fibres.
Personalised Medicine (PM)	According to the European Science Foundation (2012) personalised medicine "can be broadly described as a customisation of healthcare that accommodates individual differences as far as possible at all stages in the process, from prevention, through diagnosis and treatment, to post-treatment follow-up." The possibility to target medicine, therapy and prevention to smaller group and to individuals is based on breakthroughs in genomics and in information.
Photovoltaic (PV)	In very simple terms, photovoltaic technologies consist on transforming sunlight directly into electricity at the atomic level the photoelectric effect. This effect causes these materials to absorb photons of light and release electrons. The PV technologies which currently dominate the market are crystalline silicon (c-Si) and thin-film (TF). Novel PV concepts, currently being researched, aim at achieving ultra-high efficiency solar cells via advanced materials and photo-chemical processes.
Smart Grids (SG)	A Smart Grid is defined as one that incorporates information and communications technology into every aspect of electricity generation, delivery and consumption in order to minimise environmental impact, enhance markets, improve reliability and service, and reduce costs and improve efficiency.
Stem Cell Treatment (SCT)	Human pluripotent stem cells (hPSCs), that are embryonic stem (ES) and induced pluripotent stem (iPS) cells, show great potential for application in cell therapy of a broad range of diseases and drug discovery. First clinical applications of stem cell treatment came up at the beginning of the 1990s.)

2.2 Approach for data collection

The data collection for Major Innovations was conducted in utilising the following four complementary approaches: 1) Desk research, 2) Interviews, 3) Linking and analysing the FP data and 4) Survey. Each of these approaches is described briefly below and with more details in the Annex of this document.

Although the four basic data collection approaches were used in each case, following a unified method, the relevant importance of each approach indicated some variation. For instance, the FP analysis is not as important a source of information to cases for which the Framework Programmes did not play an important role, and similarly interviews were the chosen method to validate the existing findings, rather than sources of new information when plenty of information was readily available through previous research or expertise.

2.2.1.1 Desk research

The aim of the desk research (conducted in Task 2 and Task 3) was to have the context and main development path described for each Major Innovation. The desk research, analysing the available literature sources, formed the backbone of the study. This data gathering exercise included information searches from various sources including journals, technology and industry magazines, market data, European Commission documentation and other available information for building a preliminary picture of how the innovation was brought to the market in order to form basis for further data collection (interviews, survey, linking and analysing the FP data). The desk research was supported by customised templates detailing the analysis and providing the basic structure of the case study. The analysis of existing, and in some cases, rather scattered, literature and information sources proved to be very important data sources for the study.

2.2.1.2 Expert interviews

The purpose of the expert interviews was to validate and complement the findings of the desk research and to complete possible information gaps. The interviewees were identified through desk research. The objective was to carry out semi-structured expert interviews targeted to different types of experts in the field, leaving sufficient freedom for case-specific adjustments in both interviewee selection and interview content. Collectively, 40 interviews were undertaken varying from one to seven interviews per case. As we have experienced in other studies, it is often difficult to directly engage industry experts, which is a hindrance to developing the full picture for the cases.

2.2.1.3 Linking and analysing the FP data

Each of the Major Innovations was linked to specific Framework Programmes through keyword searches performed at the project level. The keywords were defined based on desk research and were aimed to capture the main technology fields underlying each Major Innovation[8]. The keyword searches were validated through various means, including existing listings of FP projects subject to specific theme, project lists of relevant Work Programmes and calls and, in some cases, through listings of projects of the key actors or through expert interviews in order to ensure that only the relevant projects would be included in the analysis. The descriptive analysis was undertaken based on the final project listings of each case, including analysis of funding flows over time, sub-programmes and instrument types as well as by participant characteristics (organisation type and participant geographic location). Table 7 lists the final number of FP projects linked to each Major Innovation.

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[8] The keywords are included in Annex 2a of the case studies

Table 7: Number of FP-projects linked to major innovations

	Total	FP5	FP6	FP7
Car Navigation Systems	71	26	8	37
LED Lighting	130	21	28	81
Mobile Phone (MP)	380	172	140	68
Linux Operating System	41	14	12	15
Optical Fibres (OF)	64	22	11	31
Personalised Medicine (PM)	368	27	85	256
Photovoltaic (PV)	287	70	48	169
Smart Grids (SG)	143	19	33	91
Stem Cell Treatment (SCT)	730	57	196	477
Super Jumbo Jet (A380)	319	105	88	126
Total	2533	533	649	1351

2.2.1.4 Online Survey

In the current study, an online survey was used to collect specific data on the ten Major Innovations. The data was used in the case studies and in the cross-case analysis complementary to other data and information sources (e.g., desk research, interviews, etc.). Through accessing the FP databases (constituting of over 250 000 participations from FP5-FP7) and supplementary contact details of industry players complied by Frost & Sullivan, it was possible to create a sample which could be connected to FP projects relevant for the ten Major Innovations in question. Additionally, it should be noted that for FP5 projects most lacked the e-mail address of the contact person. Since the link to the online survey was sent via e-mail, data collection regarding FP5 projects was significantly lower than the data collection regarding FP6 and FP7 projects. Therefore, in some analysis the data collected regarding FP5 projects was excluded to ensure data comparability. Figure 8 shows the respondents by country. 61.3% of respondents came from Germany, Italy, Spain, the UK, France and Italy. It is evident that most respondents were from western European countries.

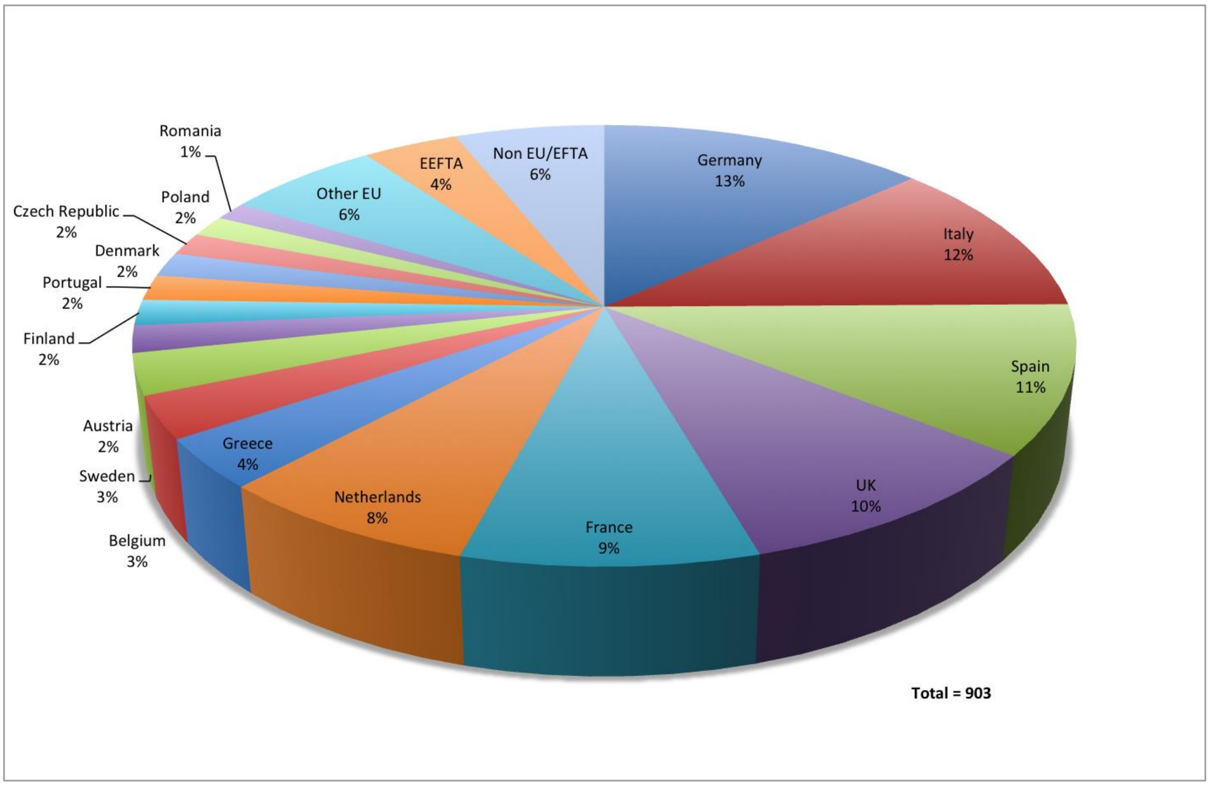

Figure 8: Respondents by country Source: JIIP based on online survey

2.3 Cross case analysis

The objective of the cross-case view is to synthesise and generalise the results, to provide the basis of the discussion of broader implications for current and future policy and the evaluation practice.

The first step is dedicated to the definition of the major success factors and significant weaknesses (based on previous tasks) to guide the cross-case analysis. A comparable synthesis of results is ensured by the fact that all ten different cases have been based on the same methodology, which has a systemic character. That means the analyses of contextual factors, the characterisation of innovation, and not only the role of public funding from the EU but also national sources, are carried out as common backbone of hypothesis and categories. All cases can be reflected against this common set of analytical questions and categories, which all have been integrated in the main instruments of analysis (interview guidelines, panel concept, items and analysis plan of secondary data analysis, survey questions). On this basis, the key common elements and differentiating factors are identified, which, in turn, guide the cross-case analysis.

Secondly, the commonalities and differences characterising the ten Major Innovations as well as the differences in the role of the Framework Programmes in initiating or supporting the development paths of Major Innovations are identified and discussed. The results will feed into the discussion of policy experts and, finally, to the formulation of policy recommendations including the evaluation and monitoring practice. These recommendations will reflect on the implications of this study for current and future policy (especially the implementation of Horizon 2020) and make suggestions that could improve future programme design, implementation and monitoring.

3 Major Innovations defined

3.1 The Innovation process

3.1.1 Background

R&D and Innovation have undoubtedly become a significant cornerstone for growth in the rather unstable economic times of today. With the ever-evolving complexity of R&D processes becoming intertwined with strategy, new product development and foresight, it comes as no surprise that the key question linked to all R&D/innovation efforts is profitability. In the past, R&D was viewed more as a symbol of scientific excellence being embedded in a product; it has now become an essential vehicle for growth that is expected to produce results in a rather convoluted global market place that is becoming asymmetric in nature day by day.

Similarly, the intervention logic of research and innovation policies is changing. From seeing R&D as the only necessary element for successful innovation (linear innovation), has been gradually changing to involve a more complex picture of innovation and including a wide variety of policy areas and instruments to support innovation activities. The importance of innovation has also steadily become more important, not only from the perspective of economic growth, but also from perspective of solving the societal challenges of our time.

Innovation has been placed at the heart of the Europe 2020 strategy as it is the best means of successfully tackling major societal challenges, such as climate change, energy and resource scarcity, health and ageing, which are becoming more urgent by day. Examples of Major Innovations in this context are electric cars, large- scale wind turbines, bio-based materials, smart grids and personalised medicine.

Europe has no shortage of potential. There are world-leading researches, entrepreneurs and companies. Europe made great strides in creating the largest home market in the world. European enterprises and civil society are actively engaged in emerging and developing economies around the world. Many world-changing innovations can be traced back to Europe, like the iPod. Core-elements are the electronic storage method and the data compression format MP3, both developed in Europe but commercialised in USA.

This chapter aims to build-up the framework to be utilised for analysing the Major Innovations. It starts with a snap-shot of the vast literature that aims to understand the innovation process, and then it describes the innovation policy intervention logic and how it has evolved overtime. What follows is some overview to the Framework Programmes together with some key evaluation studies. Finally, we present the framework for analysis for this study and some practical steps how the FP activities are linked to Major Innovations.

3.1.2 Understanding innovation process

Following the lead of Schumpeter, who first acknowledged the role of innovation in long-term economic growth, innovation and technological development are the major determinants of industrial change and consist of the introduction of **new products** (product innovation), **production processes** (process innovation) and **management methods** (organisational innovation) in an economic system.

According to Schumpeter, the cyclical nature of economic development can be explained by (radical) innovation that occurs unevenly in the economy and restructures the division of economic rents. Schumpeter identifies two major sources of innovation, namely, *new entrepreneurial firms* that distort the economy from equilibrium with radical innovations (creative destruction, Schumpeter Mark I) and *large established firms* that utilise their economics of scale and accumulated knowledge gained from systematic R&D efforts (creative accumulation, Schumpeter Mark II) to forerun technological development.

According to the so-called Schumpeterian trilogy, the process of technological development can be divided into three distinct phases: **Invention**: creation of an idea to do or make something (profitability not yet verified); **Innovation:** new product/ process commercially valuable, i.e., successfully developed inventions; **Diffusion:** the spread of a new invention/innovation throughout society or at least throughout the relevant part of society.

The work of Schumpeter has been the basis of a large body of literature that has explored the role of different factors in firms' propensity to innovate. The following aims to summarise the drivers in order to develop a framework for analysis for the Major Innovation case studies.

Innovation is demand-driven chain-linked process characterised by feedback loops

The so-called linear model of innovation suggests that technical change occurs in a linear fashion from invention to innovation to diffusion, driven mainly by research and development (R&D) activities. Innovation studies have constantly presented results against this still somewhat dominant view of innovation by emphasising how R&D may be an important factor for innovation but that it is not the only necessary element (Freeman, 1994; Kleinknecht, 1996; Marsili and Salter, 2006). For example, Kline and Rosenberg (1984) viewed the firm-level activities leading to innovation as a much more complex process formed by several steps, and more importantly characterised by continuous feedback loops between the steps. The basic starting point for innovation is *identified market need or demand* and although the following innovation process may be sequential, the process is determined by number of feedback loops that go back to existing knowledge stock before creating new scientific or technical knowledge.

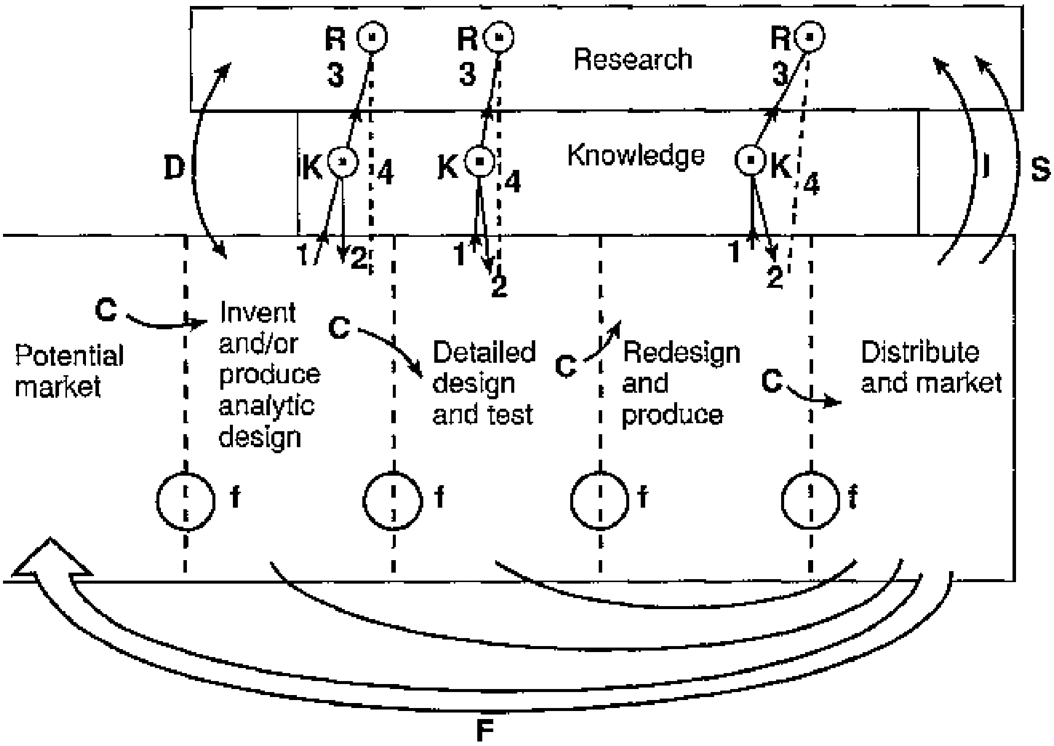

Figure 9: Chain-linked model of innovation [9]

Symbols on arrows: C = central-chain of-innovation; f = feedback loops; F = particularly important feedback.
K-R: Links through knowledge to research and return paths.
D: Direct link to and from research from problems in invention and design.
I: Support of scientific research by instruments, machines, tools, and procedures of technology
S: Support of research in sciences underlying product area to gain information directly and by monitoring outside work. The information obtained may apply anywhere along the chain.

Figure 9 above highlights the role of existing research as a source of knowledge that is used in various stages of innovation process as the great majority of innovations are not necessary based on the latest scientific or technological knowledge (Freeman, 1994), but they are often involving technological experimenting and adapting that are not necessarily rooted in formal R&D. What is important for innovation process is the firm's ability to utilise the existing research base and being capable to absorb existing knowledge that is needed for innovation. Thus the so-called "absorptive capacity" (Cohen and Levinthal, 1990) may become the barrier of innovation rather than the quality of research as such. This is why the skills to exploit the basic research and the learning capability of the human resources involved in innovation process become so important for the successful innovation (Laursen and Foss, 2003). The organisational structures should facilitate the abovementioned feedback loops and especially the accumulation of knowledge and organisational learning in order to develop the absorptive capacity required for sourcing the existing knowledge pool.

[9] Kline, S. and Rosenberg, N. (1986) "An Overview of Innovation," in The Positive Sum Strategy: Harnessing Technology for Economic Growth, ed. Ralph Landau and Nathan Rosenberg (Washington, D.C.: National Academy Press, 1986), 289.

Innovation does not happen in isolation

Innovation does not happen in isolation, rather it is characterised not only by feedback loops inside the organisation, but increasingly with actors outside the firm's boundaries. Various types of inter-company cooperation and networks have gained increased popularity during recent years. This phenomenon of open innovation has at least been attributed to increased global competition, complexity of technology and faster innovation cycles. The basic message of this line of thinking is that firm may utilise internal and external sources of knowledge for innovation in different steps of the innovation process in order to maintain abreast of competition (Chesbrough, 2003; Laursen and Salter, 2006). According to the open innovation view, the boundaries of innovative firms are becoming increasingly blurred when firms aim to sustain the maximum flexibility for the rapidly evolving markets. The utilisation of external knowledge pool, however, requires the ability to absorb the external knowledge and thus the importance of firm's absorptive capacity remains crucial. Following the understanding of open innovation on organisational boundaries the question of structure of the firm remains important as the innovation activities may include internal and external knowledge at any point of innovation cycle and firms may be embedded in various types of network structures that are aiming collectively to commercialise the innovation.

The innovation process within and between firms is embedded in operating environment providing conditions favourable for innovation. The majority of the context or innovation ecosystem factors are of policy relevance (e.g., education policy, R&D policy, industrial policy, IPR and competition policy). These include, for instance, availability of qualified human resources and labour mobility, and adequate level of public investments in R&D and mechanisms for appropriate returns on innovation activities in order to create sufficient incentives for private R&D investment. The relationship between innovation and competition has been recognised as an important determinant of innovation. The idea is that concentrated market structure enhances innovative activity, and that companies of different sizes have different incentives to invest in innovation. The explanation for sectoral differences in innovation activities is argued to be strongly influenced by the richness of technological opportunities available in the environment and by the intensity of other firms' innovation-based search activities (Nelson and Winter, 1982; Levinthal and March, 1993). In industries with high levels of technological opportunities and extensive investments in new knowledge development by other firms, a firm is prone to use internal and external knowledge sources in order to gain access to critical knowledge in an efficient and timely manner. In contrast, in industries characterised by lower technological opportunities and modest investments in R&D, there are weaker incentives to search for external knowledge sources and a firm may instead rely on solely internal ones (Klevorick et al., 1995).

3.1.3 Innovation systems, contextualising innovations

The concept of the innovation system stresses that the flow of technology and information among people, enterprises and institutions is key to an innovative process. It stresses the interaction between actors who are needed in order to turn an idea into a successful process, product or service in the marketplace.

Following the technology innovation system (TIS) framework, which is based on the central idea that the analysis of the targeted dynamic innovation diffusion should focus on systematically mapping the activities that usually take place in innovation systems and finally resulting in the innovation diffusion, those activities are considered to be functions of innovation systems.

As the name implies, the TIS framework concentrates on technological change. The analysed cases also comprise technological innovations but also non-technological innovations. Since non-technological innovation is related to larger innovation systems, which also include technologies, the TIS framework covers both technological and non-technological.

Following (Hekkert et al., 2007) an innovation system analysis is based on seven functions:[10]

1. "Entrepreneurial activities" maps the level of concrete actions taken by new entrants or incumbent companies generating and taking advantage of new business opportunities. Possible indicators may comprise the number of new entrants or diversification activities of incumbent actors.
2. "Knowledge development" maps the system's ability to learn, either by searching (research) or by doing (development). Possible indicators may comprise the number of R&D projects, patents or technology learning curves.
3. "Knowledge diffusion through networks" maps the flow of information exchange within knowledge networks. Possible indicators may comprise the number of workshops and conferences devoted to the specific innovation and other network activities.
4. "Guidance of the search" maps the selection from the results of the knowledge developing activities. Since financial resources are limited, strategic decisions by industry and government set foci guiding future investments and influencing the direction of change. Possible indicators may comprise targets set by industry or government and the number of journal articles related to the specific innovation.
5. "Market formation" maps the competition process with the embedded solution the innovation aims to replace or to change. Possible indicators may comprise the number of introduced niche markets, specific tax regimes and new environmental standards.
6. "Resource mobilisation" maps the financial and human capital resources that are needed for all the activities within the innovation system. A possible indicator may comprise funds made available for long-term R&D programmes and capacity-building policies.
7. "Creation of legitimacy" maps the process of how the specific innovation becomes part of an incumbent regime or even overthrows it. This process is guided by advocacy coalitions, parties with vested interests in the "creative destruction". A possible indicator may comprise the rise and growth of interest groups and their lobby actions. Another form can be role model uptake, such as Obama installing Photovoltaics to supply the White House in 2013.

These seven functions are used in this study to analyse the Framework Programmes (5.1).

3.2 From Innovation to Major Innovation

What distinguishes a Major Innovation from an innovation? Before we turn to Major Innovations, it is useful to re-consider the innovation concept. As described above, Joseph Schumpeter (1934) was the first to distinguish innovation from invention. Invention is a creative undertaking, but without economic relevance as such. Innovation, on the other hand, is an economic act: an organisation

[10] Hekkert, M.P., Suurs, R.A.A., Negro, S.O., Kuhlmann, S., and Smits, R.E.H.M. (2007). Functions of innovation systems: A new approach for analysing technological change. Technological Forecasting and Social Change *74*, 413–432.

(usually a firm) applying an invention in the market place, thus making an economic and/or societal contribution.

One of the most useful and widely applicable definitions from the viewpoint of public policy, economics and management is given by the OECD OSLO Manual (2005). An innovation is defined as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations" (OECD, 2005:46).

Three conditions can be defined for what makes an innovation 'major', allowing for ex post identification and evaluation of a Major Innovation. Innovation can be approached from various vantage points and domains: technological, economic, and societal. Major Innovations are associated with changes that can be considered major – important or significant in one or more dimensions – when seen from a (combination) of these vantage points. Taken together, the three domains should reflect both a level of newness and a level of importance or influence. Indeed, literature on innovation has identified distinct dimensions of 'newness', which we can use to determine what is 'major' (Garcia and Calantone, 2002, Danneels and Kleinschmidt, 2001, Johannessen, Olsen and Lumpkin, 2001, Dahlin and Behrens, 2005).

However, it is important to clarify from which perspective 'newness' is being evaluated. This can be from the point of view of the innovator, markets, industries or societies. To denote Major Innovations, we shall exclude the viewpoint of innovators, as this could lead to qualifying mere innovation adoption as 'major'. Thus, 'major' innovations should include at least one of the following types of novelty: technological newness or market newness (i.e., new to world markets). However, as indicated above, we also argue that novelty considerations alone would be insufficient, and therefore we propose also to consider the socio-economic impact-perspective of innovations. Accordingly, innovations may have important consequences for the quality of life and wellbeing of the society. Thus, also innovations that address significant needs or problems of society, or those that shape society should also be denoted as major (see Figure 12 below). Finally, the socio-economic impact of innovations is also reflected in their pattern of adoption, or diffusion (Rogers, 1995, Wejnert, 2002, OECD, 2005). Our study considers innovations that can be qualified as being major in any of these domains.

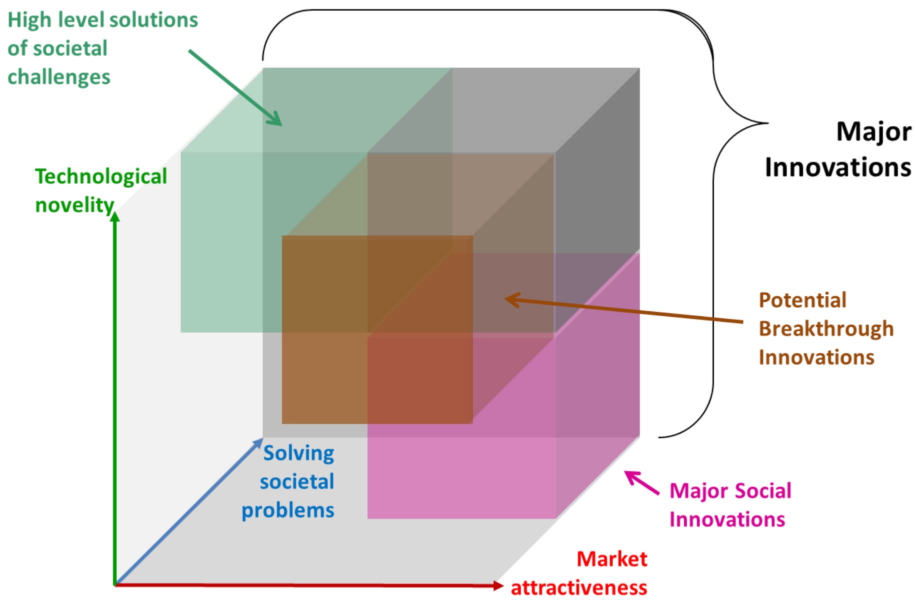

Figure 10: Dimensions of Major Innovations, Source: JIIP

A Major Innovation can, but does not need to be, a combination of various innovations. A Major Innovation thus refers to a singular or a combination of innovations, often of more than one type, that creates net benefits to the users and the socio-economic system at large in a way that deserves the adjective 'major'. Major Innovations usually do not occur in isolation, but emerge and co-evolve with others in what may be termed a family of innovations. Rather than one-off stand-alone innovations, what we observe in the real world are (sub)sets of interrelated innovations, some of which may be major. This interrelated character of certain innovations, usually a combination of different types of innovations, can also take the form of interdependencies and co-evolution of innovations. This family of innovations phenomenon is what underlies the systemic and pervasive nature of most Major Innovations.

3.3 Major Innovations in scientific and technological terms

In order to evaluate and support Major Innovations it is essential to differentiate among different arguments, which identify them as being major. The following sections collect indications and arguments showing why the selected innovations should be understood as being "major" from technological, markets, and socio-economic perspectives and compare the selected innovations along the lines of argumentation.

Technological novelty/newness of Major Innovations

The origins, novelty and breakthrough of innovation are significant concerns of business, researchers and policy in terms of radicalness and complexity. (Ebersberger et al 2005)[11] Most technologies, which are incorporated by the selected Major Innovations are not new, in the sense that they have not been developed specifically for the Major Innovation in question. Most of the relevant

[11] Ebersberger B., Laursen K., Saarinen J., Salter A. (2005) The Origins of Innovation: an analysis of the Finnish innovation database; Paper presented at the 4th European Meeting on Applied Evolutionary Economics (EMAEE): Geography, Networks and Innovation, Utrecht, May 2005

technologies applied in the Major Innovations have already been available in other technology domains. (Table 26 in the Annex provides a condensed overview of different aspects of technological novelty of the Major Innovations analysed.)

As a general pattern, technological novelty/newness of most of the Major Innovations selected is based on new “combinations” or advancements of already established technologies, knowledge and processes. Therefore, the Major Innovations predominantly can be seen as an achievement of an integration process of different already existing innovations and technologies. However, there are considerable differences between the ten Major Innovations concerning their technological origins:

1. A sub-group of the Major Innovations observed emerged from already existing intermediate technological products and processes: this group of Major Innovations show a clear combinative character. Following concepts of re-combinative invention (Utterback 1994, Fleming 2001), environmental factors and new technological opportunities offer the possibility of radical combinations and re-combinations. The selected Major Innovations ‘Mobile phones’, ‘Car navigation systems’, ‘Smart grids’ and the ‘Super Jumbo Jet A380’ primarily emerged or have been derived from previously existing technological products and processes such as advanced networks, software, hardware, communication, material, engine, power electronic and diagnostic technologies. Finally, the Linux case built on existing and partly fragmented open source elements of an operating system;
2. Another subgroup of the Major Innovations observed emerged primarily from basic research achievements, single scientific breakthroughs and technological opportunities: the selected Major Innovations ‘Stem cell treatments’, ‘Personalised medicine approaches’, ‘Optical fibres’, ‘LED lighting’ and 'Photovoltaics' can be regarded as innovations, which directly emerged from basic research in different scientific fields. The stem cell treatment and personalised medicine are based on new findings in the fields of development biology, regenerative medicine or pharmaceuticals. ‘Optical fibres’ builds on new findings of optical physics and 'LED lighting' on discoveries in material physics, crystal growth, device physics and optical physics. Similarly, the case of 'Photovoltaics' builds on previous achievements in energy, material physics and optical physics.

Technological maturity of the Major Innovations

According to Utterback and Abernathy, the progress of a particular innovation follows an S-curve. As time goes by, the maturity of an innovation (mainly originating from many minor product or process improvements) passes through different stages. Thus, innovations can be categorised as:

1) Emergent innovations: they are radical, pioneering products and practices for which universal standards are not set yet;
2) Pacing innovations: they are fast-adopting products and practices;
3) Disruptive innovations: they are commonly accepted products and practices, for which a dominant design emerged;
4) Mature innovations: established products and practices.

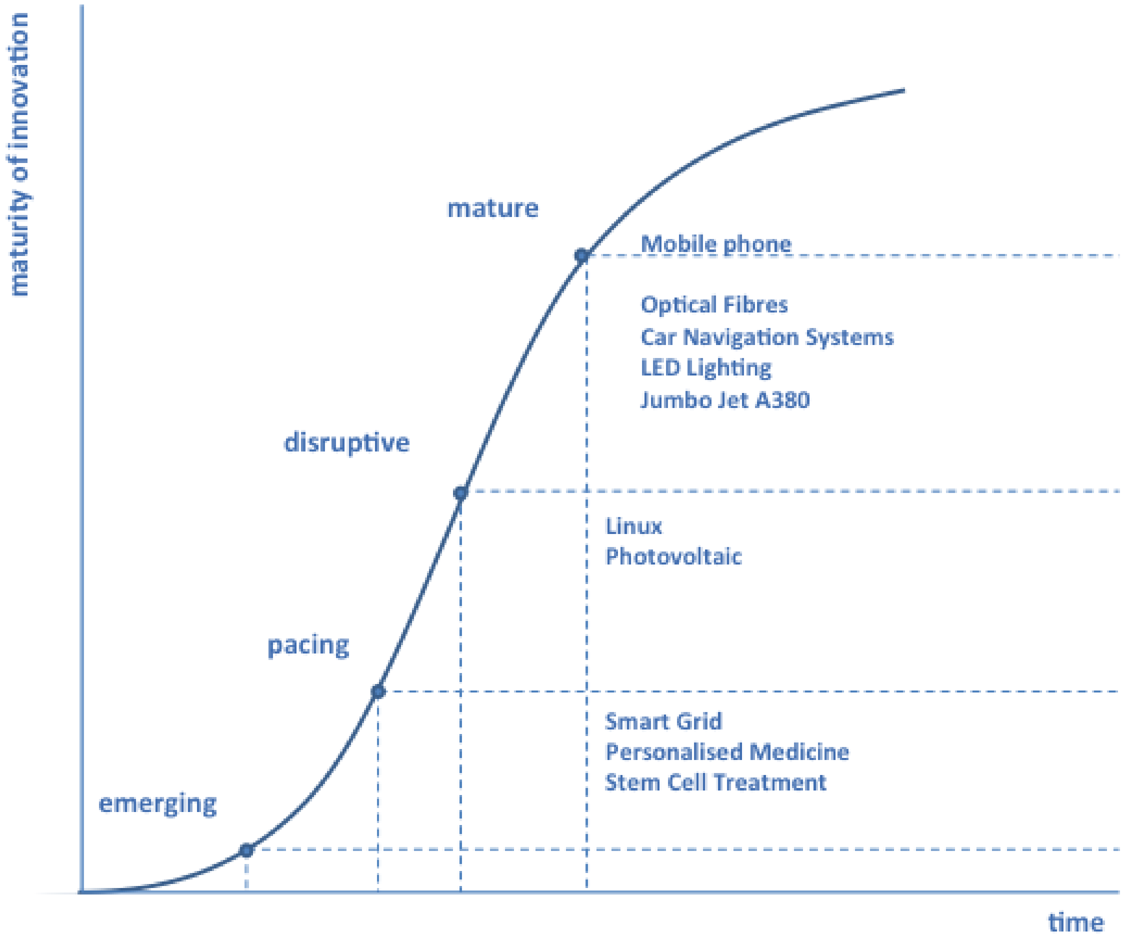

Figure 11 groups the ten Major Innovations regarding their level of technological maturity. As an innovation is described as a product or service that has been introduced in the market, eight of the ten cases have passed Technology Readiness Level 9, only personalised medicine and stem cells are still in lower TRLs. It shows that some of the ten Major Innovations in focus will reach the stage of a 'mature innovation' in the near future:

1) Personalised medicine, stem cell treatments and smart grids can be regarded as emergent innovations. They are radical, pioneering products, for which large-scale usage has not yet been reached or markets do not yet exist. Therefore, universal standards have not thus far been set and are under process;
2) Linux, photovoltaics and the Super Jumbo Jet A380 can be regarded as pacing innovations. They are fast adopting products and practices;
3) Car navigation systems, optical fibres, LED lighting and mobile phones can be regarded as disruptive innovations. They are commonly accepted products and practices, for which a dominant design already emerged. However, teething problems may yet need to be reduced by further development.

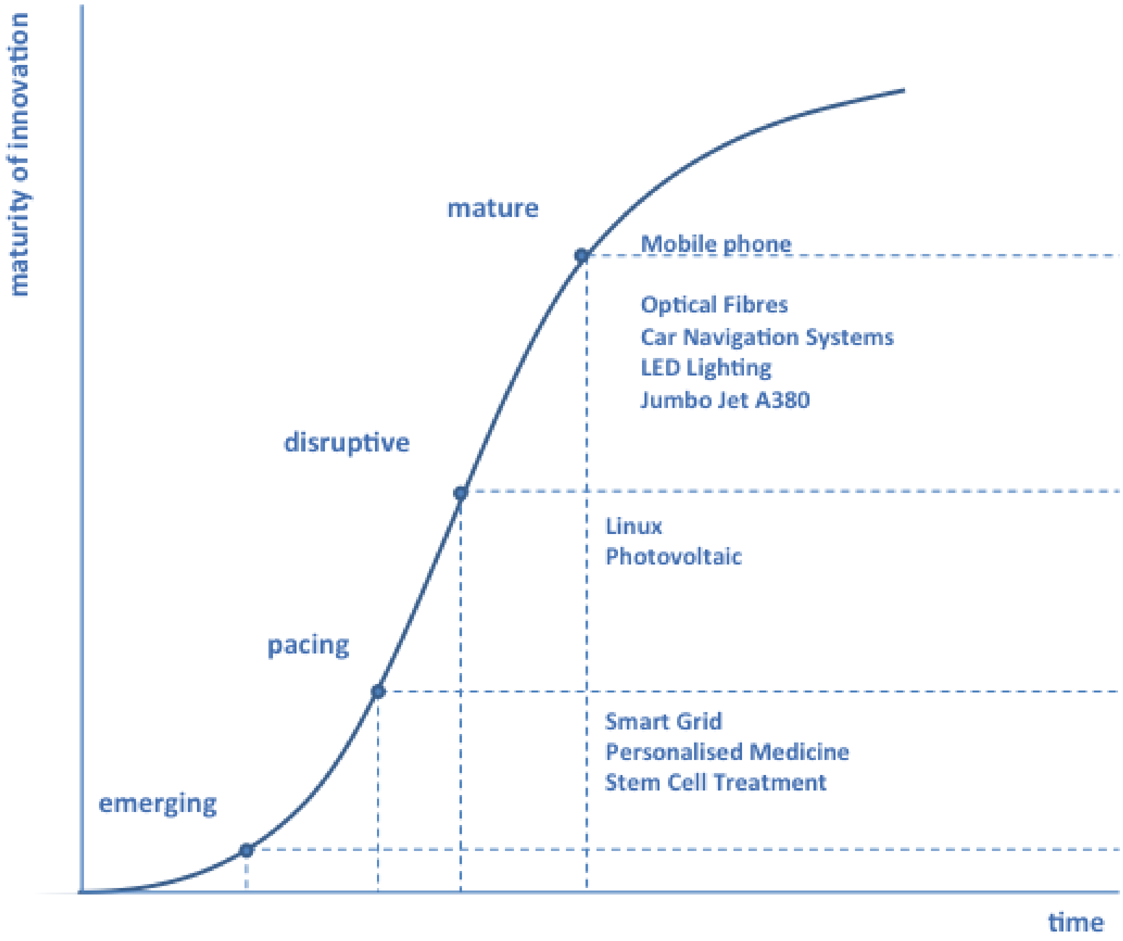

Figure 11: Maturity of Major Innovations (Source: JIIP, based on Utterback and Abernathy)

As underlined by the illustration above, some of the ten Major Innovations – optical fibres and mobile phones, and to a certain degree also car navigation – are close to being regarded as mature innovations. When observing this, it should be mentioned that innovation and product life cycles are quite different in the respective industries.

In all cases of Major Innovations, new knowledge and competences have been created which also show impacts going beyond the respective technology field. The following overview covers the main arguments, why the selected Major Innovations can be traced as being major from the perspective of their impact on the R&D and innovation system in Europe.[12]

Table 8: Impact on R&D in the related scientific field

		Co-creation[13]	Co-evolution[14]	Creation of new knowledge & competences
Car Navigation Systems		**Co-creation processes in the field of car navigation systems:** * Map Share: allowing users to add and share map changes; * TomTom's IQ Routes: uses anonymous travel time data to continuously update fastest route calculations taking into account time and day.		The combination of different technologies, such as navigation, audio, video function, and communication resulted in new technological knowledge about extensive car solutions.
LED Lighting		**Development of LEDs:** mainly driven by key scientists at universities and corporate laboratories.	**Through the discovery of white and blue LED:** the emergence of innovations such as blue laser and subsequent other innovations and research that have substantially increased the light output of LEDs.	The creation of blue and white LEDs was based on new scientific discoveries requiring completely new knowledge and combination of competences.
Linux Operating System		**Development of Linux and businesses in the software application field:** through collaboration of private and public actors in various software applications.	**Improvement of Linux:** the open source software approach of Linux has led to improvements in Linux by the worldwide Linux software development community.	This spreading of development of software among individuals and companies in Linux community has resulted in a large and efficient ecosystem and unheralded software innovation.
Mobile Phones (MP)		**Development of mobile phone and mobile communication networks:** intensive collaboration and co-creation of mobile phone manufacturers, telecommunication and network companies, service and application providers and end users of mobile phones.	**Through the development of mobile phone and mobile telecommunication technologies:** most industrial and socio-economic areas became more efficient and effective in their production and consumption solutions.	**Mobile phone and its various communication technologies (e.g., SMS, MMS, email, internet, infrared and Bluetooth communication, etc.):** creation of various forms of interactive learning, new business concepts, alleviating social and health care services or mitigation of poverty.

[12] The traffic lights indicate whether impacts on co-creation, co-evolution or new competences can be identified. Description for the light-system:

Top light: Indicates whether 'Co-creation' is obtained by the MI (red = MI was created among developers with the same scientific background; orange = MI was created among developers with different scientific backgrounds; green = MI was created by different stakeholders (scientists of different fields, public organisations, etc.)

Middle light: Indicates whether 'Co-evolution' is obtained by the MI (red = MI did not lead to the evolution of other considerable innovations; orange = MI could lead to the evolution of considerable innovations in the future; green = MI did lead to the evolution of considerable innovations. Most middle lights are green, some are yellow, none are red)

Bottom light: Indicates whether new knowledge was created by the MI (red = MI did not create new knowledge; orange = MI could create new knowledge in the future; green = MI did create new knowledge. All bottom lights are green)

[13] Co-creation defined as "Strength of the stakeholder ecosystem (industry players, R&D labs, academic institutes, government, regulatory bodies involved in accelerating innovation) and degree of involvement of users in innovation."

[14] Defined as the potential of major innovation to create change in industry, not only in terms of new processes (equipment, production methodology) but also in creating entirely new industries. Systemic nature of major innovation shows here as co-evolvement, i.e. change in one industry may trigger multiple consecutive changes in other industries.

Super Jumbo Jet (A380)		**Development of A380:** collaboration between advanced technology producers in the fields of materials & coatings, sustainable energy, ICT, advanced manufacturing, and sensors & control systems.	**Co-evolution of fuel efficiency:** it is expected that when costs decrease further, lightweight materials will be more adaptable in mass-market applications.	**The Airbus Key Competencies (AKCs):** knowledge of composites design and manufacture, architecture, manufacturing engineering and supply chain management (e.g., creation of new training programmes and career paths, to state-of-the-art knowledge management and expertise transfer solutions).
Optical Fibres (OF)		**Development of optical fibres:** existence of very few manufactures/vendors of optical fibres across the globe; technology improvements and costs/benefits are prevalent in the industry.	**Through the development of optical fibres:** gradual adoption across domains such as telecommunication, high speed internet, military and energy.	Research activities associated with optical fibres projected in-depth knowledge about optical physics, which could be employed across a wide spectrum of industries.
Personalised Medicine (PM)		**Development of PM:** major convergence of genetic data, pharma, medical technology, social media and infrastructures is needed to achieve the vision of PM.	**Through the development of PM:** adoption of pharma, biotech, medical device and data companies to completely new requirements and images of health care.	New skills and competences are needed across the “health chain”.
Photovoltaics (PV)		**Development of photovoltaics:** between PV cell and module manufacturers, material, wafer and equipment producers as well as electricity infrastructure and plant operators.	**Through the development of photovoltaics:** shaping developments of energy transmission (smart grids), energy storage and material technologies.	Development of improved and advanced materials and photo-chemical processes.
Smart Grids (SG)		**Development of SG:** important role of firms (manufacturers); in Europe, coming from the electrical sector, while in the USA, more ICT-based.	**Through the development of SGs:** new requirements for consumers in the form of applications, intelligent appliances, and consumer profiles (also becoming producers).	Strong ICT orientation with new consumer-oriented applications.
Stem Cell Treatment (SCT)		**Development of stem cell treatment:** mainly driven by key scientists at universities and corporate laboratories.	**Through the development of stem cell treatment:** significant changes of stem cell based drug development, adoption of new services and infrastructure.	Research activities associated with stem cell applications projected in-depth knowledge about various stem cells, which could be employed across a wide spectrum of treatments.

Some cases of the Major Innovations are clearly based on outstanding scientific advances whereas others are driven by more incremental improvements. What is common to all the cases is the importance of combinations of various innovations (referred to as families of innovations), often from various technologies and application fields (cross domain), to a Major Innovation. From the technological perspective, the ten Major Innovations can be broadly grouped in the following categories:

1. Integration of technologies of different domains into a working, reliable, and relatively easy and affordable system (mobile phone, car navigation system, smart grid, Linux OS, Super Jumbo Jet);

2. Innovations driven by basic science discoveries (optical fibre, LED, personalised medicine and stem cell treatment, photovoltaics).

Table 2 lists the 10 MIs and the key breakthroughs in science and technology that enabled them.

Table 9: Characteristics of Major Innovations

	Technological novelty/newness	Key technological breakthroughs
Car Navigation Systems	Car navigation systems based on various innovations (CPU and GPS navigation hardware, sensors, digital maps, screen technology and software, audio, video, other communication) is a radical and disruptive product innovation, replacing physical maps and the effort and ability to read maps.	3. GPS – global positioning system based on satellites and GPS receivers 4. Various advancements in ICT (e.g. flash memory, text-to-speech, Graphical User Interface (GUI), Bluetooth, Wifi, 3G, 4G, GPS phone, smartphone) 5. Digitalisation (digital maps, geocoding) 6. Galileo, HAD, self-driving car
LED Lighting	The development of blue and white LED represents a scientific and technological breakthrough and a radical innovation based in particular on decades of scientific research efforts related to material physics. Subsequently it has revolutionised lighting and lighting industry (new to global market). LED can be seen as a disruptive technology.	7. Light emission: semiconductor materials, technologies and processes (e.g., growing gallium nitride crystals) 8. Light management: Development of phosphor coatings to encapsulate the LED chip or the bulb cover in order to translate the blue light into white light 9. Heat management 10. Electronics: LED bulb package needs compact, economical and functional AC-DC converters
Linux Operating System	In the early 1990s, Linux as free and open source software was a unique in its kind and diffused fast. Based on improvements in ICT applications and unique characteristics of free source operating system: The end users have freedom in using, studying, sharing and	11. Improvements in ICT applications 12. Free source operating system: The end users have freedom in using, studying, sharing and modifying that software

	Technological novelty/newness	Key technological breakthroughs
	modifying that software	
Mobile Phones (MP)	Mobile phone, together with the entire mobile telecommunication system, forms a radical and complex technological system, which replaces the traditional call communication system based on analogue phone technology.	13. Advanced network technologies (e.g., HSDPA; WiMAX) 14. Advanced software technologies (e.g., MSN for cell phones, in phone video editing, etc.) 15. Advanced handset component technologies (e.g., camera, touch screen for phones, etc.) 16. Digitalisation of mobile communication technologies.
Super Jumbo Jet (A380)	The novelty of the innovation comes from quite a few aspects. These are: use of lightweight composite materials, noise reduction and high fuel efficiency, enormous transportation capacity and variability.	17. Advanced Materials (e.g., lightweight composite materials) 18. Advanced engine technologies (e.g., zero splice engine intake liner) 19. Advanced cockpit technologies (e.g., interactive displays, advanced management systems, improved navigation modes)
Optical Fibres (OF)	Utilisation of basic optical phenomenon such as refraction and reflection led to quantum computers of the present day, which is considered to be a novel innovation.	20. Semiconductor lasers 21. Microprocessors 22. Communication networks
Personalised Medicine (PM)	New classes of medicine, which are very expensive, but can be effectively used because of related diagnostic testing. Therefore major convergence of genetic data, pharma, medical technology, social media, and infrastructures is needed to achieve the vision of PM.	23. Genomic profiling 24. Improvements in diagnostic technologies (e.g., biomarkers, targeted molecular imaging, etc.) 25. Improvements in ICT and medical device technologies (e.g., Software and data management, cyber security,

	Technological novelty/newness	Key technological breakthroughs
		nanotechnology devices) 26. Biobanking
Photovoltaic (PV)	As an invention PV technology is not new. However, recent major technological advancements (e.g., thin film solar panels) have made cost of solar power comparable with that of electricity from fossil fuels.	27. Crystalline silicon modules 28. Heterojunction 29. Thin films 30. Multi-junction cells 31. Concentrated photovoltaics
Smart Grids (SG)	Part of the technology required is already available or has been used in other domains, but it is the integration of all of them (combines innovations from many areas, all KETs (except biotechnology) plus ICT) and the extreme conditions of very high voltages and currents what makes the SG complicated.	32. Integrated communication technologies 33. Sensing and measurement technologies 34. Superconductivity, storage, power electronic and diagnostic technologies 35. Advanced control methods 36. Improved interface and information systems
Stem Cell Treatment (SCT)	Stem cell treatment can be characterised as a product innovation that differs significantly from previous treatment methods. Even putatively connatural applications for different organs or sub-groups of patients significantly deviate from each other.	37. Cell therapy 38. Tissue engineering 39. Diagnostic technologies 40. Supporting technologies (e.g., Stem cell preservation methods; methods of collection processing and testing, etc.) 41. Biobanking

More than 1200 experts were interviewed (via an online survey, numbers in Annex B) concerning the ten Major Innovations. Figure 12 shows their assessment of the impact on R&D in the related scientific fields for the ten Major Innovations and distinguishes between the evident impact (the impact on R&D, which is already observable) and the potential impact (the impact on R&D, which is expected in the future). This shows that all ten Major Innovations have important observable impact on R&D, with additional potentially impact on R&D in their related scientific fields in the future.

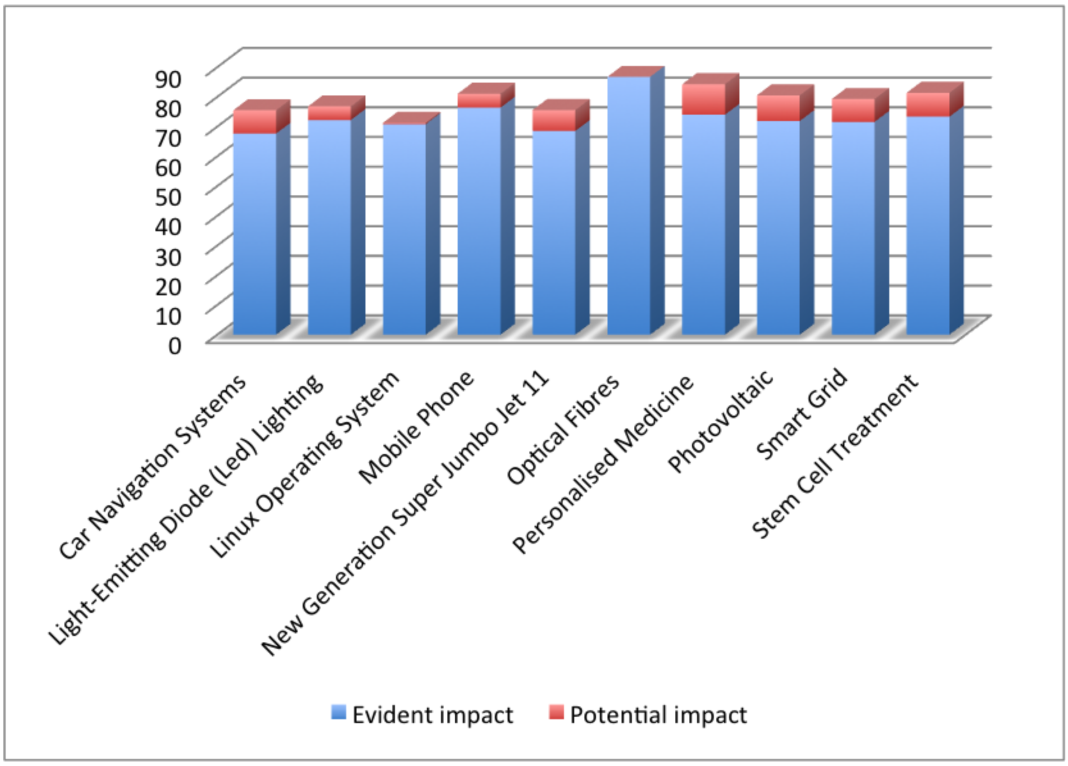

Figure 12: Impact on R&D in the related scientific field **Source: JIIP, based on online survey**

3.4 Major Innovations in terms of business, market and industry impacts

3.4.1 Economic and Market impacts of the Major Innovations

Depending on their level of embedding in different value chains, the selected Major Innovations show different paths leading to their economic impact. The stem cell value chain for instance is characterised by the profound involvement of public actors (e.g., universities, hospitals) and thus the economic impact (in terms of growth and employment) is at least for the moment mainly driven by the public sector. The economic impact of Major Innovations in the fields of optical fibres or light emitting diodes is widely spread over different value chains and industrial sectors.

For nearly all the Major Innovations, the full extent of the economic and market impact cannot yet be estimated. This is especially the case for emerging and advancing innovations. This should be taken into account when comparing the currently evident economic impact and potential future impact. Figure 13 shows different estimates concerning the evident and potential economic impact of the ten Major Innovations selected, as has been assessed by the respondents of the online survey. Personalised medicine, stem cell treatment and smart grids show the least evident economic impact. This could be explained by the fact that for those innovations no established market so far exists. Only certain applications of these Major Innovations (e.g., personalised medicine approaches in oncology or transplantation of tissue stem cells) have reached the market. However, it is predicted that the economic impact of personalised medicine, stem cell treatment and smart grids will rise considerably in the future (see Figure 13 and Box 1). On the contrary, the future economic impact of the Super Jumbo Jet A380 is perceived to be low. The present market scenario of the Super Jumbo Jet A380 concludes that it would take some time to become a commercial success. One explanation for this could be that the Super Jumbo Jet A380 was introduced to the industry when the entire aviation industry had been undergoing a financial crisis and the airlines were not encouraged to invest in a large four-engine aircraft.

Another interesting point in this context is that the evident economic impact of photovoltaics is seen as rather low, although in 2012 the PV industry production increased by 10% – making photovoltaics one of the fastest growing industries worldwide. A factor which has hindered the competitiveness of European companies in the PV solar panel market is that of dumping. European companies have openly accused the Chinese government of subsidising Chinese companies so they could be more competitive in international markets.

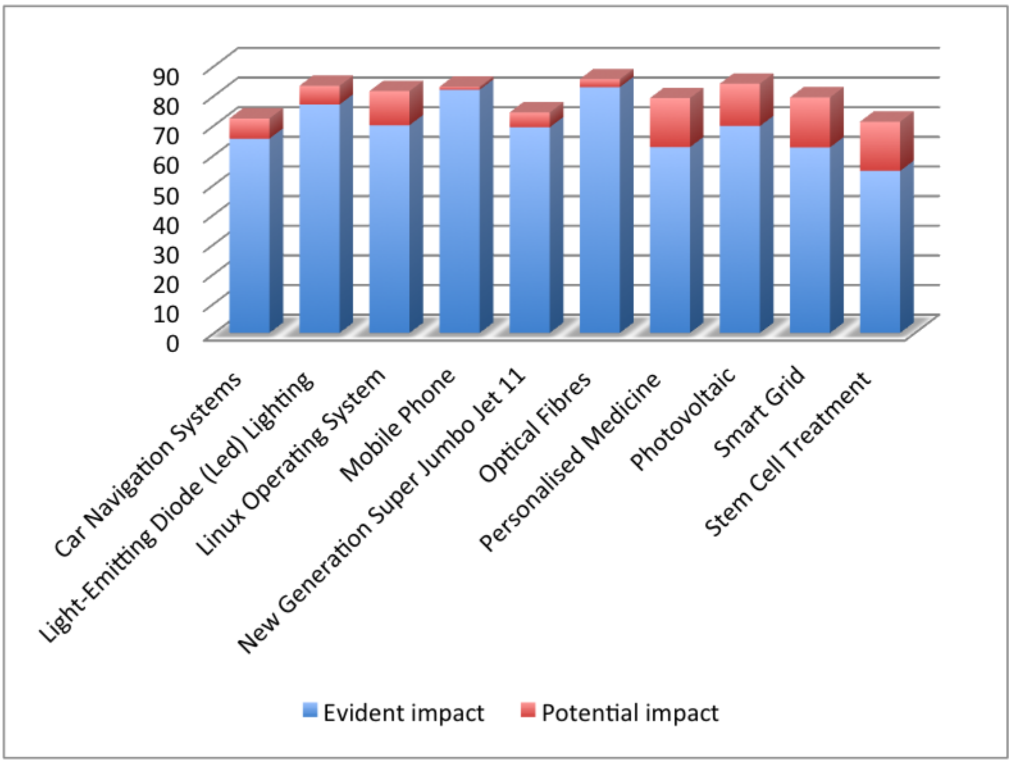

Figure 13: Economic impact of the Major Innovations **Source: JIIP, based on online survey**

Optical fibres have the highest evident economic impact. This can be seen as a logical result due to the ever-increasing demand of high speed broadband internet and high speed computing applications. LED lighting, Linux OS and mobile phones also show an increasing economic impact. In the case of mobile phones, the explanation is straightforward. The development of mobile phones revolutionised mutual connections, interaction and communication between people. Therefore, a new remarkable manufacturing industry emerged around mobile phones and telecommunication technologies, which contributes both now and in the future to economic growth.

In the case of LED lighting, the evident economic impact can be traced back to the creation of huge markets due to the numerous LED applications across different sectors. It is foreseen that a large part of the potential economic impact of LEDs can be expected with simultaneous breakthroughs in general illumination.

Box 1: Economic impact of personalised medicine, stem cell treatment and smart grids (Source: Case studies)

Personalised medicine:

Personalised medicine was first adopted in the area of oncology. Other disease areas, such as (1) immune-related, (2) paediatrics/pre-natal and (3) infectious disease areas, had already performed first transitory steps towards personalised medicine and are likely to enter the market in the near future. The biggest commercial success in the field of personalised medicine may be obtained in the development of drugs with companion/associated diagnostics and the development of advanced diagnostic techniques for screening and risk identification. Those more effective and efficient preventions and treatments contribute to managing the cost of health care and will enable new business opportunities.

Stem cell treatment:

Taking into account that there are currently only a few stem cell treatments on the market (e.g., reproduction and transplantation of skin and bone marrow), and most of them are still in the early stages of research or undergoing clinical trials, the market growth data are enormous (European share of the global stem cell market 2010: $132 million; 2017: $322 million). Stem cell treatments – similar to personalised medicine – will contribute to managing the cost of health care (e.g., reduction of costs of drug development and cancer treatments) and will enable new business opportunities.

Smart Grids:

Smart grids are still under development and far from complete, but they address current concerns about existing power systems, such as ageing infrastructure and increasing peak demand, and they are an important element to spread the use of a number of low-carbon technologies including, among others, electric vehicles and 'variable' renewables (wind, solar PV, tidal, and wave generation). Still, the roll-out of SG is not only a complex technological problem but it also requires substantial investment and a major barrier is the current economic crisis that started in 2008. Although those costs will end up being transferred to final users, it is not clear whether other savings (in fuel, gas, carbon, etc.) will compensate for these costs. However, the economic impact is expected to be important although restricted within the sector.

Industry impacts of the Major Innovations

The Major Innovations observed also showed impacts on industrial structural change. These impacts can be categorised in the following way: industry changes, industry creation and industry diffusion.

Table 10 summarises how they impacted changes in respective industries for the individual Major Innovations. It shows that each Major Innovation impacted the industries either by triggering industry change, by creating a completely new industry sector or by pushing industry diffusion forward. Only in the case of stem cell treatments, those impacts cannot yet be evidentially seen. However, it is expected that the development of stem cell treatments will cause considerable changes in the medical industry.

Mobile phones can be considered as a Major Innovation, which has already dramatically impacted various industries. It replaced, mainly, the fixed broadband phone call system and changed related industry structures. It created the mobile phone equipment industry and mobile telecommunication industry and according to the International Telecommunication Union (ITU), the number of mobile-cellular subscriptions worldwide is approaching the number of people on earth (ITU ICT Facts and Figures 2014).

Table 10: Industry impacts of Major Innovations Source: Case studies

		Industry change	Industry creation	Industry diffusion
Car Navigation Systems		3.4.1.1 Creation of economic activity in various industries which a the Satnav system OEMs and vendors comprises: * Digital mapping companies * Supplying industry (processors, GPS chips, memory storage, audio, screens/video, mobile telephony) * Service industries (weather, other car (points of interest, nearest fue station; help/safety/emergency) services, etc.).		Mass market adoption took place from the early 2000s with the arrival of portable navigation systems (PND) in 2004. Smartphone enabled Satnav to form a second wave of mass market adoption.
LED Lighting		LEDs challenged the traditional lamp manufacturing and lighting industry	* entrance of new companies to the market * creation of a new lighting industry	LED applications have diffused across various industries and sectors: * automobile; * electronic devices; * aviation; * traffic signalling; * general lighting.
Linux Operating System		**Strong impact of Linux on the fastest supercomputer business:** In 2013, more than 95% of the world's 500 fastest supercomputers ran some variant of Linux.	In 2008, IDC analyst Al Gillen cited a nearly 24% annual growth rate for the Linux industry, which values a $21 billion in 2007 technology at $49 billion in 2011. The companies involved in Linux include industry leaders such as IBM, Fujitsu, Hewlett-Packard, Oracle, Intel, Hitachi, NEC, and Novell.	Linux OS has diffused on the fastest supercomputer business.
Mobile Phones (MP)		* Mobile phone has replaced the fixed broadband phone call system mainly and hence changed related industry structures essentially. * Around mobile telecommunication and related software and application many of new industries have emerged. * Mobile telecommunication is a part of ICT revolution penetrating to and changing dynamics of most traditional industries and businesses.	* Mobile phone and cellular network industry * Mobile telecommunication industry * Applications industry: health, gaming, maps and navigation, etc.	According to the International Telecommunication Union (ITU), the number of mobile cellular subscriptions worldwide is approaching the number of people on earth (ITU ICT Facts and Figures 2014). Mobile cellular subscriptions will reach almost 7 billion by the end of 2014, corresponding to a penetration rate of 96%.
Super Jumbo Jet (A380)		Changes in the aviation market (growth of the long-haul markets).	* Long-haul markets (e.g., Asia-Europe with 116 weekly frequencies) * Creation of industries, who serve the airport requirements to support the use of large planes	* Demand for A380 is rising * Technologies developed for the A380 are expected to be adopted in other industry areas
Optical Fibres (OF)		* Replacement of copper based mechanical cables * establishment of separate optical fibre markets in industries such as telecoms, information, healthcare, energy, defence and automotive.	Although optical fibre changed and challenged different industries, it did not create so far a completely new industry.	Optical fibres applications have diffused across various industries and sectors: * telecommunication * networking * data storage * medical * transportation
Personalised Medicine (PM)		PM approaches are likely to change the health industry (e.g., companion diagnostics)	As PM will be absorbed by different market segments there is expected to be new industry creation.	Market diffusion started in the mid-2000s and is gathering pace.

		Industry change	Industry creation	Industry diffusion
Photovoltaics (PV)		Has so far not changed the conventional energy industry, but has the potential to revolutionise it.	Photovoltaic industry is rapidly growing. Its importance varies from country to country in Europe.	PV applications have diffused across various industries and sectors.
Smart Grids (SG)		The electrical industry is adapting to this technology with products meeting the requirements. In some cases, unclear benefits for utilities (who pays for the deployment). Appliance manufacturers are also adapting their products.	So far, it is mainly the evolution of existing firms that are adapting to this new environment. Some firms coming from the ICT realm are developing final-user applications.	This technology is being deployed slowly, with some uncertainty, but in the future can be used worldwide (countries do not have to be highly developed and they could use it to leapfrog others with not such good infrastructure).
Stem Cell Treatment (SCT)		The main fields of potential applications of stem cell treatment opened up during the past decade still show limited readiness to market and therefore no change in industry has occurred yet.	Beyond a modest but growing scene of small biotech firms, stem cell treatment up to now did not force industry creation.	SCT applications are expected to diffuse across various industries and sectors: * Clinical SCT; *Drug development and disease modelling; * (Re) programming of tissue cells * Identification/treatment of cancer stem cells.

3.5 Major Innovations in terms of societal and environmental impacts

3.5.1 Societal impacts of Major Innovations

Comparing the selected Major Innovations, the (online) survey respondents reveal the highest evident societal impact in the cases of mobile phones and optical fibres (see Figure 14 and Box 2). It should be mentioned that respondents did not expect a further increase of societal impact in these two cases. Both Major Innovations are represented by commonly accepted products, for which a dominant design has already emerged. In the future, technological changes may not be radical, but incremental in nature.

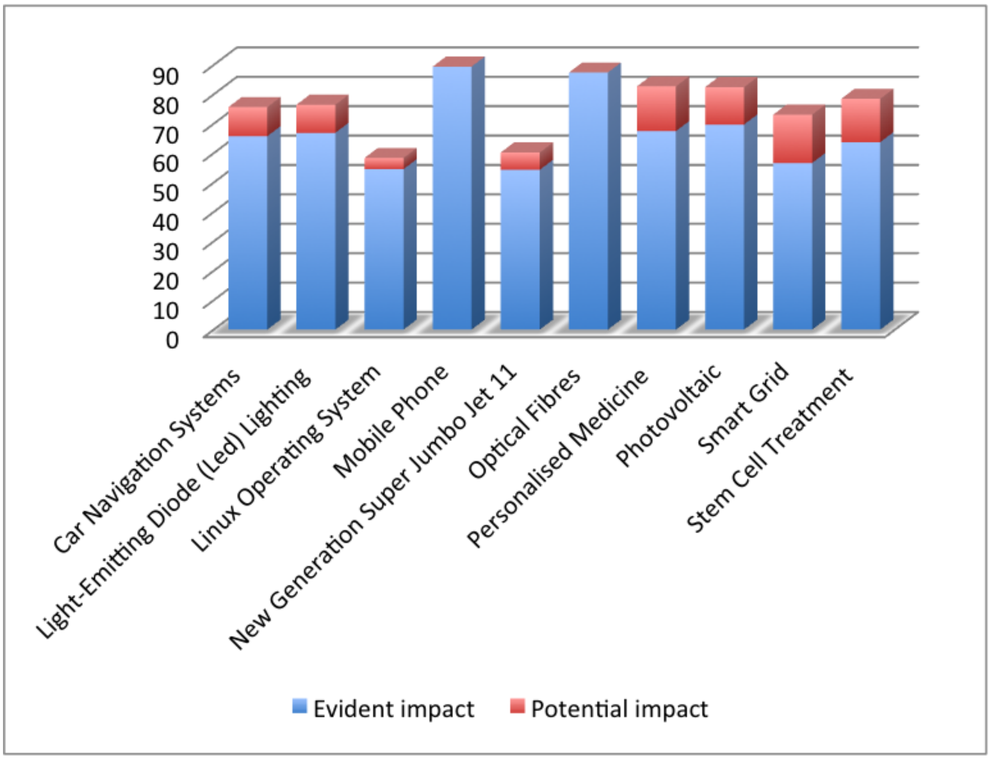

Figure 14: Societal impact of Major Innovations Source: JIIP, based on online survey

The least evident and potential societal impact is achieved by Linux OS and the Super Jumbo Jet A380. An explanation for this could be that their societal impact is limited to a small segment of society (in case of Linux OS to companies and researchers participating in the Linux economy; in the case of the Super Jumbo Jet A380 to the passengers, who are reliant on long-haul flights between metropolitan areas).

The difference between evident and potential societal impacts is the most striking with personalised medicine, stem cell treatments and smart grids. This can be explained by their nature – most of the applications of these fields are still in early stages of the innovation process (often, at the stage of scientific research). Therefore, impact on society can only be predicted.

Box 2: Societal impact of mobile phone and optical fibres Source: Case studies

Mobile phones:

The basic idea of the mobile phone is to free the user from a fixed telephone network by replacing physical telephone wire through the use of radio wave technology, i.e., telephone and network are connected via radio waves. Mobile phones have wide-ranging and permeable impacts on socio-economic development and everyday life. Mobile phones enable mutual connection, interaction and communication among people flexibly, irrespective of time and place. Communicative interaction is the essence of human interaction, learning and behaviour. Mobile phones have facilitated communication radically compared to fixed broadband phone systems and made it easy and flexible.

Optical fibres:

With the use of optical fibres, the transmission of information became safer and secured, which enabled people to exchange data. The main impact will be speed of data transmission. Connectivity will increase and, hence, society as a whole will begin to depend on a more virtual platform for social and economic transactions as well as those related to entertainment.

Car navigation systems and LED lighting also display a smaller expected future societal impact. Compared to personalised medicine, stem cell treatments and smart grids, applications for car navigation systems and LED lighting are already established on the market. However, mass-market sales happened only recently (car navigation systems: since 2000; LED: since the mid-1990s (not including general lighting)).

3.5.2 Environmental impacts of the Major Innovations

Several Major Innovations show direct links to environmental objectives and impacts. Not surprisingly, photovoltaics, smart grids and LED lighting show a high positive environmental impact (see Box 3) as these technologies are directly linked to the aim of developing more energy-efficient and environmentally sustainable energy sources.

Box 3: Environmental impact of LED lighting and photovoltaic Source: Case studies

LED lighting:

A light-emitting diode (LED) is a two-lead semiconductor that generates light when an electric current is passed through it. LED produces light by combining positive and negative charges inside a chip, which consists of semiconductor material. Therefore, most importantly, LED is substantially more energy-efficient than the traditional sources of lighting and thus enables enormous energy savings and carbon-emission reductions. LED-based white light sources require ten times less energy than ordinary light bulbs. According to estimations, the use of solid state lighting (LEDs and organic LEDs, OLEDs), if combined with intelligent light management systems, may in the future cut present-day electricity consumption by 70%.

Photovoltaics:

The wider adoption of photovoltaics is expected to create great environmental benefits. It has been estimated that photovoltaics could generate 12% of Europe's energy needs by 2020 and by 2050 save 65 billion tonnes of CO^2 equivalent, compared to the current energy generation mix. Therefore, solar energy is seen as the only renewable energy source that could meet all the world's energy needs, and it has the full potential to revolutionise the energy production at a global scale.

Figure 15 provides a comparative overview of the environmental impacts of the selected ten Major

Innovations as perceived by the respondents of the survey. The Major Innovations, which show limited evident and potential environmental impact, are personalised medicine, stem cell treatments and Linux OS. For personalised medicine and stem cell treatments – as they are still in early stages of the innovation process – it is hard to say in which way (positive/negative) they will influence the environment.

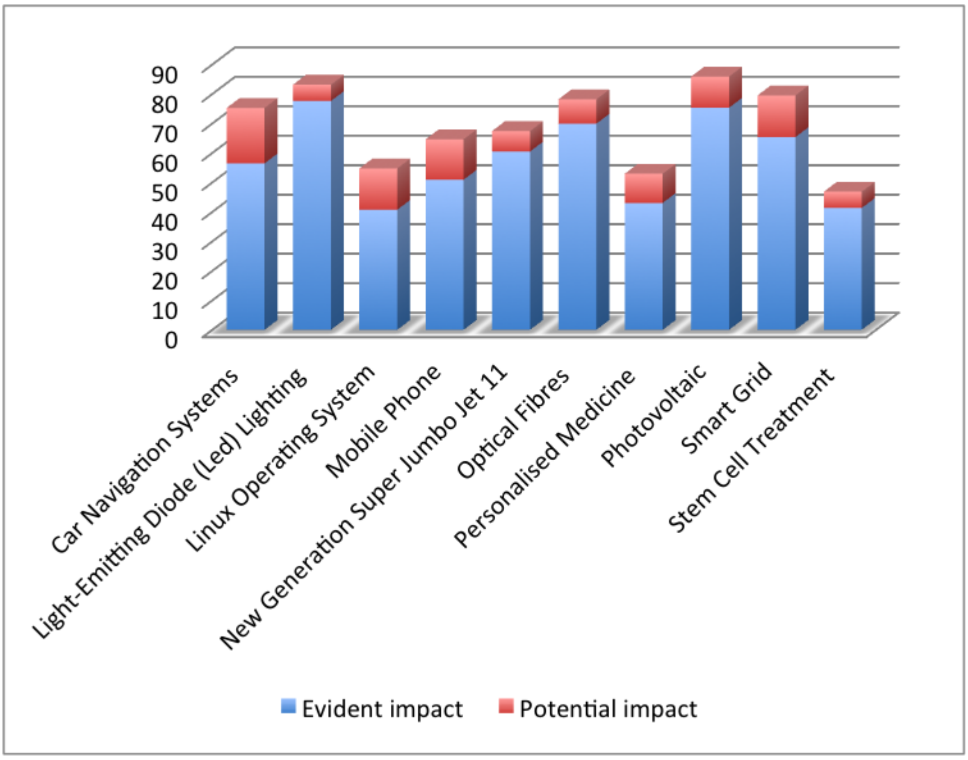

Figure 15: Positive environmental impacts of Major Innovations (Source: JIIP, based on online survey)

It is also interesting that Figure 15 indicates for mobile phones and the Super Jumbo Jet A380 a low positive environmental impact, which is straightforward due to the electronic waste and pollution produced by mobile phones and airplanes. However in the future, the positive environmental impact of these innovations seem to rise. New technological achievements regarding materials and engine technologies, as well as the need to meet stronger environmental regulations, could explain this expectation. The Super Jumbo Jet A380 for example, was praised for its lightweight composite materials, noise reduction and high fuel efficiency and in the case of mobile phone production, the first attempts towards the development of a 'FairPhone' (a mobile phone which does not contain conflict minerals) have been made.

In Table 11 the societal and environmental impacts of the ten Major Innovations are once again summarised.[15] A column with other major drivers is added.

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[15] Description for the light-system:

Top light: Indicates whether 'Societal Impact' is obtained by the MI (red = no; orange=not clear/only for a certain society segment not for the overall society; green=yes; different colours=in some aspects yes - in some aspects no)

Table 11: Societal and environmental impacts of Major Innovations

Source: Case studies

	Societal impact	Environmental impact	Other major drivers
Car Navigation Systems	*** Enables people to travel easier, safer and more efficient** *** Reduction of the workload of the driver and reduction of frustration/irritation** *** Reduction in time spent in travelling to destination (up to an estimated 18%)**	*** Decreases fuel consumption due decreases in driving distance and waiting time in traffic jams** *** Decreases greenhouse gas (GHG) emissions** *** Other environmental benefits (less damaging emissions; nature preservation)**	*** Connection of GPS-based navigation to advanced car security vehicle tracking systems** *** GPS-based car navigation may lead to safer transport and mobility** (fewer accidents): The driver can concentrate better on his driving, with potential positive effects on his driving performance.
LED Lighting	* **Better access to lighting:** Providing possibilities for a cheap and sustainable light source in off-grid areas * **Purifying drinking water cheaply and efficiently** (through ultraviolet LED technology)	* **Enormous energy savings and carbon-emission reductions:** High energy-efficiency compared to traditional sources of lighting *** Less production of heat and therefore less need of cooling air conditioning in buildings**	*** Reduction of energy consumption in lighting** *** Energy efficiency**
Linux Operating System	* **Development of large and efficient ecosystem:** Spreading of development burden amongst individuals and companies (unheralded software innovation)	Application of Linux software to support sustainable environmental development	
Mobile Phone (MP)	* Revolutionised social life communication, core enabler of “social media” and flexible communication * Changed interaction of people with each other/expectations of social interaction * Enabled numerous mobile applications in various socio-economic fields, remote working, etc.	* On one hand, creation of **remarkable electronic waste problem**, on the other hand, "Moore´s Law", material technology enable continuous **miniaturisation in size, reducing environmental impact.**	* Digitalisation, realisation of Moore´s Law, and miniaturisation enabled by nano and related new material technologies.
Super Jumbo Jet (A380)	*** Enabled mass transportation and therefore provided more flexibility of movement for people**	*** Achievement of optimum fuel efficiency through usage of environmentally benign technologies** *** Usage of new technologies to meet the stronger environmental regulations**	* **Expanding middle class** (even bigger passenger traffic) * **Rise in migration, tourism and international students** (creation of megacities) * **Stronger demand in emerging economies** (e.g., Asia Pacific and Middle East region)
Optical Fibres (OF)	*** Safer, secured and faster transmission of information (growing communication exchange)** *** Creation of a more virtual platform for social, economic and as well as entertainment related transactions**	* **Bringing down of power demand:** does not generate heat like copper cables; data centre cooling systems become unnecessary	* **Demand of billions of users to exchange information:** developing business, learning, sharing, being entertained and staying in touch with friends and family) * **Financial Benefit:** faster communication by even a

Bottom light: Indicates whether 'Environmental impact' is obtained by the MI(red = no; orange=not clear yet; green=yes; different colours=in some aspects yes - in some aspects no)

		Societal impact	Environmental impact	Other major drivers
				millisecond could be worth of a significant amount of money
Personal-ised Medicine (PM)		* **Improving the population health:** more people will live longer in a more healthy manner * **Right treatment for the right disease and the right patient** * **Cost efficiency:** ensuring that medical and nursing care remains affordable in an ageing society with growing numbers of chronically ill persons	* **No significant environmental impact** (from today's perspective)	* **Availability of advanced technological tools to discover and develop new biomarkers** * **The explosion of data from genome sequencing and other sources** * **The advent of technologies like the mobile, wireless capability, better sensors, interoperable devices and the Internet:** effective patient monitoring and treatment outside the traditional medical care * **Demographics:** certain illnesses are more widespread in certain geographical areas * **Social and political awareness:** precaution instead of aftercare
Photovoltaic (PV)		* **Possible new job opportunities:** although the Europe PV market is currently struggling * **Contribution towards sustainable development, economic and social convergence of regions:** less concentrated energy production and more politically stable society * **Self-preservation:** electricity consumers become electricity producers	* **High environmental benefits** (e.g., generation of energy needs through renewable energy; saving of CO^2)	* **Social and political awareness:** understanding their own environmental responsibility and therefore the positive environmental impact of PV * **Financial benefits for the consumer:** prices of other energy sources are more volatile and are rising constantly. * The more technology develops, the lower the costs of production of electricity. Time of recovery of investment is being reduced.
Smart Grids (SG)		* **Improvement of the efficiency of the current electric grid at the generation and the consumer sides alike** (significant reduction in greenhouse gas emissions) * **Incorporation of the particular requirements of electric vehicles** (EVs)	* **Helping in the decarbonisation plans** * **Efficient usage of renewable energy sources and electric vehicles** (reduction of the environmental burden)	* **Societal commitment to renewable energies** (versus shale gas, nuclear energy –fusion-, coal, etc.) * **Incentives to reduce consumption and eliminate energy waste** (smart home and buildings). * **Successful development of related technologies** (energy storage, fuel cells, etc.)

		Societal impact	Environmental impact	Other major drivers
Stem Cell Treatmen t (SCT)		* **Increasing the success rates of treatments of blood cancer or third degree burns** * **Reduction of the risk and social costs of a withdrawal of a product/drug from market** * **Meeting challenges of an ageing society:** new therapeutic solutions for malfunctioning organs and the treatment of chronic illnesses based on stem cell treatments.	* **Stem cell treatments show limited environmental impact**	* Public perception: public education initiatives should provide information on both sides of the 'stem cell' coin and should contribute to an public opinion forming process * **Demographics:** certain illnesses are more widespread in certain geographical areas

4 Drivers of Major Innovations

This section focuses on the identification of the key elements explaining the occurrence of Major Innovations. The circumstances, which initiated the evolution, integration or application of underlying technologies of each Major Innovation, have been quite different. In some cases, this was a clear result of targeted business strategy, e.g., mobile phones or the Super Jumbo Jet. In other cases (e.g., the Linux case) it was a by-product of activities, which had a different goal in mind. These findings are analysed in more detailed in the following section.

4.1 Key technological breakthroughs and R&D-related drivers of Major Innovations

The following overview shows the relevance of different R&D and technology related drivers of the ten Major Innovations observed.

Table 12: Relevance of different R&D and technology-related drivers of the ten Major Innovations

R&D related drivers of innovation ✓✓ distinct driver ✓ contingent driver × no significant driver	Car Navi-gation Systems	LED Light-ing	Linux Oper-ating System	Mobile Phones (MP)	Super Jumbo Jet (A380)	Opti-cal Fibres (OF)	Personal. Medicine (PM)	Photo -voltaic (PV)	Smart Grids (SG)	Stem Cell Treat-ment (SCT)
Outstanding scientific knowledge	×	✓	×	×	×	×	✓✓	✓	×	✓✓
Technological breakthrough	×	✓✓	×	×	×	✓✓	✓✓	×	×	✓✓
Technological novelty/newness based on (re-) combination	✓✓	×	✓✓	✓✓	✓✓	×	✓✓	✓	✓✓	✓✓
Existing standards (e.g., procedures, protocols, etc.)	✓✓	×	✓✓	✓✓	✓✓	×	×	×	✓✓	×
Creation of interfaces between different disciplines	✓✓	×	✓✓	✓✓	✓✓	✓	✓✓	×	✓✓	✓✓
Co-creation	×	×	×	×	✓	✓	✓✓	✓✓	✓✓	✓✓
Data availability / management (data collection, data preparation)	✓✓	×	✓✓	✓✓	×	✓✓	✓✓	×	✓✓	✓✓
Single hotspots and players driving technology development significantly	✓✓	✓✓	×	✓✓	✓✓	✓	✓	✓✓	×	✓
Fragmented international community driving technology development	×	✓	✓✓	✓		✓✓	✓✓	×	✓✓	✓✓

All Major Innovations observed are characterised by technological novelty or a combination thereof. Some cases of the Major Innovations are clearly based on outstanding scientific progress and technological breakthrough whereas some others are driven by regulation or existing standards. However, it is important to note that all Major Innovations commonly build on different inventions, which already exist, and technologies from different fields. These are Major Innovations where the creation of interfaces between different disciplines commonly played a role.

Figure 16 shows four dominant patterns among the ten Major Innovations selected.

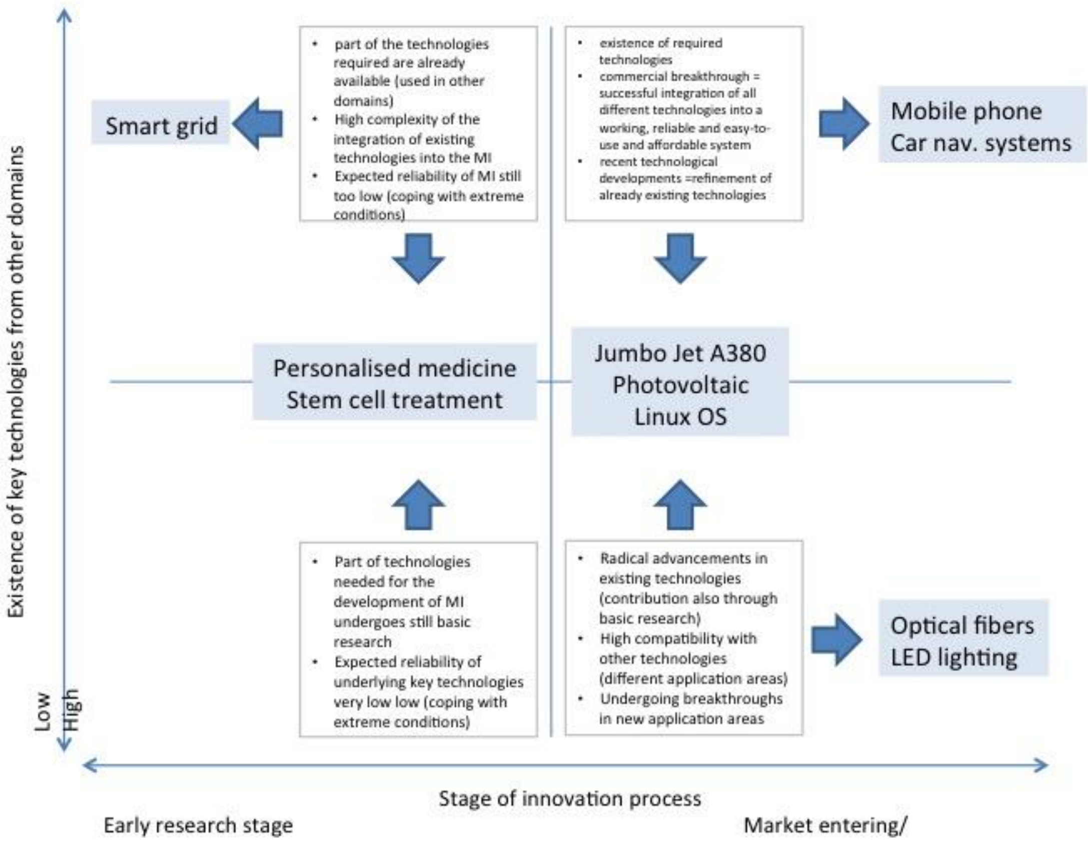


Figure 16: Major Innovations in connection with existing key technologies and their stage of innovation process (Source: Case studies)

Looking backwards, the commercial success of mobile phones and car navigation systems can be understood as successful integration of technologies of different domains into a working, reliable, easy and affordable system.

The technologies used to develop smart grids already partly existed in other domains. The biggest obstacle in the case of smart grids is the successful integration of those technologies. This integration is characterised by high complexity and extreme conditions (e.g., high voltages and currents) and therefore the reliability of smart grids is still considered to be low.

Optical fibres and LED lighting are not so much the product of existing technologies from different domains, but more of discoveries in materials, device and optical physics, crystal growth (basic research) and consequent radical advancements in existing technologies (e.g., semiconductor laser and materials, microprocessors, communication networks; light management; etc.).

The Super Jumbo Jet A380 incorporates technologies from different domains, of which some can be considered as radically advanced technologies (e.g., lightweight composite materials, zero splice engine intake liner, interactive displays, advanced management systems, improved navigation modes, etc.). Some of those technologies (e.g., fuel efficiency, concept of light-weighting) have the potential also to be applied in other sectors (e.g., automotive sector). Similar characteristics apply for Linux OS and photovoltaics.

The characterisation of personalised medicine and stem cell treatment in terms of underlying key technologies and their current stage of innovation process depend largely on the application area under consideration. For both Major Innovations, there exist possible applications (e.g., embryonic and induced pluripotent stem cell treatments) which are still in the early stage of research and therefore rely only to a small extent on existing key technologies. Other applications (e.g., personalised medicine in oncology; reproduction and transplantation of hematopoietic stem cells) can be considered as practice in use and have been refined and improved over the years.

The survey responses show the following picture on the geography of the Major Innovations (see Figure 17). The EU28 countries are seen as global forerunners in the fields of car navigation systems, Linux OS, the Super Jumbo Jet A380, photovoltaics and smart grids, whereas the USA and Canada are positioned as leaders in the fields of mobile phones, personalised medicine and stem cell treatments. This picture cannot fully be explained by existing framework conditions or policy attention in Europe. A closer look at the former cases of Major Innovations (where Europe has a strong position) shows that strategic decisions and initiatives of single or small groups of innovation carriers frequently played a significant role (e.g., Daimler and TomTom in the case of car navigation systems, a Finnish academic in the case of Linux OS or EADS, and Airbus in the case of the Super Jumbo Jet). In other cases, like photovoltaic panels, LED, stem cell treatments or personalised medicine, the community of key innovators is comparatively broader.

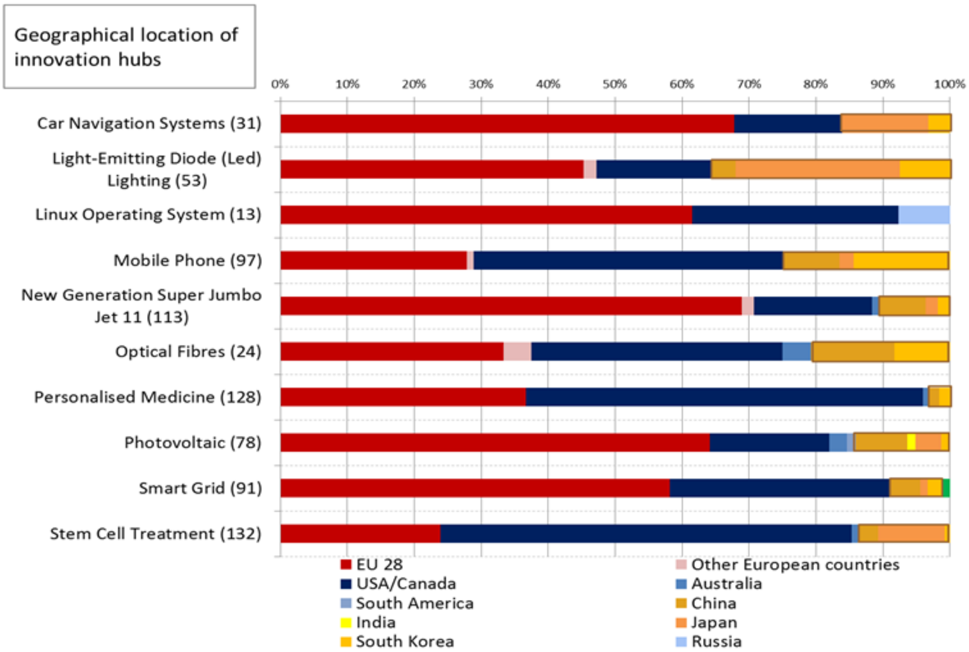


Figure 17: Geographical location of innovation hubs Source: JIIP, based on online survey

According to the survey respondents, Asia (especially, China, Japan and South Korea) was not seen as a global forerunner in R&D of the selected Major Innovations. However, from the case studies it could be learned that Japan especially is active in the development of stem cell treatments (see Case Study 'Stem cell treatments'), Korea, in the case of mobile phones and China, in the case of photovoltaic panels. In the following section, we will however see that a strong position in R&D does not necessarily correspond with forerunner positions from the production and market perspective.

Box 4: Europe's role in R&D in the fields of car navigation systems, photovoltaics and Super Jumbo Jet A380 Source: Case studies

Car navigation systems:

European companies, such as Philips, Bosch, Siemens, Tele Atlas, automotive companies like BMW, Daimler, Fiat, mapmaker Tele Atlas and TomTom, all played important roles in the development and rise of car navigation, with Philips (CarIn, prototype 1985, market introduction 1994), Tele Atlas (digital maps, founded in 1984) and TomTom (introduction of the all-in-one PND, 2004) standing out in terms of technological breakthroughs and innovations. Tele Atlas (now part of TomTom) and Here (former Navteq, part of Nokia) continue to play a role in providing digital maps and other dynamic content for navigation and location-based services, also in the newest market segment, app-enabled car navigation. TomTom nowadays cooperates closely with the large automotive companies, such as Renault, Fiat and Volkswagen.

Photovoltaics:

The strong European position in R&D in the field of photovoltaics can be traced back largely to the strong boost from European sustainable energy policies aiming to promote the use of energy from renewable sources. As a result, Europe was, until 2013, the world's leading region in terms of cumulative installed capacity of PVs, and the number of patent applications grew from 138 in 2000 up to 2344 in 2011.

Super Jumbo Jet A380:

The EU has been instrumental in contributing to the developments associated with the A380. This is greatly attributed to the UK-based engine manufacturer Rolls-Royce and many of the component suppliers for Airbus based out of Germany, France and UK. In addition, it could be mentioned in this regard that some of the critical components belonging to the wings, engine and fuselage could be sourced directly from this belt. Lastly, a number of research projects which were initiated by the EU framework programmes influenced the development of innovative material composites, engine and electronics of the Super Jumbo aircraft.

4.2 Major 'contextual', systematic drivers: society, markets, policy

We learn from all observed cases that single triggering contextual factors (especially market competition, societal needs and demand or regulation) crucially influenced the emergence of Major Innovations. Examples are:

- the opening up the competition of the European telecommunication markets in the mobile phone case;
- the world-wide opening of the NAVSTAR Global Positioning System and draw back of an European alternative in the case of car navigation, and for the development on smart phones, the telecom liberalisation and the roll out of higher bandwidth standards (UMTS, 3G, 4G) for mobile communication;
- the policy agreement for a European joint activity in the case of the Super Jumbo Jet, which is strongly based on EU trade policy;
- the need and policy decision to foster internet access/use in Europe for optical fibres, supported as well by telecom liberalisation;

- the raise of ethical aspects concerning embryonic stem cells and scientific breakthrough concerning induced pluripotent stem cells in the case of stem cell treatment, and the EU ethical framework, which creates more clarity on the boundaries;
- the clear commitment to Kyoto targets and turnaround in European (sustainable) energy policy in the cases of LED, photovoltaics and smart grids (which is also driven by for instance transport policy).

The contextual factors touch upon a much broader range of policy areas beyond R&D and innovation. The following overview (Table 13) shows the driving role of different societal challenges and changes. In the light of specific emphases on addressing societal needs and challenges given by the current Framework Programme, H2020, this is of specific interest. Demographic changes as well as the reduction of the environmental burden commonly played a driving role for several Major Innovations observed. Another important driver both from the demand and diffusion side was the growing presence of ICT applications in everyday life.

Table 13: Driving role of different societal challenges

Societal, environmental and other drivers ✓✓ distinct driver ✓ contingent driver × no significant driver	Car Navigation Systems	LED Lighting	Linux Operating System	Mobile Phone (MP)	Super Jumbo Jet (A380)	Optical Fibres (OF)	Personal. Medicine (PM)	Photo-voltaic (PV)	Smart Grids (SG)	Stem Cell Treatment (SCT)
Societal commitment / public perception	×	✓✓	×	×	×	×	✓✓	✓✓	✓✓	✓✓
Changes in the social fabric (due to new needs, socio-economic challenges (ageing society), etc.)	✓✓	✓✓	×	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Demographics (e.g., rise in migration; tourism; but also human characteristics influenced by their geographical location, etc.)	✓✓	×	×	✓✓	✓✓	✓✓	✓✓	×	✓✓	✓✓
Facilitation (Usability) for the end user	✓✓	×	✓✓	✓✓	✓✓	✓	×	×	×	×
Growing presence of ICT in every-day life	✓✓	✓	✓✓	✓✓	×	✓✓	×	×	✓✓	×
Reduction of the environmental burden (e.g., energy efficiency)	✓✓	✓✓	×	×	✓✓	✓✓	×	✓✓	✓✓	×

4.2.1 Market and business models

The following overview focus on market-related drivers shows that private demand or need and changing industrial behaviour have been relevant drivers for most of the Major Innovations.

Table 14: Market-related drivers

Market related drivers ✓✓ distinct driver ✓ contingent driver × no significant driver	Car Navigation Systems	LED Lighting	Linux Oper-ating System	Mobile Phone (MP)	Super Jumbo Jet (A380)	Optical Fibres (OF)	Personal. Medicine (PM)	Photo volt-aic (PV)	Smart Grids (SG)	Stem Cell Treatment (SCT)
Open up a market niche	×	✓✓	✓✓	×	✓✓	×	×	✓✓	×	×
Market readiness	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	×	✓✓	×	×
Responses to market trends	✓✓	×	×	✓✓	×	×	×	×	×	×
Strong public demand	✓	✓✓	×	✓✓	×	✓✓	✓	✓✓	✓✓	✓
Strong private demand	✓✓	✓	✓✓	✓✓	✓✓	✓✓	✓	✓	✓	✓
Change of industrial behaviour	✓✓	✓✓	✓	✓✓	✓	✓✓	✓	✓✓	✓	✓
Changes in end user behaviour	✓✓	×	✓✓	✓✓	✓	×	×	✓✓	✓	×
Demand in emerging economies	✓	✓	✓	✓✓	✓✓	✓✓	✓	✓✓	✓	✓✓
Becoming an industry standard	✓✓	✓	✓✓	✓✓	✓	✓✓	✓	✓	✓	×
Ease of use & functionality	✓✓	✓✓	✓✓	✓✓	×	×	×	×	×	×
Creation of common eco-system	×	×	×	✓✓	×	✓✓	✓	✓✓	✓	×
Provision of necessary infrastructure	✓✓	×	×	✓✓	✓	✓✓	✓	✓✓	✓	✓
Affordability (price cuts)	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	×	✓✓	×

Furthermore, among selected Major Innovations several cases can be identified, where the ease of use and functionality played a significant role, while in other cases user needs and solutions co-evolved by creating a common eco-system (communities involving users and other stakeholders).

The market structure and dominating business models associated with the selected cases differs substantially (see Table 27 in Annex A). Furthermore, it has to be considered that Major Innovations emerge and co-evolve in a family of innovations. In most cases, Major Innovations cannot solely be associated with a single market. For example, the car navigation market consists of three sub-markets or market segments, namely the 'in-dash' GPS navigation system market; the GPS-based Portable Navigation Devices market and the app-enabled GPS navigation market. Another example is the stem cell treatment market, which consists of the following sub-markets: (1) clinical stem cell treatment, (2) drug development and disease modelling; (2) (re)-programming of tissue cells and (4) identification/treatment of cancer stem cells.

In the long term, the markets associated with Major Innovations become blurred with the rise of new applications, business models and changing user patterns (e.g., the car navigation systems market is strongly related to service-based markets due to the rise of in-car entertainment; the personalised medicine market will become strongly related to the nutrition market). The observed Major Innovations often lead to changes in previous business models (see Box 5). Major Innovations seem to motivate new business ideas and attract new entrants to the market. In many cases, these are start-ups or SMEs trying to make use the potential of the technological novelty/newness of the Major Innovations. In some cases – as has been learned from the qualitative interviews of the stem cell and personalised medicine case for instance - SMEs are threatening the top tier of companies in the market by their willingness to take considerably higher risks.

Box 5: Emergence of new business models due to Major Innovations Source: Case studies

Car navigation systems:

Today's car navigation market consists of three sub-market or market segments: 'in-dash' GPS navigation systems (both built-in in new cars and as 'aftermarket' product), GPS-based Portable Navigation Devices (PNDs) (portable navigation) and smartphones with app-enabled GPS navigation. Until recently the in-dash segment typically showed the characteristics of a closed innovation model, with core R&D happening in-house. Closed innovation also applies to the PND segment, especially in the early 2000s. In recent years, this has gradually changed, with players active in the PND segment active in the in-dash segment (e.g., TomTom), and vice versa (GM OnStar). Various new players have entered the Satnav market via the apps segment: Google, Nokia, and a number of smaller app and map makers, offering free and paid Satnav solutions. The three remaining PND vendors TomTom, Garmin and MiTAC have increasingly entered the in-dash market, both in strategic collaborations with incumbent automotive companies and in offering aftermarket in-dash solutions at the lower price range, whereas the automotive companies themselves are competing with incumbent PND vendors with new solutions (e.g., the rear mirror OnStar by GM). Since 2008, the overall car navigation market has witnessed considerable consolidation.

LED Lighting:

As a radical innovation, LED has challenged and strongly affected the strategies of the incumbent lighting companies. Globally, the traditional lamp market has for long been dominated by three big players: Philips, Osram and GE. At the turn of the millennium, these three reacted to the emergence of LED by creating joint ventures with semiconductor companies and later by acquiring these ventures (e.g., Philips Lumileds, Osram Opto Semiconductors and Gelcore). Also in more general terms, recently the LED industry has increasingly moved towards open innovation as exemplified by the proliferation of various types of networks, joint ventures, alliances and consortia.

Compared to the R&D perspective (see Figure 18 and Figure 19), the survey respondents perceived that Europe is in much weaker position concerning the economic exploitation (production) of Major Innovations, as explained below. The EU28 countries are considered to be forerunners only in the case of the Super Jumbo Jet A380. The manufacturers and suppliers of the components required for the Super Jumbo Jet are largely located in EU28 countries.

The USA and Canada are considered as leaders in production in the fields of personalised medicine and the application of stem cell treatments. This can be explained by the better framework and financing conditions for biotech start-ups (e.g., venture capital) in North America.Asia, and particularly China, are perceived as clear leaders in the production of photovoltaic panels. Even if the invention of the photovoltaic panel is original European, further technological development towards innovation took place mainly in US. However, the public support in terms of strong industrial policy in Europe plays an important role as China has set the photovoltaic sector as one of the priority areas for economic competitiveness. It has even been estimated that China's PV industry accounts for more than 95% of total solar cell production worldwide. Production costs are considerably lower than in Europe. However, it has to be mentioned that Asian producers significantly gained from policy incentive and subsidies provided in Europe (see also the case study on Photovoltaic) as European by Chinese products because of lower prices.

In the case of mobile phones, Europe (especially Nokia) recently lost its previously very successful position in the global market. Nokia Communicator was among the first forerunners in smart phone markets. Nokia was the market leader prior to 2010. However, since then competition emerged in the Asia Pacific region with brands such as Micromax, Nexian, and i-Mobile and chipped away at Nokia's market share. Android powered smartphones also gained momentum across the region at the expense of Nokia.

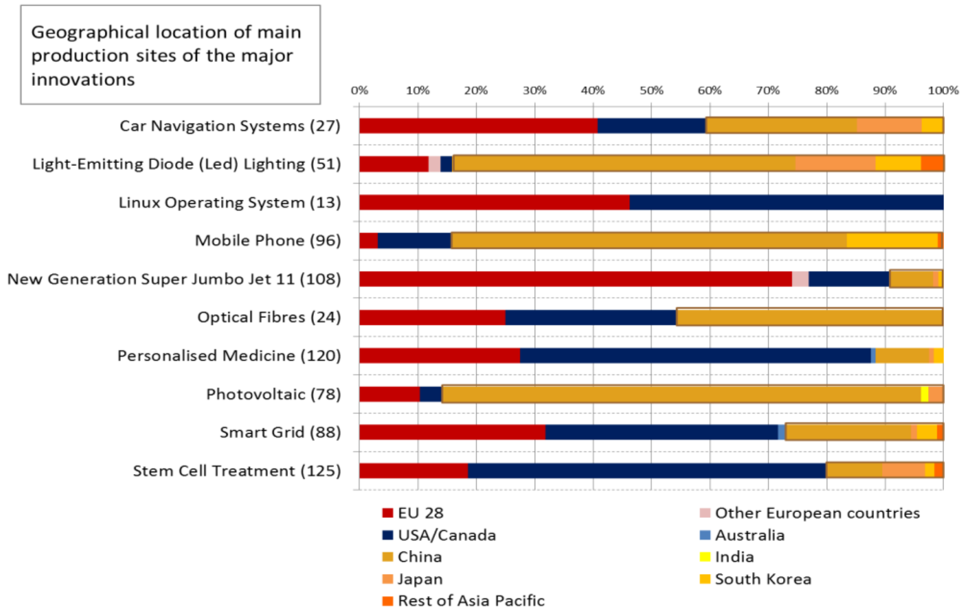


Figure 18: Geographical location of main production sites Source: JIIP, based on online survey

Box 6: Financing the valley of death in personalised medicine and stem cell treatment Source: Case studies

Europe's problem of financing the so-called 'valley of death' in personalised medicine and stem cell treatments

Europe, compared to the USA, is successfully positioning itself amongst the scientific competition in the field of personalised medicine. However, a key European problem is still the financing of the so-called valley of death, the gap between the end of the research phase and early clinical trials and the entry of the final product on the market. Europe has a very poor success rate with venture-capital funds. Therefore, Europe must take care that innovative products, although their scientific source lies within Europe, will not be commercialised on the large scale in the USA. Countering this development requires, beside the commitment of financial donors, also a mentality shift: closer cooperation between academia and industry already in early stages of research would help to create a smoother transition from research results towards commercialisation of market products.

In Figure 19, the geographical location of the main markets of the Major Innovations are depicted based on the assessment of respondents of the online survey. According to the survey respondents, Europe is considered as the main market area for car navigation systems and LED lighting. The case study analysis and expert interviews clearly showed that the European market for car navigation systems and LED lightening is strong, but cannot be considered as main market area. In case of car navigation systems, the USA and Asia can be considered as strong markets as well – especially due to the fact that nowadays tone of the most important devices for phone-enabled SatNav are smart phones. In case of LED, the strong Asian market is placed next to the European market.

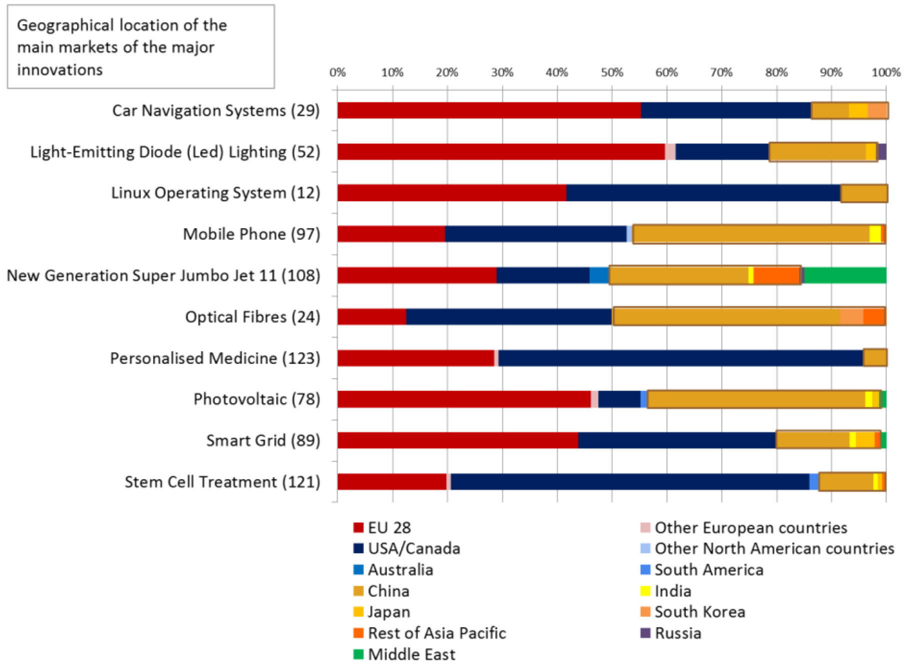


Figure 19: Geographical location of the main markets Source: JIIP, based on online survey

The biggest markets for personalised medicine approaches, stem cell treatments and Linux OS software are considered to be in the USA and Canada, whereas Asia is considered as a main market in the fields of mobile phones, photovoltaics and optical fibres (see Box 7). In the case of the Super Jumbo Jet A380, the market seems to be evenly distributed among the EU18 countries, the USA/Canada, Asia and the Middle East (see Box 7). This can be traced back to the fact that the aim of Airbus – by developing the Super Jumbo Jet A380 – was to create a global niche market for long-haul flights.

Box 7: User/consumer demand of optical fibres and Super Jumbo Jet A380 Source: Case studies

Optical fibres

China has been projected as the main driver of demand for the optical fibre market globally, since it accounts for around 40% of world demand. The demand in China has been boosted further by network operators' efforts for improving connectivity as well as to cater to demand arising from 3G/4G usage. The demand for optical fibres in other nations, such as the USA, Japan, Germany, and the Netherlands is also experiencing growth since they want to implement Fibre-to-the-Node and Fibre-to-the-Home (FTTH) networks.

Super Jumbo Jet A380

The Asia Pacific region tops the list of maximum demand for very large passenger aircraft (622) followed by the Middle East (341). Europe is positioned third in line with the capacity of 150. The Middle East could be considered as the major centre for air transport and the share of passenger aircraft in the world operated by these regions doubled in the last 10 years. This, in turn, also projects growth of the global fleet of wide-body aircraft by 24%. Another interesting point is that the Middle East represents the only region where the wide-body fleet is larger than the single-aisle fleet. Globally, air traffic has doubled every 15 years; in the Middle East, ASKs multiplied three and a half times in the last 10 years alone. Medium and long-haul routes between the Middle East and Asia-Pacific or Europe constitute the core growth markets for air traffic.

Figure 19 shows how the end user behaviour, the public and private demand influence the development and improvements of the ten Major Innovations. Overall, it can be seen that changes in the end user behaviour, as well as the private, and to lesser extent the public, demand drive the development and improvements of the Major Innovations.

Public demand seems to be a less important driver for the Major Innovations. For example, in the case of Linux OS, public demand does not seem to be very important driver. This could be explained by Linux OS software mainly being used by individuals and organisations. Nevertheless, the objective of adopting open source software and, therefore, also Linux OS has been embraced by many different levels of governments in Europe and beyond (for example the governmental initiatives in Spain, UK and Brazil). The European Commission has a dedicated strategy on the use of OSS within its institutions. It is however not an easy process to switch from proprietary to free and open source software. The City of Munich, famously, switched its desktops to GNU/Linux and OpenOffice.org — but the process took thirteen years.

Changes in end user behaviour seem to be the most important driver for personalised medicine, smart grids and mobile phones. Personalised medicine and smart grids are both Major Innovations, which are still in early development and have only limited reach in the market. Still, as presented in the case studies, public awareness of environmental protection, renewable energies and health topics may lead to changes in end user behaviour. In contrast, changes in end user behaviour do not seem to influence the development of the Super Jumbo Jet A380 and optical fibres. This can be explained by both Major Innovations emerging from standards: the Super Jumbo Jet A380 as a standard airplane for long-haul flights and optical fibres as standard media for carrying information.

Finally, strong private demand relevantly drives the development and improvements of all Major Innovations, but especially again in the cases of mobile phones, optical fibres and photovoltaics. On the other hand, private demand is a less important driver for the development and improvements of Linux OS and stem cell treatments (due to very low public perception).

4.2.2 Differences between location of R&D, innovation, manufacturing and markets

In a number of the Major Innovation cases, we notice a shift from knowledge creation, innovation, production and markets. The main two cases we wish to highlight here are photovoltaics and LED.

In a simplified view, we see significant differences between R&D outputs (publications), innovation outputs (patents[16]) and production outputs for LED in Figure 20.

It shows that R&D publications are reasonably balanced between the different regions, and that the EU lags behind in patenting, but manages to take a large share comparably in the production of LEDs. Japan on the other hand has a low share of the publications, set off against an extremely large share of the patents, exceeding its share of manufacturing and home market. China, however, has a very limited patent share and relatively high manufacturing and home market share. Both shares (the manufacturing and home market share)are expected to rise significantly in the next years., This can be explained by the fact that patents are generally perceived as less of a barrier to the Chinese home market, than it is for foreign markets.

[16] Based on top 50 patent assignees

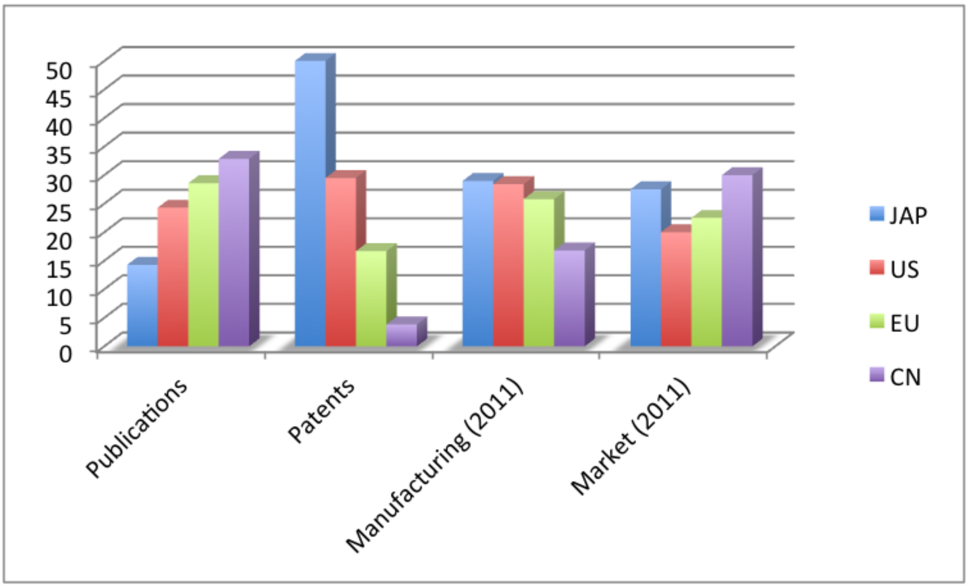
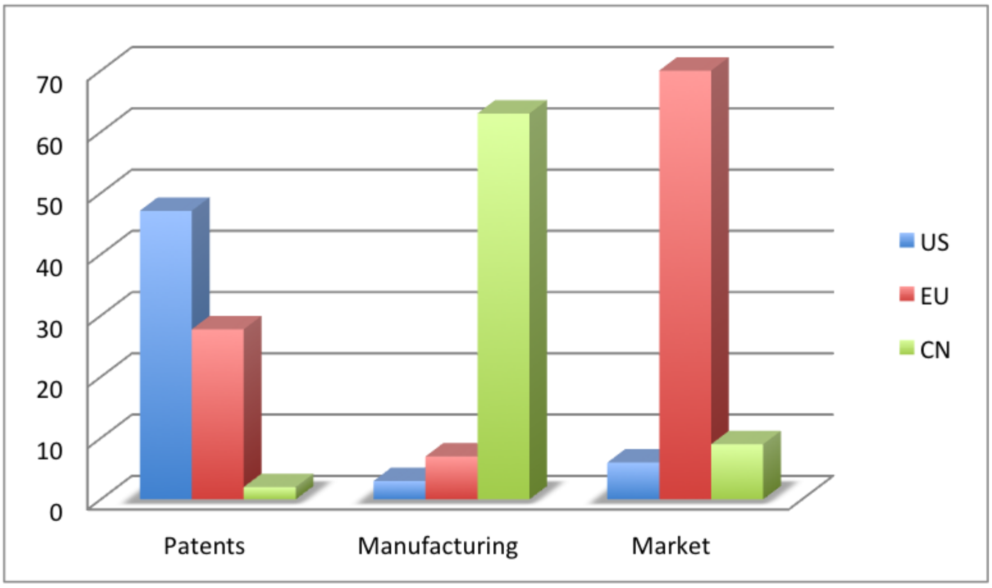


Figure 20: LED publications, patents manufacturing and markets[17,18]

For photovoltaics, the picture is highly unbalanced. The US leads in patenting[19], with a relative high share for the EU (around 30% of the EU patents are from Germany), whereas China has hardly any patents. When we compare with the manufacturing data[20] we see (as explained in other sections of the report) market domination from China with 63% of the shipments against 7% shipments from the EU compared to a global consumer market of 70% in 2011.



[17] Publication data from Xin Li1, Yuan Zhou, Lan Xue2, Lucheng Huang: Roadmapping an emerging industry with bibliometrics and patent analysis: A case of OLED industry in China, 2014 (note: limited to publications in OLED)

[18] Manufacturing and market data adapted from McKinsey and Company, Lighting the way, perspectives on the global lighting market, 2012

[19] Top 50 patent assignees

[20] Alan C. Goodrich, Douglas M. Powell, Ted L. James, Michael Woodhousea and Tonio Buonassisi, Assessing the drivers of regional trends in solar photovoltaic manufacturing (2012)

Figure 21: Photovoltaics patent, manufacturing and market shares

Until 2007, the EU produced on a par with or at higher levels than China. A decisive factor of the production shift is the rapid decrease of prices per watt. They have dropped by as much as 7-8% on an annual basis between 1995 and 2011 and the price drop accelerated after 2012 with decreases of 12-15%[21].

One explanation is that to produce efficiently, Chinese firms specialised in producing solar PV products, particularly silicon wafer solar cells; the standardised production process of silicon wafer solar cells allows the company to purchase its turn-key production technology without much internal investment in R&D, in other words the PV production and value chain is fully commoditised.

Of the global top 20 PV production firms, six are based in China; furthermore, despite the fact that no PV patents had been granted to any of these firms between 1996 and 2006, their global PV capacity is very high. This may reveal that the entry barriers to solar PV technology are not so high that latecomers, particularly those specialising mainly in the production of silicon solar cells, can focus on production by purchasing their turn-key technology, as opposed to becoming directly involved in R&D activities[22].

This in our view only partially explains the huge unbalance, other explanations include regional/state subsidies, tax incentives, indigenous factors as low labour rates (be it that these are partially offset against higher inflation and cost of capital), and supply chain and scale advantages. The combined advantage according to some sources could be as high as 20-25% over US manufacturers[23].

As regards the other case studies:

- In the case of mobile phones, Europe (especially Nokia) recently lost its previously very successful position in the global market by missing the upcoming development of the smart-phone market.
- The USA and Canada are considered as leaders in production in the fields of personalised medicine and the application of stem cell treatments. This can be explained by the better framework and financing conditions for biotech start-ups (e.g., venture capital) in North America.
- Super Jumbo Jet is a European effort (France, Germany, Spain, and the United Kingdom) designed to challenge US manufactured Boeing in the large-aircraft market, but has not so far been a commercial success.
- Optical fibre, Linux, smart grids and car navigation system are Major Innovations for which Europe, North America and Asia are all having both user and demand growth and manufacturing potential.

[21] For residential/consumer use

[22] Roadmapping an emerging industry with bibliometrics and patent analysis: A case of OLED industry in China, Xin Li, Yuan Zhou, Lan Xue, Lucheng Huang (2014)

[23] Alan C. Goodrich et al.

4.2.3 Policy drivers for major innovations

When discussing public intervention in the context of innovation policy, R&D funding is in the spotlight. R&D incentives and funding are key drivers for the development and improvement of the Major Innovations. Major Innovations especially, which are still in early research and lack substantial financial resources from private investors due to uncertainty inherent to R&D, rely to a great extent on public R&D incentives and funding (e.g., personalised medicine, stem cell treatment);

However existing regulatory and legal frameworks or standards regarding the development procedures, guidelines, protocols also play an important role for the development and improvement of Major Innovations.

Table 15: Policy drivers

Policy drivers ✓✓ distinct driver ✓ contingent driver × no significant driver	Car Navigation Systems	LED Lighting	Linux Operating System	Mobile Phone (MP)	Super Jumbo Jet (A380)	Optical Fibres (OF)	Personal. Medicine (PM)	Photo-voltaic (PV)	Smart Grids (SG)	Stem Cell Treatment (SCT)
Political commitment (governmental intervention)	×	✓✓	×	×	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Existing regulatory and legal framework	×	✓✓	×	×	✓✓	✓✓	✓	✓✓	✓	✓
R&D incentives and funding	✓	✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Private funding (e.g., venture capital, seed capital, etc.)	✓✓	✓	✓	✓✓	×	✓✓	✓✓	×	×	✓✓
Subsidies for end consumer	×	✓✓	×	×	×	✓	×	✓✓	✓✓	×

Figure 22 shows survey based expert assessment of the relevance of policies like regulations and standards.

The regulatory and legal environment was of high relevance for the development and implementation of photovoltaics, smart grids, stem cell treatments, as well as in the case of car navigation systems.

One of the most important drivers of photovoltaics and smart grid development is public policy regulating the energy market and the national incentives provided to increase the use of sustainable energy. Public policy focused on awareness building (e.g., educational work, public initiatives) together with adequate measures and subsidies for end users to approach the grid parity of photovoltaic power has been an important facilitating factor in some countries (e.g., the German feed-in tariff model; see Table 28 in Annex A).

In the case of stem cell treatment, the existing regulatory and legal environment should ensure that the treatments entering the market are safe, effective and will not intentionally harm human health.

In this respect, it is important that highly qualified, multidisciplinary advisory boards are established with the responsibility to asses the quality, safety and efficacy of stem cell treatments and to follow scientific developments in this field (see Table 28). In 2007, stem cell therapies have been classified as "Advanced Therapy Medicinal Products" (ATMP) by the European Commission Regulation 1394/2007. However European stem cell research is suffering from an increasing number of different national legislative regulative measures concerning embryonic stem cells.

Linux OS is a very specific case allowing open access and use. Standards are important for the development and improvement of the software. The development and enforcement of standards in this case is driven bottom-up without public intervention.

Existing standards in terms of development procedures, guidelines, protocols, etc. drive especially the development/improvement of car navigation systems, mobile phones, smart grids and stem cell treatments (see Table 28). Particulary in the case of the development of stem cell treatments, they seem to be highly relevant. It is observable that in early research/preclinical work, harmonised standardised protocols and technologies are not as well established as they should be. This, however, could lead to a remarkable hampering factor when it comes to the clincal work/market establishment due to a considerable lack of data.

In the case of LED lighting, existing standards seem to play the least important role (see also Figure 22). A possible explanation could be that so far no harmonisation of standards across countries occurred and therefore, there are still considerable differences of safety and performance standards. Some have even been considered as inefficient and as an obstacle for the development of LED lighting.

Looking at the role of IPR in the development of Major Innovations it is obvious, that IPR is crucial in the development of key technologies which led to Major Innovations across all cases. However, possible conflicts regarding key criteria for patentability may arise with personalised medicine approaches and stem cell treatments as indicated below.

Box 8: User/consumer demand of optical fibres and Super Jumbo Jet A380 Source: Case studies

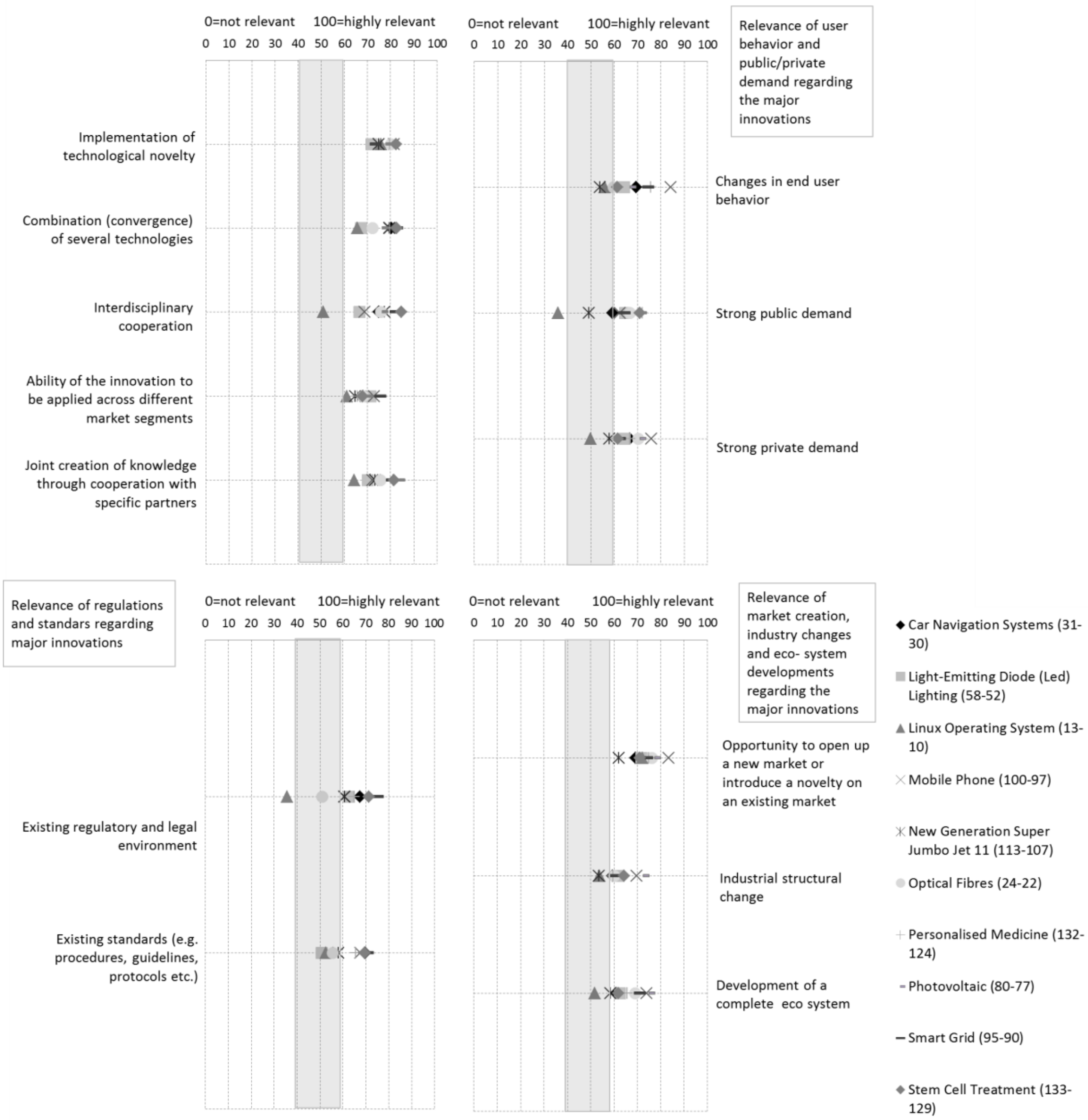
The role of IPR in stem cell treatment

According to the overall patent criteria, an invention to be patentable must be new, useful and inventive compared to previously known information. It can be in some ways hard in drafting patent claims for stem cells as they are complex living systems and not describable by a fixed chemical structure like pharmaceuticals, proteins or nucleic acid molecules. This unpredictability of stem cells becomes also a major challenge for patent claims on medical applications as it is not sure how successfully they can be used in treatments. In Europe, it is possible to patent the method of stem cells isolation, but not the cells itself and therefore the treatment. However, removal of this legal protection could have a major influence on stem cell research and therefore on the stem cell treatment market. Currently, the issue of whether stem cell techniques can be patented has been a matter of debate in the European Union. The starting point for those discussions has been the withdrawal of the patent on neural precursor cells derived from hESCs from the stem cell scientist Oliver Brüstle by the European Court of Justice in 2001. The European Court of Justice justified the withdrawal with making reference to the European Biopatent Directive, Article 6. There it is specified that "uses of human embryos for industrial or commercial purposes" cannot be patented.

Apart from the policy drivers, there are important contextual aspects that can be influenced by a wider public policy (see more detailed mapping in Annex) which can be categorised as follows:

42. **Provision of necessary infrastructure:** the provision of necessary infrastructure drives the development and improvements of Major Innovations. This has been proved especially in the case of car navigation systems. Opening up the NAVSTAR satellite system by the Clinton Administration in 2000 can be characterised as milestone in the development procedures of car navigation systems. Smart grids, in fact, are a key infrastructure in the EU's energy policy aimed to secure the supply, sustainability and market efficiency and address current concerns with the electricity system infrastructure, such as meeting peak demand with an ageing infrastructure;
43. **Privacy and ethics:** privacy concerns regarding the security of personal data especially affect some of the Major Innovations. Personalised medicine and stem cell treatment are not Major Innovations only in terms of revolutionising the way diseases are defined, but also in the way patient data is collected, stored and used effectively to provide preventions and treatments for diseases. Also for optical fibres (as they become the technology of choice for transmission of data at high speed and over long distances) and smart grids (need of use of consumer data) with the accurate handling of private data and security issues being a concern;
44. **Awareness and perception:** as already mentioned, public awareness and perception are a major driver in the development of Major Innovations like personalised medicine, stem cell treatments, smart grids, photovoltaics, etc. Policies can target these.

Figure 22: Factors influencing the development and success of Major Innovations Source: JIIP, based on online survey



4.3 Key driving factors and trigger events in a nutshell

The previous sections presented relevant factors driving the occurrence and success of Major Innovations. However, ingredients by themselves are not able to define or determine the outcome and success sufficiently. Evolutionary innovation and complexity theory put us on guard against deterministic simplification. This section attempts to synthesise triggering events and decisive factors, which tipped the balance in the case of the selected innovations to become major.

Table 16: Triggering events and factors for Major Innovations Source: JIIP

	Trigger event(s)/trigger factor(s)
Car Navigation Systems	* Existence of main technologies and innovations underlying GPS car navigation since the 1990s * The completion (by 1995) and full opening up (by 2000) of the **GPS–NAVSTAR satellite system for civilian use**: led to a far more accurate GPS signal (at least of a factor ten, improving the accuracy of GPS from 300-400 feet to 30-40 feet) * The introduction of the **Portable Navigation Device (PND) in 2004** (by the Dutch software company TomTom): lead to the entry of car navigation into the mass market
LED Lighting	* Discovery of **blue and white LED** (late 1980s/early 1990s) in Japan and UK; * High **importance of investment in research infrastructure and private funding** in Asia (e.g., Nichia Chemicals investments on Shuji Nakamura's research) * **Regulation has been important accelerator** of the diffusion of LED technologies (e.g., ban of inefficient lighting technologies); higher efficiency than light bulbs, contrary to fluorescent lamps no volatile hazardous substances * **multi-facetted applicability in different areas** (e.g., automobile, electronic devices, traffic signalling, etc.)
Linux Operating System	* **GNU project** (started 1983): Creation of a complete Unix-compatible software system composed entirely of free software * **Development and open dissemination of the Linux kernel** by Linus Torvalds (1991) * **Adoption as industry standard** with subsequent software applications building on it due to the fact that it is a free and open source software * **Increasing presence of ICT in everyday life**: from applications in the home and work environment to healthcare to communication to transport and safety
Mobile Phone (MP)	* **Liberalisation of the European telecom markets and high competition building on first experience in US** * rapid propagation of mobile network infrastructure * EU FP (4) projects on **mobile telecommunication standardisation** (e.g., 3G) * Successful integration of additional functions (camera, MP3, etc.)
Super Jumbo Jet (A380)	* **Joint study** on very large commercial aircraft **by Airbus and Boeing** (1994) * Steady **rise of passenger travellers preparing the field for the opening up of a niche market** * One **key FP6 project** that has been found **relevant to the development of the A380 aircraft**: the project pertains to the development in materials that could be directly utilised for advanced aircraft structural applications.
Optical Fibres (OF)	* **Increasing demand** for **safe and secure transmission of information** via high-speed broadband internet and high speed computing applications: capability to carry more information as compared to an ordinary cable * **Rapid progress of information society and exponentially increasing need for data exchange and storage.** * **Consumption of electronic products** combined with **AirPlay devices** boost the demand for optical fibres (especially in China)
Personalised Medicine (PM)	* **Boosting the efficiency of drugs:** approximately more than a third of all patients may either be treated with the wrong drug or a wrong dose * **Challenges concerning cancer treatment and ageing society in highly developed health systems in Europe:** growing health costs *Offensive network and community building (e.g., **EU conference European Perspective in Personalised Medicine**, 2011)
Photovoltaic (PV)	* **Oil crisis** (1973): stimulation of rapid rise in the production of photovoltaic solar power during the 1970s and early 1980s. * **High sensitivity to public policy and support from policy makers:** regulations have been an important accelerator of the diffusion of photovoltaic technologies (e.g., German feed-in tariff (FIT) model): the result of such policies has been that the industry structure has evolved, resulting in strong distributor and dealer networks with well-trained installers and good customer support capabilities.
Smart Grids (SG)	* Smart grids as way to **increase sustainability** (in Europe) * Smart grids as a way to **modernise their current electric system** (in the USA and other parts of the world) * **Reduction of the frequency and duration of power outages, number of power quality disturbances, the probability of regional blackouts** * **Growing environmental awareness** and the usage of renewable energies * **High sensitivity to public policy** and support from policy makers: regulations are seen as an

	Trigger event(s)/trigger factor(s)
	important accelerator of the diffusion of smart grid technologies (e.g., EU's energy policy fostering interoperability)
Stem Cell Treatment (SCT)	* **Scientific curiosity and breakthroughs (e.g., the discovery of induced pluripotent Stemcells)** * **Challenges concerning cancer treatment and ageing society in highly developed health systems in Europe:** growing health costs *Availability of private risk and venture capital ('privileged' situation in USA) * **Political commitment and public perception** to booster the stem cell research/strategy (e.g., Japan, USA or UK)

Among the selected Major Innovations, a few seem to be rather more driven by private research/innovation efforts, entrepreneurial spirit and smart marketing and others seem to be rather more driven by public policy commitment, public perception and societal or grand challenges:

- *Major Innovations driven by private research/innovation efforts, entrepreneurial spirit and smart marketing:* we can identify car navigation systems, mobile phones, the Super Jumbo Jet, optical fibres and Linux as Major Innovations, which have been mainly driven by private research/innovation efforts, entrepreneurial spirit and smart marketing. However, this does not mean that public policy was irrelevant. There is clear historical evidence that in both cases, car navigation systems and mobile phones, key policy events boosted the entry of the Major Innovations into the mass market (car navigation system: opening up of the GPS–NAVSTAR satellite system for civilian use (2000); mobile phones: liberalisation of the European telecom markets).
- *Major Innovations rather more driven by public policy commitment, public perception and social and ecological challenges:* personalised medicine, stem cell research, smart grids, photovoltaic panels as well as LED lighting are Major Innovations addressing societal and ecological challenges, which received policymakers' broad attention and support, both via funding and privileging regulations. Regulatory measures or indirect subsidies favoured or at least encouraged LED lighting, photovoltaic and smart grids. Regulations are seen as an important accelerator of the diffusion of those technologies. Similar findings could also be seen in the case of personalised medicine and stem cell treatment[24] (e.g., the clear political commitments regarding iPS cells in Japan).

[24] However, it has to be mentioned here, that regarding the development of stem cell research the EU intentionally adopted a 'wait and see' position regarding its clear political commitment. The reasons therefore are on the one hand ethical aspects regarding the human embryonic stem cells and on the other hand, high safety concerns regarding stem cell treatments.

5 Major Innovations in the EU Framework Programmes

The following section will provide an overview of the strategic orientation, intervention and evaluation logic of the Framework Programmes. Furthermore, it will discuss in how far the Framework Programmes have been engaged and supportive in the case of the selected Major Innovations. This prepares the basis for a discussion of potential scope for improvements of the FP evaluation scheme and programme management.

5.1 Role of policy in an innovation system

If we follow the Technology Innovation System (TIS) approach as explained in section 3.1.3 we can map the potential roles EU policy and the FP's can play a role in the system to the functions. The development of all MI's has followed different paths, with stronger or less relevance of some of the functions as shown in the previous sections.

Table 17: TIS functions mapped to EU policy and FP

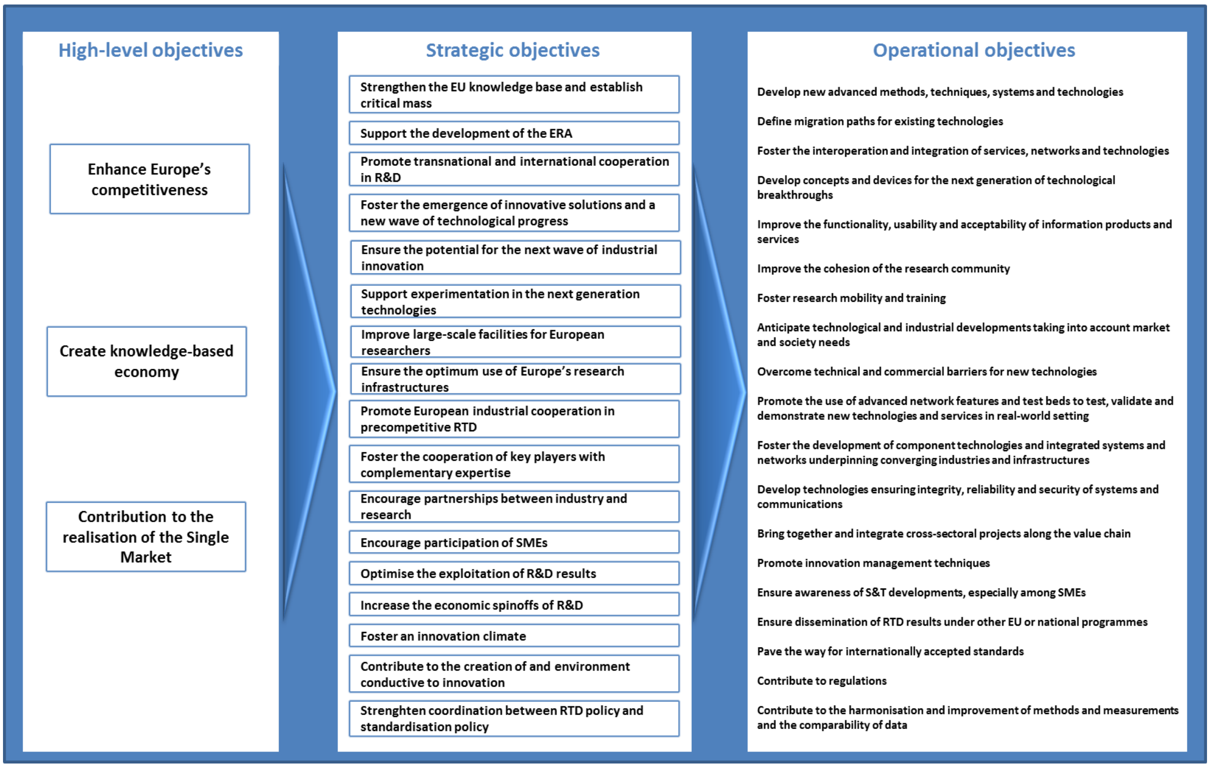
TIS Function	Role EU policy and FP's
Entrepreneurial activities	•Regulation plays a role here, to remove barriers, allow easy entry to the market. •The FP's as such play a complementary role
Knowledge development	•A key role for the FP's •Also policy as a driver (energy policy for instance)
Knowledge diffusion	•A key role for the FP's •networking and diffusion of knowledge have been a key pillar in the FP's
Guidance of the search	•A key role for the FP's •in particular in the programming phase where strategic directions are chosen
Formation of markets	•A complementary role for the FP's •in particular in the programming phase where strategic directions are chosen
Mobilization of resources	•A key role for the FP's, especially in generating a sufficiently large pool of knowledge resources. •Financial resources and facilitation of access to finance are important factor
Creating legitimacy	•A complementary role for the FP's, mainly through including all stakeholders in different phases of development; A key role in managing the policy process and engaging stakeholders also in regulation and policy

5.2 Focus and Contribution of the EU Framework Programmes

5.2.1 The Background of the FPs

The Framework Programmes (FP) for Research and Technological Development are the main instruments of the European Union to promote and support R&D. The first Framework Programme for Research and Technological Development (FP) was implemented in 1984 and dedicated to the promotion of co-operative R&D, the strengthening of science – industry linkages, R&D infrastructure and researchers, in order to increase Europe's global competitiveness. The conceptual background of the Framework Programme is clearly influenced by a systemic, complex and evolutionary view of innovation, corresponding with the idea that innovation processes could start anywhere in the innovation system but not necessarily with (basic) R&D. This explains the strong emphasis of networking, the building of institutions, and the broader setting of thematic priorities and agenda.

The overall intervention logic of the subsequent FP's shows that the focus has been on both longer term objectives (such as Emergence of new technologies or fields of science, Technological trajectories, Integration of research, Cohesion of Europe, Diffusion of innovation in products, processes or services, Strengthened competitive position of industry, Innovation in policy-making, Innovation in the socio-economic sphere) and mid term objectives (such as Knowledge exploitation, Collaboration in R&D, Technology exploitation, Innovation in industry, Innovation in market structures, Knowledge spill-over in the education system, Knowledge spill-over to other R&D policies, Improved policy development & regulations, Innovation acceptance among end users). Operationl and strategic goals have been defined largely at thematic and programme level, and focus mainly on research and support activities. Even though some of these are industry and innovation related, they are mid to long term, meaning the FP's should contribute to those goals on the mid to long term. This corroborates what we have found in this study, the FP's do contribute on the mid to long term to the Major Innovations, but not directly. The following figures provide an aggregated overview of the intervention logic of the subsequent FP's[25]



[25] From Understanding the Long Term Impact of the Framework Programme, Eric Arnold et al, 2011

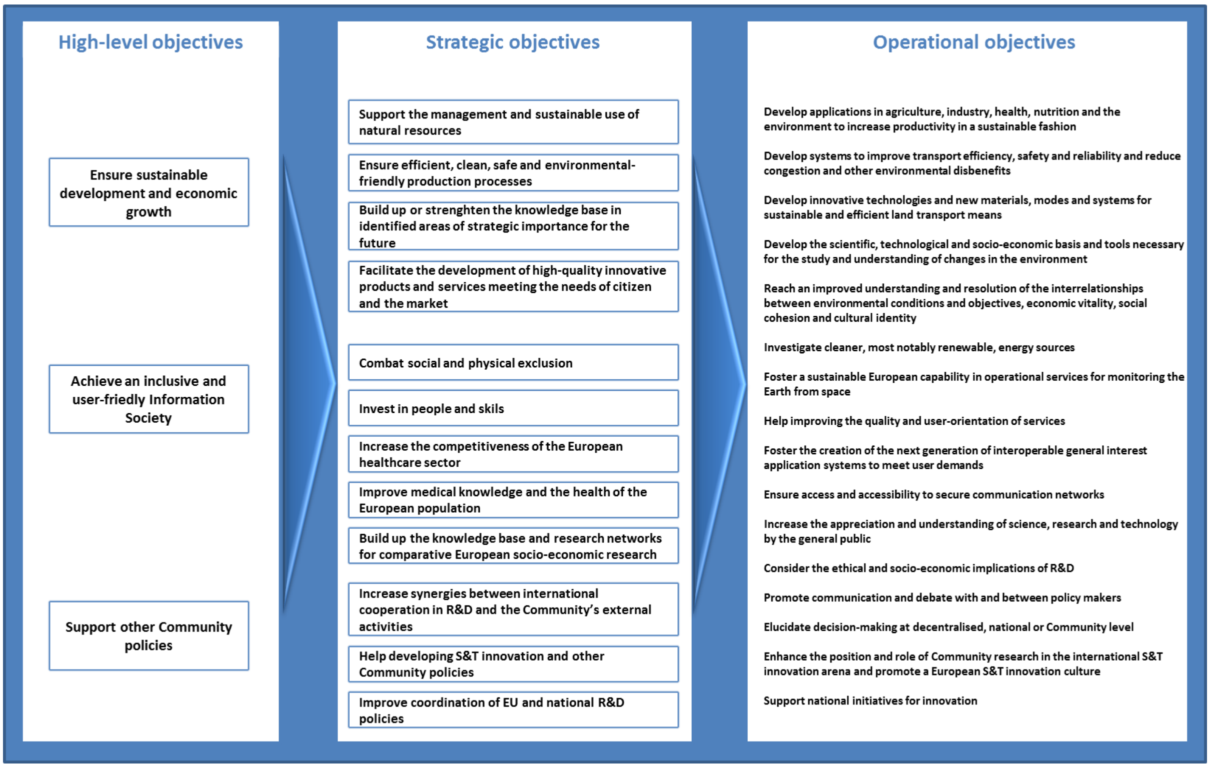


Figure 23: Intervention logic FP's

Besides focusing on industrial R&D, universities and other research organisations are the core institutions regarding their contribution to the strategic utilisation of the knowledge base in the European Union, being placed strategically at the intersection of research, education and regional, national and European development policies.[26] Since the beginning of the 1990s, the definition of the framework programme was accompanied by foresight activities dedicated to anticipate future trends and needs. Since its introduction, the FPs as well as the character of European Added Value justifying policy interventions at the European levels changed gradually (see Table 18):

Table 18: Evolution of intervention logic focussed on European Added Value in the FPs (Source: JIIP Compilation)

Logic of intervention and European Added Value	FP1	FP2	FP3	FP4	FP5	FP6	FP7	H2020
Overcoming the specifically high-risk of pre-competitive R&D **(**in high-tech industries**) technology push**								
Critical mass and financial **benefits** of scaling up at the European level								
Complementarity to Member States initiatives								
Cohesion of a European Research Area across national borders								
Promotion of uniform institutions (laws and standards)								
Fostering quality and competitiveness via EU-wide competition and providing access to follow up financing like InnovFin								

[26] Five-Year Assessment of the European Union Research Framework Programmes 1999-2003

Mobilisation and Exploitation of innovative potentials **(SMEs, Human potential)** to raise European economic competitiveness

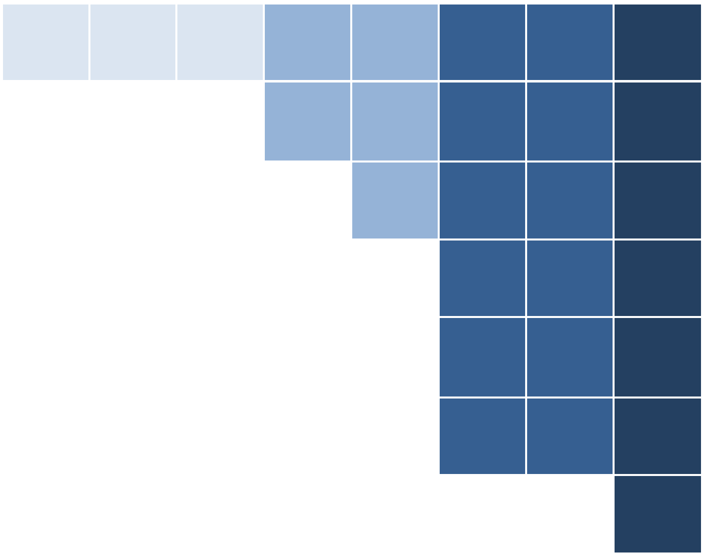
Contribution to the solution of societal problems/ grand challenges

EU-Internationalisation: Fostering "Third Country" co-operation

Coordination of R&D and Innovation Policy in Member States/regional level and at the EU level (ERA)

Structuring the R&D community and building large scale **(thematic)** communities, **including industry**

Fostering **international** market/use orientation and increasing **international** permeability for excellence



The first three Framework Programmes (**FP1 to FP3)** (1984-1994), aimed to ensure the competitiveness of high-tech industries and pursued technology-push objectives, especially in information and energy technology. The main driving forces for FP1 to FP3 were market failure arguments - due to the high-risk nature of pre-competitive R&D endeavours in high-tech industries - and consequently cost sharing motives and the creation of critical masses and internalisation of knowledge spillovers. Knowledge spillovers are essential in the development of those Major Innovations where a critical mass of knowledge diffusion and cross sector application of the knowledge is required.

With the implementation of **4th Framework Programme** in 1994, with a final budget of ECU 13.215 billion[27], basic research became of importance in the FPs' funding objectives as reaction to the emergence of so-called science-based technologies, such as biotechnology or microelectronic[28] Furthermore, knowledge diffusion objectives, user orientation of technologies, as well as training and mobility measures for researchers and support mechanisms for small and medium-sized enterprises (SMEs) were added to the portfolio of the Framework Programmes. The objectives of FP4 were implemented by 15 thematic programmes (including Euratom) covering different technological and scientific areas, and three horizontal activities, covering the improvement of dissemination and optimisation of results, the stimulation of training and mobility for researchers, as well as cooperation with third countries.

The major novelty of the **5th Framework Programme** (1998) was its stronger focus on translating scientific advances and breakthroughs into marketable innovations and solutions to address societal and economic challenges[29]. Starting with FP5, pathbreaking innovations in a narrow sense can be taken as an objective. Moreover, the structure was simplified, consisting of four thematic programmes and three horizontal programmes. This approach was principally reinforced by the 'Key Action' concept. 'Key actions' deal with concrete problems through multi-disciplinary approaches

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[27] European Currency Unit

[28] Five Year Assessment of the European Community RTD Framework Programme 1997, COM(97) 151

[29] DECISION No 182/1999/EC of the European Parliament and of the Council concerning the fifth framework programme of the European Community for research, technological development and demonstration activities (1998 to 2002)

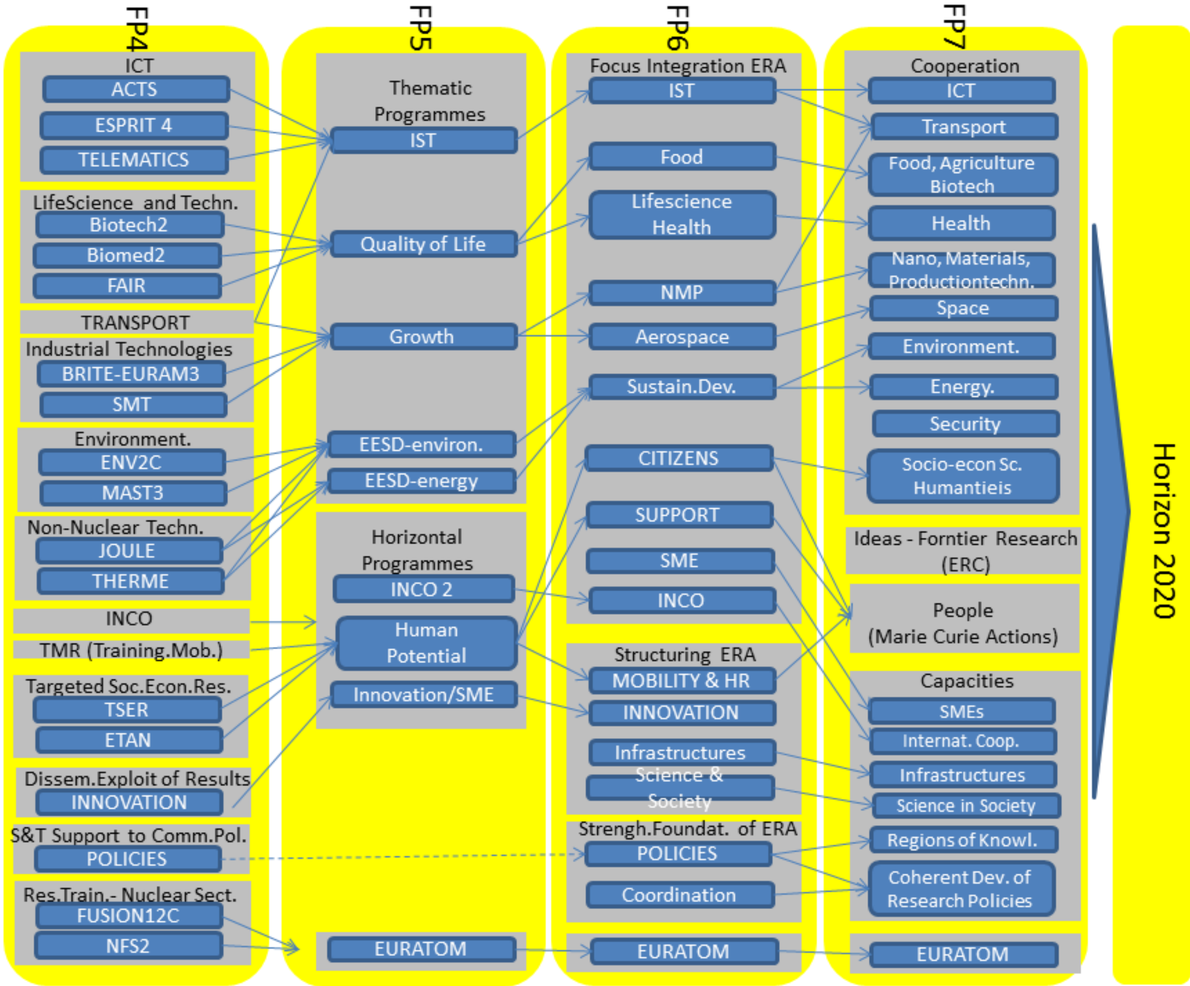
involving all concerned parties, including the user community. Even if not put in front, elements of co-creation and building eco-systems were adapted implicitly at that time. Figure 24 provides an overview of thematic and programme topics and their evolution from FP4 to FP7. During the implementation of FP5, major structural changes took place regarding RTD policies in the European Union. The communication of the European Research Area (ERA) as well as the implementation of the Lisbon agenda in 2000 addressed the weakening of EU's global position in industrial competiveness (compared to the USA and Japan) and an on-going exodus of scientific talent of European countries.[30]

The **6th Framework Programme** subsequently was designed to act as the main legal and financial instrument of the EC to implement the ERA with an overall budget of 17.5 billion Euro, accompanied by national efforts and other European cooperative research activities.[31] FP6 was made up of three blocks. The first block focused on a further integration of ERA, comprising seven thematic priorities (with 12.348 billion Euro for the largest area in FP6), where coordinated research was supposed to provide significant added value for Europe, as well as wider fields of activities and research, including research for policy support, support for SMEs and international co-operation activities. The second block was constructed to address structural weaknesses regarding coordination of European research (infrastructure, R&I regulatory environment, Science and Society linkages), as well as to contribute to the development of excellent human resources. The objective of the third block was the coordination of national R&D programmes and funding schemes and the support of joint activities among national institution in the European Union ("ERA-NETs").

[30] COM(2012) 392 final: A Reinforced European Research Area Partnership for Excellence and Growth

[31] European Commission (2014): The Sixth Framework Programme in brief

Figure 24: Structure of Framework Programmes 4 - 7 (Own compilation)



With an overall budget of 50.521 million Euro, the 7th **Framework Programme** goes far beyond previous FPs, both in budgetary terms, as well as regarding the overall aim of contributing to Europe's development as a knowledge-based economy and becoming a world-leading research area, based on the principle of excellence in both applied and scientific research.[32] Building on the achievements and structure of FP6, activities were grouped in four main categories. *Cooperation* accounts for the major part in terms budget (32.413 million Euro), providing funding to excellent and collaborative research projects of academic or industrial institutions, along thematic priority areas.[33] The scale and impact of the thematic priorities should be enlarged by the new instrument of Joint Technology Initiatives, providing co-financed research funding of FP7 and European Technology Platforms (ETP) for certain objectives, defined by ETPs Strategic Research Agenda (SRAs).[34] The category *capacities* mainly continued actions of the second and third block of FP6, comprising coordination activities, with new instruments for the establishment of EU and Member States' Public-Public partnerships[35], and innovation support for SMEs. Emphasis on the development of human capital was put in the categories *ideas* and *people.* With the European Research Council

[32] Interim Evaluation of the Seventh Framework Programme, Report of the Expert Group, 2010

[33] DECISION No 1982/2006/EC

[34] These are: Innovative Medicine Initiative (IMI), Clean Sky in Aeronautics, ARTEMIS in embedded systems, ENIAC in Nanoelectronics and the Hydrogen and Fuel Cells Initiative (FCH)

[35] Joint Programming Initiatives, Article 185, Initiatives

(ERC), a Europe-wide highly autonomous funding mechanism for frontier research was implemented, relying on the principle of competitive individual grants targeting different stages of scientific careers, awarded on the principle of scientific excellence. The Marie Curie Actions of the category *people* aim at supporting the quality of human resources in Europe by five measures comprising training, exchange and mobility programmes.

FP7 also introduced a number of new instruments compared to FP6. The most important ones are support for frontier research6, joint technology initiatives (JTIs) and the Risk-Sharing Finance Facility (RSFF). Support for frontier research was introduced to fund basic 'blue-sky' research, whereas the other two instruments were conceived to support close-to-the-market innovation activities with the aim of fostering industry participation, which has steadily decreased since FP4.

The RSFF is a financial instrument designed to improve access to debt financing of research, development and innovation (RDI) investments on acceptable terms for private companies or public institutions promoting activities in the RDI field. Target beneficiaries of the RSFF also include European research-intensive entities and research infrastructures. The European Commission, through DG Research and Innovation, monitors the RSFF in terms of eligibility of projects and budget allocation from FP7, while the EIB is in charge of the daily operations. The instrument is jointly financed by the EU and the EIB. The maximum EU contribution under FP7 for the RSFF was set at one billion euro.

The RSFF's main objective was to foster 'private sector investment across Europe in research, technological development and demonstration as well as innovation'. This was to be achieved by leveraging that private investment with a target of 10 billion euro in additional RDI loans.

Under RSFF, 96 operations amounting to 9,5 billion euro had been approved up until the end of 2011. As not all approved operations resulted in an actual signature of the loan operation between the EIB and the borrower, the loan amount of signed projects reached 7,3 billion euro and disbursements were almost 5 billion euro. According to DG Research and Innovation, the leverage effect of the EU contribution is 6,6 (each euro of EU contribution has led to more than 6 euro of the RSFF loan finance). DG Research and Innovation further estimates that the RSFF has a multiplier effect of 28 on total RDI investment (each euro from the EU budget contributed to total financing of 28 euro of RDI investment). The RSFF has also a wide country diversification. As of the end of 2011, the RSFF portfolio included signed projects from 21 countries. However, three Member States (Germany, Spain and Sweden) accounted for more than half of total RSFF transactions.

5.2.2 Towards a policy framework for a European Research Area

Addressing the weakening of EU's global position in industrial competiveness (compared to the USA and Japan) and an on-going exodus of scientific talent of European countries, the Lisbon Treaty proposed the implementation of a **European Research Area (ERA)**. The ERA was to be dedicated to carrying forward the development of a knowledge-based, innovative economy and society in Europe, by enforcing coordination and co-operation in research policies and funding from the EU Member States.[36] ERA was also to contribute to the target of all Member States investing 3% of GDP in R&D and innovation by 2020. Within the ERA "…*researchers, scientific knowledge and technology*

[36] COM(2000) 612 final: Making a reality of the European Research Area: Guidelines for EU research activities

[should] *circulate freely, and encouraging it* [the EU] *to become more competitive, including in its industry, while promoting all the research activities deemed necessary by virtue of other Chapters of the Treaties.*"[37] The initial objectives of the ERA comprised five areas to be emphasised either by Member State coordination or by initiatives of the EC[38]:

- Research activities: coordinated implementation of national programmes, networking of excellence in public (universities) and private institutions, large-scale targeted (industrial) research projects;
- Research and innovation, encouraging "start-ups" and SMEs: strengthening technological innovation capacities, especially by supporting research in and for SMEs
- Coordination and development of (large-scale) research infrastructures;
- Human resources: strengthening Europe's human STI resources by focusing on mobility and career development, participation of women and increased attractiveness of research careers;
- Science, Society and Citizens: strengthening the link between research activities and policies and society.

Based on an on-going assessment of strengths and weaknesses in 2012, five new priorities have been defined, implemented along actions, and contributing to an 'aligned' ERA:[39]

- More effective national research systems: increased national competition;
- Optimal transnational co-operation and competition;
- Open labour market for researchers;
- Gender equality and gender mainstreaming in research;
- Optimal circulation, access to and transfer of scientific knowledge, including via a digital ERA.

5.2.3 EU-FP Evaluation Framework – short review

Since the implementation of the Framework Programmes, they have been accompanied by evaluations. In the European Commission, the trend towards evidence-based policy making, better regulation and the increasing complexity of policy problems have served to accelerate the uptake of policy assessment procedures in policy development. The evaluation activities support the implementation and management of the FPs and the further development of research policy.

The evaluations have gained increased attention and commitment since the early years of FPs and form an integral part of the reforms for sound and efficient management. Knowledge about how evaluation scope and practice evolved over time, anticipating the strategic objectives of several Framework Programmes is fundamental for understanding how the FPs have acted as enabling and supportive factors for Major Innovations. With the overall goals of the Framework Programmes appearing to shift from purely technological objectives to a broader approach where research, innovation and industrial solutions are intended to contribute to major societal challenges, evaluation practices had to be adjusted over time to allow for more a comprehensive assessment of success in meeting these goals.

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[37] Article 179 of the Treaty of the Functioning of the European Union (Version 2012)

[38] COM(2000) 612 final: Making a reality of the European Research Area: Guidelines for EU research activities

[39] COM(2012) 392 final: Reinforced European Research Area Partnership for Excellence and Growth

Evaluations in the first FP were undertaken at the project level, mainly based on the scientific expertise of panellists, focusing on scientific and technological relevance, rather than on overall economic and societal impacts of the programme.

The first meta-evaluation on programme level was undertaken for the final assessment of FP2, based on evaluation studies applied for each of the Specific Programmes (SP). For FP3 until FP5, the evaluations were performed in five-year cycles, so called Five Year Assessments (5YA) between the years 1992-2003. For FP3 and FP4, the structure was again similar, incorporating the reports on an SP-level as well as submissions of stakeholders from the European Commission, national governments and institutions.[40] Overall, they were more similar to monitoring reports, focusing on the function and efficiency of the programme structure, instead of dealing with its impacts and effects on stakeholders and economies. The third 5YA[41] included a wider set of evaluation studies encompassing a meta-analysis of FP performance for the first time. The report however did not yield wide conclusions on the outcomes of FP5.[42]

Since the implementation of FP5 in 1999, annual monitoring of the programme functioning and output was separated from the evaluation, i.e., the assessment of impacts and how the FP was meeting its objectives. From 2000 until 2006 (FP5 and FP6), monitoring reports were undertaken by external experts, at the beginning focusing on different topics of the FP or special characteristics like its support for human capital[43], mainly based on descriptive statistics like number of participants, success rates, etc. and expert assessment. Whereas expert panels for monitoring and evaluation mainly comprised scientists and technologists of the respective fields at the beginning, they were changing over time, incorporating the stronger expertise of science policy experts and evaluation specialists.[44]

With the start of FP7, the monitoring system was fundamentally restructured to become an internal management tool run by the European Commission, to assess the performance and implementation of the FP7 and its topic areas, based on a standardised and coherent set of indicators covering various performance and efficiency aspects of the programme.[45] Additionally indicator sets were included addressing the participation and output performance of projects by priority area. This should allow for a structured overview of the functioning and structural composition of FP7 and provides an important quantitative basis for the programme evaluation reports, as it was also the case since the first restructuring of the monitoring and evaluation system in 1999.

Whereas until FP6 Framework Programmes have been evaluated 'ex post', since FP7 a mid-term evaluation is also requested due to the extended time period of seven years. These programme evaluations are based on qualitative assessments provided by external expert panels, incorporating

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[40] Five Year Assessment of the European Community RTD Framework Programme 1997, COM(97) 151

Five-Year Assessment of the European Union Research and Technological Development Programmes, 1995-1999, COM(2000) 659 final

[41] Five Year Assessment of the European Union Research Framework Programmes, 1999–2003

[42] See Arnold, E. et el. (2011) Understanding the Long Term Impact of the Framework Programme, Final Report, European Commission, DG Research

[43] FP5 External Monitoring Report Improving Human Potential and the Socio Economic Knowledge Base 2002

[44] See Ex post evaluation of the Sixth Framework Programme 2009

[45] See First FP7 Monitoring Report 2009

information and data of the *monitoring reports* and *additional evaluation studies* undertaken to explore various characteristics of impacts of FPs in their thematic areas as well as some on specific aspects (e.g., participating institutions, researcher mobility, bibliometrical output, innovation activities, network building or technological transfer), most of them on behalf of the European Commission.

However, the Member States also conduct impact assessment reports on their FP participation. These Member State impact reports are very much based on assessing the impact on participating institutions, national policy and funding structure, rather than exploring economic effects on a more aggregate level, e.g., on employment, trade or competitiveness in terms of labour costs.[46]

The ex post evaluations are the most comprehensive FP assessment studies and they focus on the achievements, structure and design, implementation and management aspects of the FPs. They provide information about who participated in the FP, how the FP functioned, and some general overview of the outputs, outcomes and impacts. Whereas the ex post evaluation of FP6 strongly relied on knowledge provided by external studies and evaluations, the interim evaluation of FP7 was mostly based on monitoring reports and expert assessments by members of the Commission's DGs and science and policy advisors.[47] Direct perspectives on innovation impact and the contextual sense as described in the study however, was not part of the mandate or focus. Separate or parallel studies have been undertaken to measure impacts and in certain cases contextualise them, but they were done on an ad hoc basis and not as an integral part of the evaluation process.

Evaluation methods have evolved over time. Arnold et al. (2011) recently provided a broad review of methodologies applied in FP-related evaluations since 1999.

Up until now, the exploitation of EC data and documents in combination with participant surveys and interviews are the most common practice for evaluations and impact analysis. Those surveys are very much aligned on institutions' assessment in realising their goals by participating in FPs, as well on administrative issues of the programmes to provide a foundation for recommendations and improvements. The focus was mainly on effects on participants by their qualitative assessment, e.g., on the creation of new knowledge, cooperation and strategic alliances for R&D, effects on employees or the internationalisation of R&D.[48]

The evaluation of the impact of FPs on the Austrian R&D System[49] also incorporated assessments on the impact of radical innovations and the development of new products. Nevertheless, these surveys are still based very much on qualitative opinions, without allowing for any quantification of impacts. In recent years, other types of evaluation tools have increasingly been applied, like social network and econometric analysis, often in combination with those mentioned before. The Innovation

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[46] E.g., see Arnold, E. et al. (2008), Impacts of the Framework Programme in Sweden, VINNOVA; Simmonds, P. et al. (2010), The impact of the EU RTD Framework Programme on the UK; Schibany, A. et al. (2001), Evaluation of Austrian Participation in the 4th EU Framework Programme, JOANNEUM Research, Technopolis, VTT

[47] Interim Evaluation of the Seventh Framework Programme, Report of the Expert Group, 2010

[48] E.g., see Schibany, A. et al. (2001), Evaluation of Austrian Participation in the 4th EU Framework Programme, JOANNEUM Research, Technopolis, VTT; Simmonds, P. et al. (2010), The impact of the EU RTD Framework Programme on the UK

[49] Arnold, E. et al. (2010), Evaluation of the Austrian Support Structures for FP7 & Eureka and Impact Analysis of EU Research Initiatives on the Austrian Research & Innovation System, Technopolis

Impact Survey[50], for example, used econometric analysis to assess the impact of the participation of firms and research organisations on industrial innovation, exploiting data from the Community Innovation Survey (CIS), complemented by an additional survey.

Case studies appeared to be rarely used in recent years, though they might provide interesting insights about concrete impacts of the FPs on the increase of capabilities for product development and technology improvement considering relevant context specific factors. For the study of impacts of the EU Framework Programmes on Sweden[51], for example, effects were analysed for the Swedish vehicle sector, with special attention on Volvo, on the level of concrete research and technology developments, to assess whether the FPs contributed or enabled them. A recent analysis focused on the determinants of successful conversion of research into commercial success focusing on EU-funded research projects in the field of industrial technologies.[52]

All in all, these evaluations refer very much to a certain point in time, like the period of participation or the point on time of the survey. The scope of analysis is often short-term and does not look at effects of the FPs after the FPs have finished (usually even at the ex post evaluation stage a significant percentage of projects is still ongoing). The longer-term perspective is needed to understand the impacts on innovations (which can range between several months to decades), as this study demonstrates. Although horizontal, evaluations tend to concentrate to domain assessments and comparisons (in terms of funding participation profile, outputs) and do not or to a very limited extent assess cross-domain outputs and issues, which are highly relevant when thinking in terms of complex and Major Innovations. FP evaluations with a thematic or sectoral focus allow deeper insights and context specific analyses and discussions, however they are performed less frequently than horizontal analysis.

The current study complements these approaches by taking actual Major Innovations as the starting point and tracing back the drivers and FPs that supported them.

5.2.4 The funding of EU FPs for Major Innovations

Before analysing the achievements of EU FPs in supporting Major Innovations, it is necessary to understand how much emphasis and funding FPs spent for the selected Major Innovations. The only solid database available does not provide a readymade label or icon for 'Major Innovations'. Thus relevant projects to be associated with Major Innovations had to be identified on the basis of a keyword search which has been refined manually case by case. For reasons of data availability and quality, the following analysis does not include FP1 to FP4.

The total contribution of FPs to R&D activities constantly increased over time. Figure 25 shows the annual EC contribution (m€) to the selected ten Major Innovations through the Framework Programmes from FP5 until FP7 (from first FP5 projects starting in 2000 until the last FP7 projects that will finalise in 2017).

It can be seen that the FPs (5 to 7) did not steadily fund each Major Innovation, with the exception

[50] Polt, W., Vonortas, N., Fisher R., (2008), Innovation Impact, Final Report to the European Commission, DG Research

[51] Arnold, E. et al. (2008), Impacts of EU Framework Programmes in Sweden, Technopolis

[52] Ruhland, S. et al. (2013) Innovation - How to Convert Research Into Commercial Success Story? Part 1 : Analysis of EU-Funded Research Projects in the Field of Industrial Technologies; KMU-Forschung, Oxford Research

of the Super Jumbo Jet 380. The Mobile Phone has particularly been supported by FP5, FP6 and during the early days of FP7. The peak periods of FP funding correspond with the time of the rise of mobile phones and growing penetration of society by mobile telecommunication. In Horizon 2020, the presence of mobile phones and broader mobile telecommunication areas is represented by an integrated horizontal approach of mobile technologies to various substance areas, targeting higher productivity and related contributions in different economic sectors. The Major Innovations stem cell treatment and personalised medicine have also been funded intensively since the beginning of FP6 (with the focus on the understanding of the basic knowledge of stem cell technologies/treatments and the development of tools for new therapies and medicines based on stem cells). However, towards the end of FP7, the EC showed a clear commitment to boost personalised medicine as well as stem cells. The support via funding has been accompanied by many auxiliary activities and events, e.g., the conference on European Perspectives in Personalised Medicine. Albeit on a reduced scale, smart grids and photovoltaics show similar funding patterns.

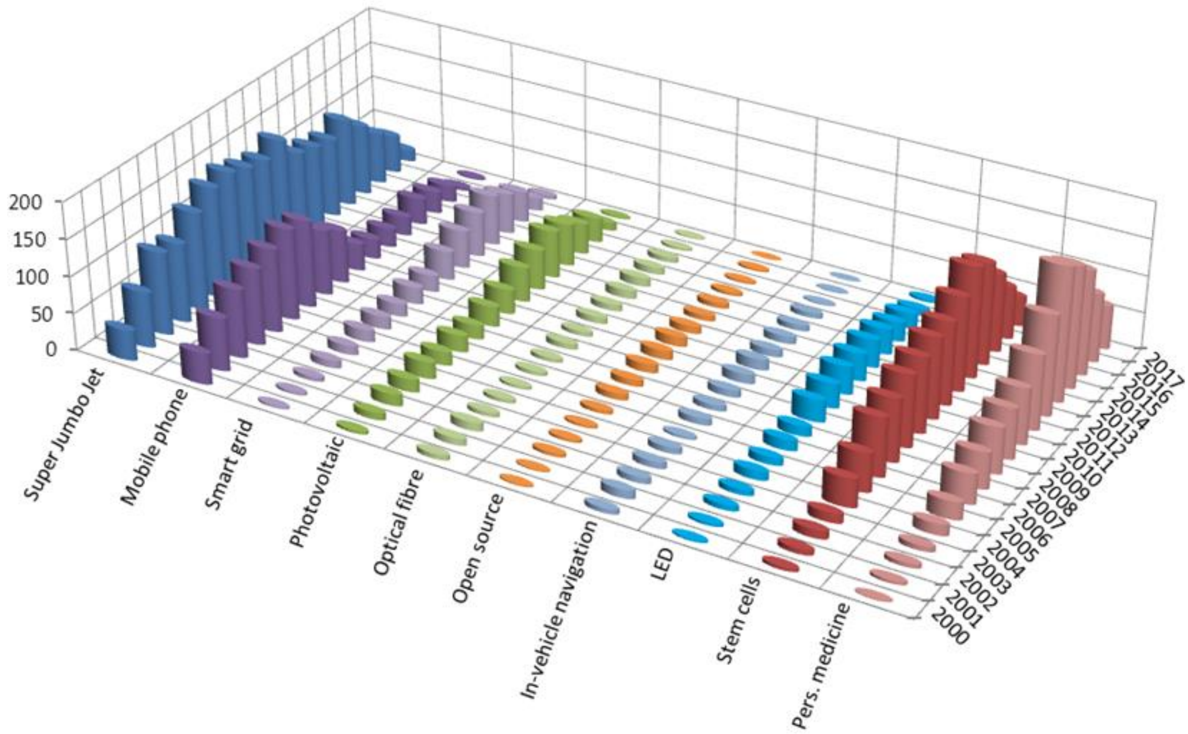

Figure 25: EC contribution (m€) to Major Innovations FP5-FP7 Source: JIIP, based on eCorda and online survey

The comparison among cases of Major Innovation on money or absolute number of projects does not allow the drawing of conclusions regarding the contribution of FPs, as the different Major Innovations have been funded at different absolute levels. Optical fibres, Linux (open source) and car navigation systems received the lowest amounts (albeit steady) of funding from FPs 5 to 7. In the case of Linux OS, only very few projects funded by FPs could be identified which does not mean that open source development has not gained from FP attention. The European Commission intensively supported open source activities since FP4. We learned in previous chapters more about the specific needs of Major Innovations to emerge and assert successfully. Interviewed experts, who participated in Linux projects funded by the FPs, stated that the projects would not have been conducted without the corresponding financial support. This is in fact quite plausible, as incentives for firms to invest in Linux are affected by the fact that it is a form of free and open source software.

The FPs deployed various instruments to support the MIs. Figure 26 shows the EC financial contribution by instrument type throughout FP5-FP7. One sees a confirmation of the picture in Figure 25. The highest EC contributions for RTD activities were received by Super Jumbo Jet A380, stem cell treatment, personalised medicine and mobile phones. Compared to the other Major Innovations, stem cell treatment also received the highest EC contribution for knowledge transfer and networking (209 m€) and personalised medicine for innovation and adoption (159 m€).

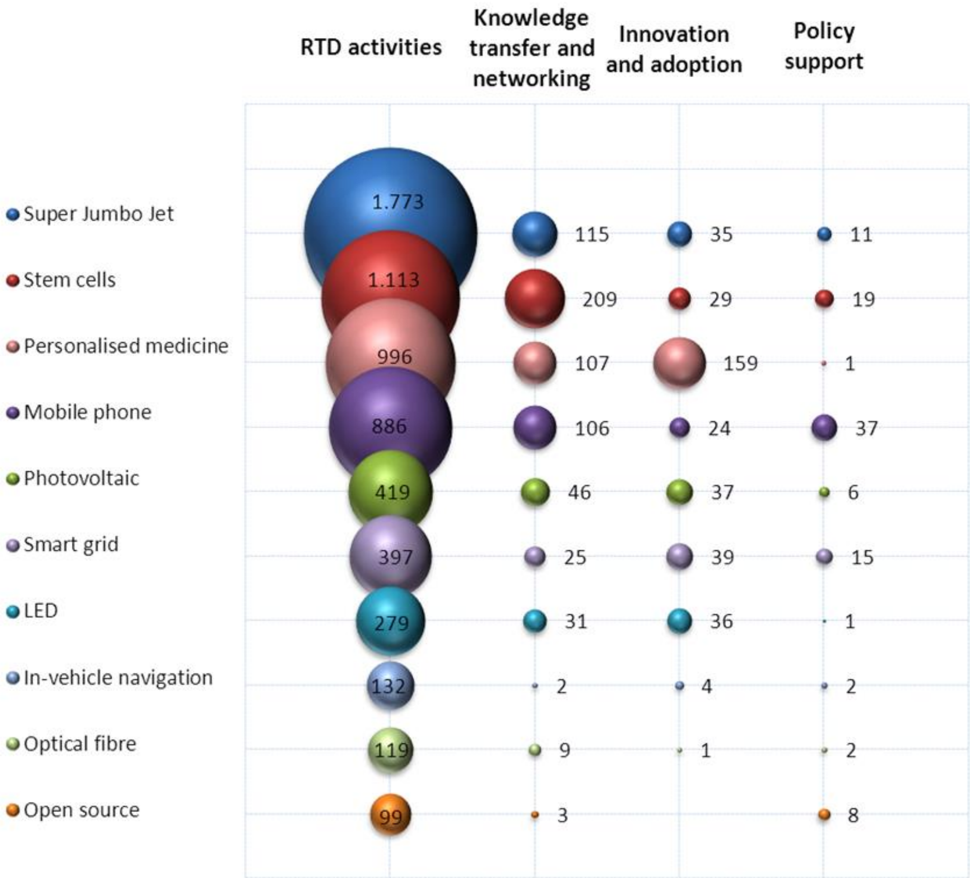

Figure 26: EC contribution (m€) by instrument type FP5-FP7 (Source: JIIP, based on eCORDA and online survey)[53]

[53] the different categories are defined in Annex 2a; Policy support includes preparatory, accompanying and support measures (FP5), Specific Support Actions (FP6) and Supporting Actions (FP7)

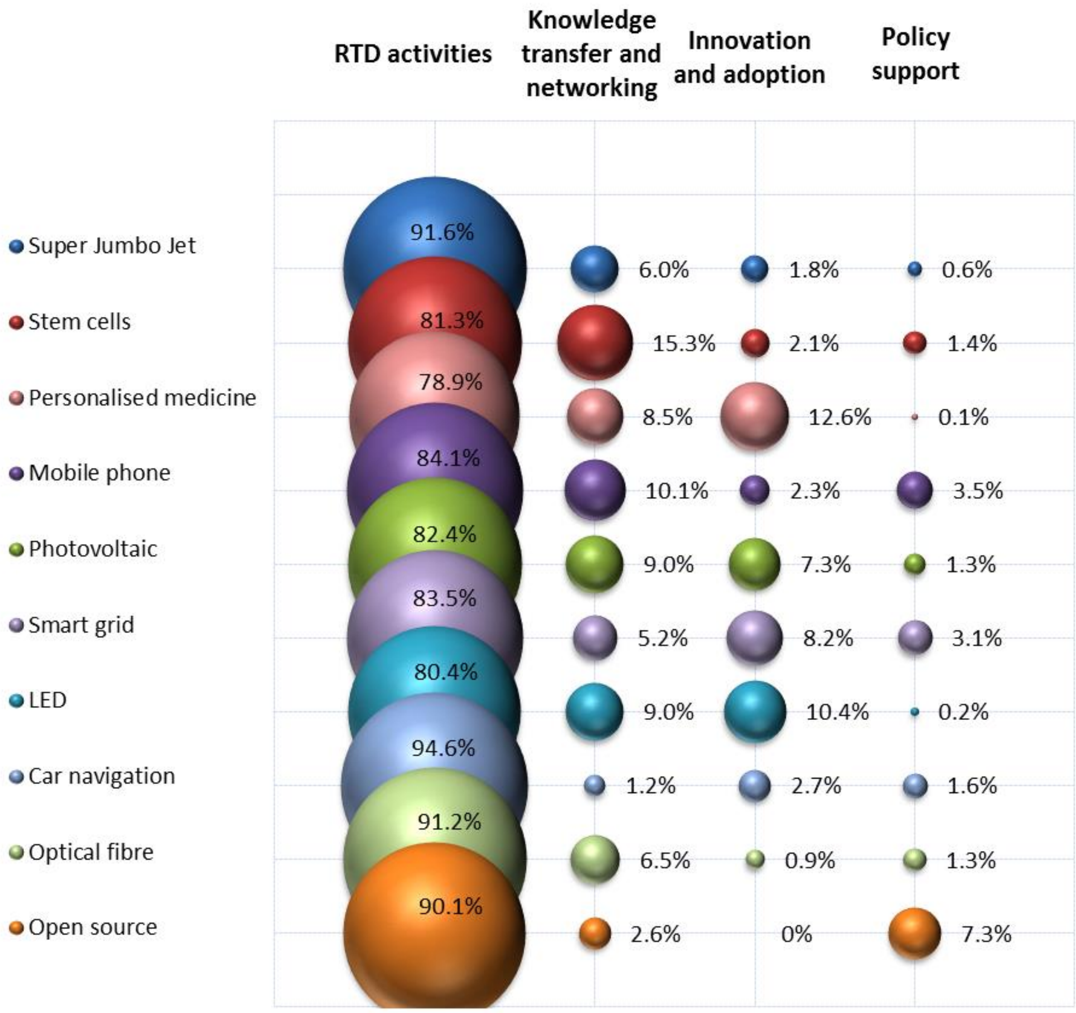

Figure 27: Share of EC contribution (m€) by instrument type FP5-FP7 (Source: JIIP, based on eCORDA and online survey)

In the case of stem cell treatment, this includes especially in FP5 thematic and research network contracts and research grants and fellowships; in FP6 Marie Curie Actions and Network of Excellence; and in FP7 European and International Re-integration grants, Initial Training Networks, Intra European Fellowships and Support for training and career development of researcher (CIG), whereas in the case of personalised medicine, this includes especially cooperative and networking activities like cooperative research contracts, joint technology initiatives, etc. In fact, one of the five Joint Technology Initiatives (JTI) set up under FP7 has been the Innovative Medicines Initiative Joint Undertaking (IMI JU). Through IMI JU, the European Commission is partnering with the European Federation of Pharmaceutical Industries and Associations (EFPIA) to fund research aiming to overcome bottlenecks in pharmaceutical R&D. The ultimate goal is to provide effective and safer medicines for patients. The European Commission contributes EUR 1 billion to the IMI research programme, an amount matched by mainly in-kind contributions (consisting mostly of research activities), worth at least another EUR 1 billion from EFPIA member companies. Interestingly the Major Innovation Linux (open source) received comparatively high EC attention via ‘policy support’.

We could see that the selected ten Major Innovations have been funded by the EU Framework Programme in differing extents. However, this leaves the question of how far other funding sources have been relevant. To answer this question, data sources are limited. This question was included in the survey amongst the experts.

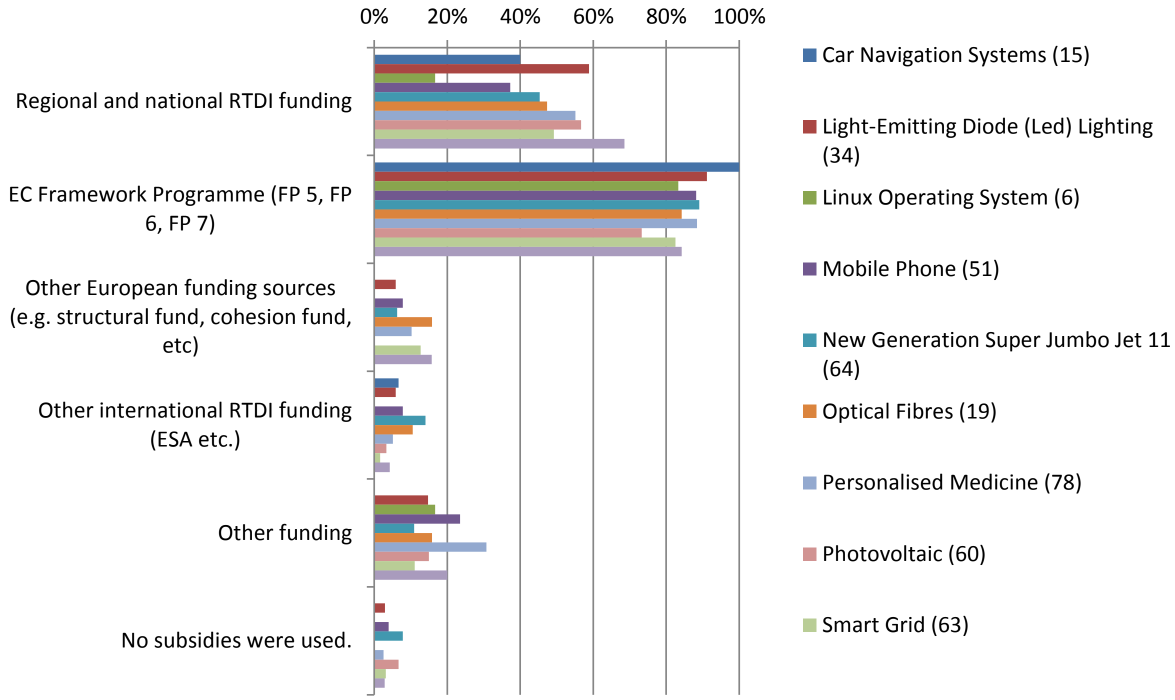

Figure 28: Funding schemes used in the development of stand-alone, core and supportive technologies for Major Innovations Source: JIIP, based on online survey

The survey focused on academics and innovators in the fields of selected Major Innovations, who participated in FP projects. Figure 28 shows the complementary public funding schemes, which the respondents used to develop stand-alone, core or supportive technologies of the Major Innovations.

While open source software showed a relatively low relevance of complementary R&D and innovation funding, respondents in the areas of the Major Innovations stem cell treatment, personalised medicine, LED, or photovoltaics made greater use of complementary funding sources.

An analysis of 90 funded projects under the RSFF scheme[54], shows that there is not direct link between FP7 projects and the RSFF loans. Even at beneficiary level (although marginal overlap) there is no connection between FP projects (both in general and in relation to the MI's) in which a particular beneficiary was active and the object for the loan received from the EIB.

The various evaluations and assessments of the RSFF make no mention of direct linkages between FP7 projects and RSFF loans[55,56,57]. The RSFF financing is primarily aimed at large and large midcap companies.

The nature of the funding and the financial assessment, based on bankability criteria, be it with

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[54] http://www.eib.org/projects/loans/list/index.htm, filtered on RSFF

[55] ECA, Has the Commission ensured efficient implementation of the Seventh Framework Programme for Research?, special report nr2, 2013

[56] Financial instrument facilities supporting access to risk finance for research and innovation in Horizon 2020, Ex ante evaluation 2013

[57] Second Evaluation of the Risk Sharing Finance Facility (RSFF), EIB June 2013

accepting higher risk factors (lower grading) than would be the normal practice as well as the size of financing (average 50 M€ per loan), seem to make the RSFF as such less likely as a direct follow up instrument to FP project funding.

In addition (according to the second interim evaluation) there was no clearly laid out intervention logic for the RSFF, which makes it difficult from the outset to place the FP projects in the context of the RSFF.

Overall the RSFF was positively evaluated, however. The findings of the first (2010) and the second interim evaluation (2013) of the RSFF[58], by two groups of independent experts, were largely positive. The experts concluded that the RSFF:

- proved to be attractive to RDI companies
- met or exceeded its loan volume targets,
- improved its geographic coverage,
- enabled EIB to increase the bank's capacity to make riskier loans.

The experts supported the demand-driven approach taken in implementing the RSFF, and underlined the importance of the Commission's and EIB Group's ability to quickly adapt the design of the instrument to changing circumstances. The expert group's recommendations again drew on an evaluation of RSFF activities conducted by the EIB's independent Operations Evaluation function[59], and encompassed the better targeting of innovative midcaps with specific financing products, including higher-risk finance (such as mezzanine).

The Court found[60] that the RSFF has enhanced the research-funding landscape and that beneficiaries had found it useful. A point of concern raised by the Court is that there is no evidence that RSFF funding had led to investments above the level that beneficiaries would have undertaken without public money, as a survey of RSFF beneficiaries showed that access to finance was not a major barrier to beneficiaries investing in R&I, as over half of respondents had stated that the lower interest rate was a decisive or major factor for taking a RSFF loan.

5.2.5 ERA activities accompanying FPs

FP6 and FP7 set much more emphasis on coordination of R&D and innovation policy in the member states. Since FP6, the implementation and Framework Programmes are closely related. However the FPs are complemented by a growing number of multilateral instruments and activities that bring stakeholders together to develop joint agendas and activities. Table 19 shows an overview of these activities relevant for the Major Innovation cases:

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[58] For the report by a group of independent experts on the second interim evaluation of the RSFF, see http://ec.europa.eu/research/evaluations/pdf/archive/other_reports_studies_and_documents/interim_evaluation_report_rsff.pdf

[59] *Second Evaluation of the Risk-Sharing Finance Facility (RSFF)*, EIB Operations Evaluation, May 2013

[60] *Has the Commission ensured efficient implementation of the Seventh Framework Programme for research?*, Special Report No. 2, European Court of Auditors (2013).

Table 19: ERA multilateral activities in the context of Major Innovations Source: EC 2015

Major Innovation case	ERA activity
Car Navigation Systems	ETP nem
LED Lighting	ERA-NET OLAE+
Linux Operating System (open source)	ERA-NET E-infranet
Mobile Phone (MP)	ETP eMobility (Mobile and Wireless Communications TP),ETP net!works, ETP EPoSS (Smart Systems), ERA-NET CHIST ERA, PPP Future internet
Super Jumbo Jet (A380)	JTI clean sky
Optical Fibres (OF)	FET Flagship GRAPHENE
Personal. Medicine (PM)	ERA-NET TRANSCAN, JTI IMI
Photovoltaic panel (PV)	ETP Photovoltaics, Solar ERA-NET, Innoenergy KIC (EIT), Climate KIC (EIT), PPP energy efficient buildings
Smart Grids (SG)	ETP Smart Grids, EIP Smart Cities
Stem Cell Treatment (SCT)	JPI Neurodegenerative Disease Research

5.3 Contributions of the EU Framework Programmes to Major Innovations

The focus of the Major Innovation project is on the time period related to the EC's FP5-FP7 and therefore from 1998 until 2013. The case studies demonstrated the timelines needed to observe major innovations and impacts of factors and measures on major innovations. Taking into account the average time lag between R&D activities and commercial success it has to be mention, that the ICT sectors shows relatively short innovation cycles (6 to 9 months) for individual innovations while other sectors like the energy sector or pharmaceutical sector show quite long innovation cycles (far more than 15 years). The development of a family of a major innovation will take much longer. Usually funding schemes support individual innovations among the family of a major innovation.

A few important starting points have to be taken into account when making this assessment (these are further elaborated in Chapter 6):

1) The **timeline** of the Major Innovations: The first applications of many Major Innovations (and therefore the development of technologies and innovations underlying them) had already been achieved by early/mid 1990s, before FP5 started in 1998. So FP5-7 could not impact their birth and first applications. Taking into account for instance the average time lag between R&D activities and commercial success, the ICT sectors shows relatively short innovation cycles (6 to 9 months) for individual innovations while other sectors like the energy sector or pharmaceutical sector show quite long innovation cycles (far more than 15 years). The development of a family leading to a major innovation can take even longer.
2) The **complexity** of the Major Innovations: as we demonstrate, most of the MIs are based on a variety (family) of innovations that do not happen simultaneously. These innovations may not have the same 'breakthrough value' in the process, but are still essential for the Major Innovations. This means that FPs can contribute at different levels to the Major Innovations at different points in time. Usually funding schemes support individual innovations among the family of a major innovation
3) The **aims of the FPs**. The exploratory nature of FP5 to FP7 aiming at pre-competitive

research (TRL 1-4), whereas 8 out of 10 Major Innovations passed TRL9. This implies that much of the results of the FP's may contribute to the Major Innovations through networking, aligning agendas, knowledge creation and diffusion and less in directly applicable innovation outcomes.

In the following paragraphs, the role of FP5, FP6 and FP7 on the development of key technologies underpinning the Major Innovations will be analysed.

The survey asked the experts who contributed to the development of the Major Innovations , if the development of the specific innovation would have occurred without the FP project(s). The overall feedback was positive. . Of the 485 experts replying to this question, 312 respond that the FP was important for their innovation. 173 respondents, however, stated that their progress would have been possible without the FP (Table B.3).

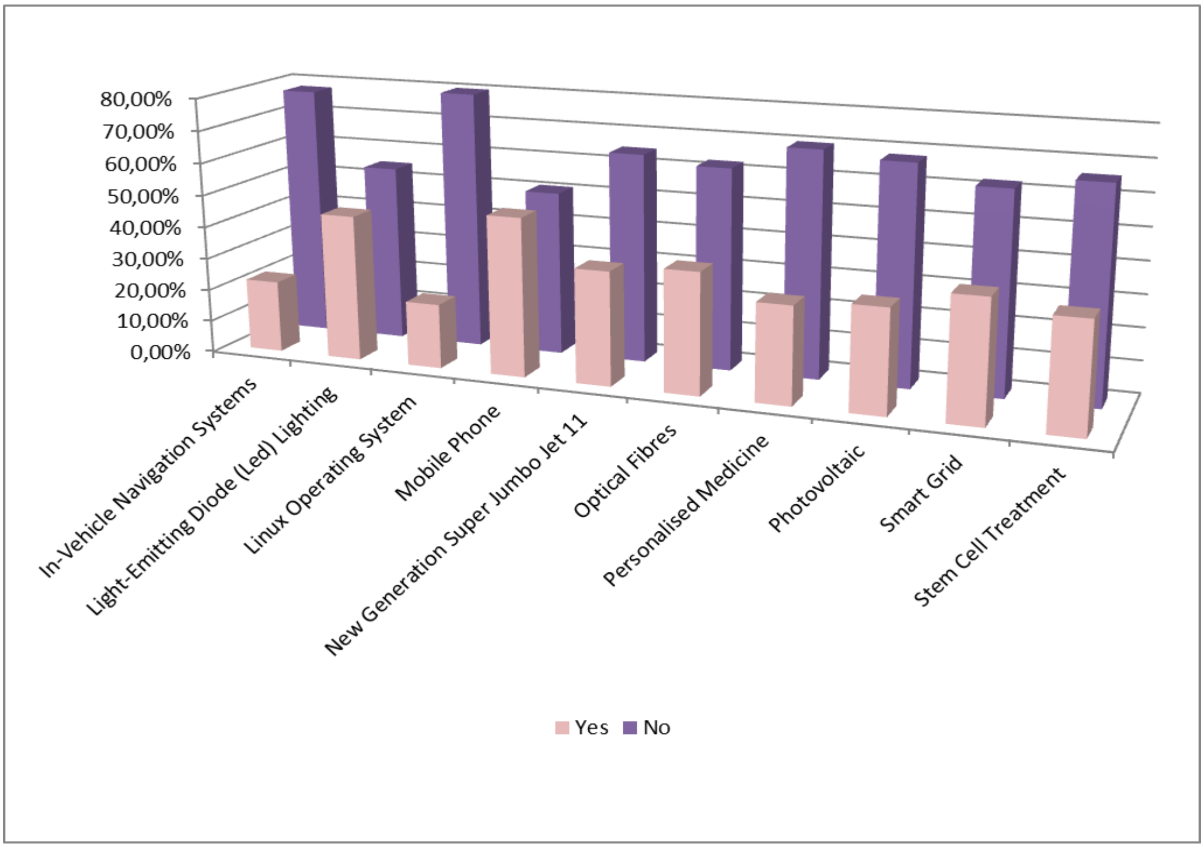

Figure 29: Did the framework programme significantly influence the initiation or success of your individual innovation

Source: JIIP based on online survey

Also, statistics contribute, like the number and size of projects or the destination of funding in terms of beneficiary organisations (companies, research institutes, universities, others) or countries. It is also possible to cluster projects and analyse the way they are embedded and connected to the overall Major Innovation. But that would not be sufficient to conclude about the FP contribution to the MIs. Far more is required. One would have to go beyond the mere programme statistics and systematically focus at the project level, their results and outcome. This would require an overall assessment of the projects, individually and as clusters/sub-programmes, in terms of innovation contribution, to the overall trajectory from first idea to successful market launch. This was not possible in the context of this study. The Major Innovations were analysed on the FP contributions with the following angles in mind:

- Direct contribution of the FPs to the initiation and emergence (origin);
- Direct contribution to the development and introduction of one of the major successes ;
- Contribution to the conceptual basis for regulatory development, policy development and standardisation (focus on externalities and synergies);
- Contribution by providing a broad exploration space for new technological possibilities:
    - Contribution to the broader diffusion and downstream application of Major Innovations (transfer from frontrunners to followers);
    - Generation of knowledge and technology spill overs within and across themes, which is critical for the development of Major Innovations, due to their complex and often cross cutting nature;
    - Contribution by networking and collaborating, exchange of ideas and open innovation (possible focus on next generation innovation);
- Contribution by capacity building and strengthening technology competence or sectoral systems piggyback on Major Innovations.

In the following parts, these angles haven been born in mind. They are based on the FP statistics, the MI case studies (summed up in Annex A), experts interviews and the online survey (for FP6 and 7 only).

5.3.1 The role and contribution of FP5 (1998-2002) to key technologies underpinning the Major Innovations

In Table 20, the EC financial contribution and the number of projects (in parenthesis) are depicted across all 10 Major Innovations. It becomes obvious that projects connected to the development of the Super Jumbo Jet received the biggest share of EC contribution – namely 545 m€. The most projects were conducted in the field of mobile phones (172 in total). The case of the Super Jumbo Jet is interesting as a relatively high funding activity could be observed from FP5 to FP7. These statistics may lead to the conclusion that the EC contribution in FP5 played a considerable role in the development of the Super Jumbo Jet A380. However, one has to be careful. FP5 started two years after a “Large Aircraft Decision” had been formed in 1996 and ended at the time when component manufacturing started in 2002. Thus, FP5 contributed to the development at a critical moment. However, it is obvious that the Airbus 380 was not the first and largest airplane ever built, as French-based Airbus initiated its research on large aircrafts in the early 1990s. Starting the Super Jumbo Jet, project engineers had a concrete picture of challenges to be met. The EU started cooperating in aerospace with the second Framework Programme (FP2) through the BRITE-EURAM initiative (launched in 1989) on advanced industrial materials. Thus, the Framework Programmes already looked back to a long funding history and strategic coordination of European research and funding agenda at that time. This might explain why the FP contribution could be seen as a necessary and coordinated complement to the policy initiated elsewhere at EU level. The most important theme that was relevant towards the development of the Super Jumbo Jet in FP5 was in the thematic programme “Competitive sustainable growth”. This is evident as the aerospace sector is highly competitive with very strict environmental regulations especially within the European Union. One of the main achievements of FP5 concerning the Super Jumbo Jet may have been the alining of this flagship-project with the strategic agenda of the aeronautics sector in Europe.

Table 20: EC contribution in millions of euros to and number of projects (in parentheses) of the Major Innovations in FP5

Source: JIIP

	EC Contribution (m€) and number of projects										
	FP5 Total (number of projects)	Open source	Smart grids	Photo-voltaic	Stem cells	Pers. medicine	LED	Optical fibre	Mobile phones	Car navigation	Super Jumbo Jet
Thematic Programmes:											
1. Quality of Life	2378 (2947)	0 (0)	0 (0)	0 (0)	51 (42)	24 (18)	0 (0)	0 (0)	7 (3)	0 (0)	0 (1)
2. User-friendly information society	3494 (2518)	14 (14)	3 (2)	3 (2)	1 (2)	1 (1)	20 (11)	40 (19)	306 (159)	38 (20)	24 (11)
3. Competitive and sustainable growth	2525 (2207)	0 (0)	0 (0)	9 (7)	0 (0)	0 (0)	4 (4)	0 (2)	4 (5)	4 (5)	518 (91)
4. Energy, environment	2036 (2007)	0 (0)	27 (17)	50 (53)	0 (0)	0 (0)	1 (2)	0 (0)	4 (4)	2 (1)	3 (2)
Horizontal Programmes:											
5. International role	404 (1198)	0 (0)	0 (0)	0 (2)	0 (0)	0 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
6. Innovation and SMEs	42 (147)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
7. Human research potential	1308 (5709)	0 (0)	0 (0)	2 (6)	1 (13)	1 (7)	1 (4)	0 (1)	1 (1)	0 (0)	0 (0)
TOTAL	12187 (16733)	14 (14)	30 (19)	63 (70)	54 (57)	26 (27)	26 (21)	40 (22)	321 (172)	45 (26)	545 (105)

During the 1990s, the European Commission, through its FPs, put considerable attention on information technology and the successful transition towards an information and knowledge society. This played the most important role towards the development of mobile phones, optical fibre, LED lighting, car navigation systems and open source (e.g., Linux), whereas the energy and environment theme was most important for developments in the field of smart grids and photovoltaics and the quality of life theme in the field of stem cells and personalised medicine.

In the specific case of the mobile phone, FP5 could build on previous steps made in FP4 concerning standards allowing internet use via mobile phones, which prepared a relevant basis for today's smart phones. Furthermore, FP5 funded several projects focusing on mobile applications for different purposes (e.g., location-specific services, access to news and media) or functions increasing usability of mobile phones (e.g., voice control or speech recognition). However, unlike the 3G development concretely supported by FP4, FP5 activities were somewhat accompanying and auxiliary to the broader movement.

Similarly, but at a lower level of activity, FP5 funded a number of projects in the field of car-navigation, which treated various issues relevant at that stage (e.g., multimedia integration in a car, speech-driven interfaces or navigation use for pedestrians).

Box 8: Funding pattern for car navigation systems and LED lighting throughout FP5, FP6, FP7 and Horizon 2020

Source: Case study

Car navigation systems:

The main technologies and innovations underlying GPS car navigation were developed in the 1980s and 1990s. In-dash car navigation systems appeared in production cars in the early and late 1990s. The mere fact that the EU Framework Programme 5 started in 1998 shows that there is no direct contribution or relationship between the Framework Programmes, specifically FP5, and the early development and subsequent market introduction of car navigation systems. For the obvious and same reason this also holds for its successors FP6 (2002-2006) and FP7 (2007-2013). This is not to say that the Framework Programmes 5, 6 and 7 did not support R&D projects in GPS car navigation or contribute to its further development. They did. But rather than contributing to satnav becoming a Major Innovation, these were aimed at specific elements related to its further maturation and development with various improvements and new functionalities (incremental innovations). Whether earlier Framework Programmes, from FP1 (1984-1988) to FP4 (1994-1998) contributed to the development of GPS car navigation systems, and to what extent, was not part of the current research project. However, the search for material (written accounts and documents, interviews) on the development of car navigation and its underlying technologies did not reveal any evidence that pointed into this direction.

LED lighting:

The analysis shows that EU FP activity in the LED technology area has substantially increased from FP5 (29 projects, EC contribution 26 M€) to FP7 (81 projects, EC contribution 254 M€). However, the share of LED research of the whole of FP funding has remained relatively small. In FP5 it was 0.2%, in FP6 0.3% and in FP7 0.5% of the total funding. Hence, although EU funding has grown 10-fold, its relative share of FP funding is still very limited. At the same time, many countries, such as China, Taiwan, Japan, Korea and the US, have also heavily increased their investments in this area (e.g., Weir & Archenhold 2011). Earlier studies have shown that up to FP5, the EU's investment in LED technologies lagged behind the US and Asian countries (Walsh et al. 2008). This lack of specific initiatives for LED innovation was also reflected in European countries' minor share of LED patents at that time. Given the high global investments in the LED area, it is likely that this situation has not substantially improved from Europe's point of view. In this regard, it is also noteworthy that there has not been dedicated funding for LED in the FP5, FP6 or FP7, but funding in this area has been channelled under ICT, electronics, photonics or material physics.

FP5 contributed to the broader diffusion and downstream application of the Major Innovations LED, where Europe was lagging behind. The small number of projects funded in the cases of car navigation, photovoltaics or optical fibres also dealt with single applications, however without a clear accumulation of certain topics. FP5 contributed directly to the development process of the Super Jumbo Jet, where capacity building and strengthening technology competence could piggyback on Major Innovations at a time when the aeronautic industry was slowly starting to open towards innovation-potential SMEs. In all cases, especially in the cases of personalised medicine and stem cells, FP5 has contributed to networking and collaborating, exchange of ideas and open innovation (e.g., networks for stem cell registries) and by providing the basis for regulatory development and standardisation (e.g., a network concerning ethical, safety & regulatory data). These finding corroborate the findings of other studies.

Summing up, the positive effects of FP5 on innovation in general at firm level found in other studies[61] are confirmed in this study and the technology areas relevant for the selected Major Innovations have been addressed in varying degrees in the programme. We have not identified direct impacts of FP5 on the initiation or core development of the selected Major Innovations, due to the exploratory nature and the timeframe of FP5. FP5 has contributed more through capacity and

[61] Innovation Impact study, page 65-67, OPOCE 2009 (http://bookshop.europa.eu/en/the-impact-of-publicly-funded-research-on-innovation-pbNBNA23100/)

network building, finding partners for joint research and innovation, and by providing a basis for standards and regulation.

5.3.2 .The role and contribution of FP6 (2002 to 2007) to key technologies underpinning the Major Innovations

As mentioned before, FP6 set a wider scope of activities including measures aimed at settling not only the structural weaknesses of coordination of European research, but also at improving coordination of national R&D Programmes. Table 21 shows the EC financial contribution and the number of projects for the Major Innovations in FP6. Projects referring to the Major Innovations were spread among different thematic priorities (e.g., stem cell treatment and personalised medicine in the life sciences theme, smart grids and photovoltaics in the sustainable development theme, car navigation, mobile phones and optical fibre in the information society theme, etc.).

Table 21: EC contribution in millions of euros to, and number of projects (in parentheses) of the Major Innovations in FP6

Source: JIIP

	EC contribution (m€) and number of projects										
	FP6 Total (Number of projects)	Open source	Smart Grids	Photo-voltaic	Stem cells	Pers. med.	LED	Optical fibre	Mobile phones	Car navi-gation	Super Jumbo Jet
I Focusing and integrating ERA											
Thematic priorities											
1. Life sciences	2336 (602)	0 (0)	0 (0)	0 (0)	323 (67)	209 (52)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
2. Information society	3799 (1089)	44 (10)	18 (4)	0 (1)	0 (0)	3 (1)	45 (10)	19 (7)	529 (126)	39 (7)	30 (5)
3. Nanotechnologies, materials and new production methods	1534 (444)	0 (0)	0 (0)	1 (1)	33 (6)	0 (0)	10 (5)	0 (0)	2 (1)	0 (0)	29 (4)
4. Aeronautics and space	1066 (241)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	5 (1)	0 (0)	556 (73)
5. Food quality and safety	754 (189)	0 (0)	0 (0)	0 (0)	4 (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
6. Sustainable development	2301 (666)	0 (0)	73 (27)	82 (26)	0 (0)	0 (0)	3 (1)	2 (1)	1 (1)	0 (0)	13 (2)
7. Citizens and governance	237 (143)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Specific activities											
Policy support	604 (520)	0 (0)	1 (1)	0 (0)	8 (5)	5 (4)	0 (0)	0 (0)	2 (1)	0 (0)	0 (0)
Horizontal research involving SMEs	463 (490)	0 (0)	0 (0)	9 (9)	2 (1)	1 (1)	0 (0)	0 (0)	4 (6)	1 (1)	2 (2)
International cooperation	350 (351)	0 (0)	1 (1)	2 (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
II Structuring the European Research Area											
Research and innovation	224 (240)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Human resources and mobility	1723 (4546)	0 (1)	0 (0)	5 (8)	50 (108)	12 (25)	8 (12)	0 (3)	0 (3)	0 (0)	2 (1)
Research infrastructures	718 (147)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	3 (1)
Science and society	80 (163)	0 (0)	0 (0)	0 (0)	4 (6)	2 (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
III Strengthening ERA											
Coordination of activities	304 (99)	0 (0)	0 (0)	3 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Research & innovation policies	14 (19)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
EURATOM	186 (19)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
TOTAL	16692 (9949)	46 (12)	93 (33)	102 (48)	426 (196)	232 (85)	66 (28)	21 (11)	535 (140)	40 (8)	635 (88)

Compared to FP5 (see Table 20), we see a significant increase in EC contribution to the development of stem cell treatment. After a long discussion of ethically controversial research methods with the European Parliament, the opening of FP6 towards stem cell research was a large step and an obvious policy breakthrough. The main focus was on research on adult stem cells and tissue engineering. However, the use of embryonic stem cells was crucial at that time, as these cells have the natural ability to develop into any type. The state of research during FP6 was nascent, and the promising alternative "induced pluripotent stem cells" had not been discovered before the very end of FP7 in Japan (2006/2007). Not without reason, the number of projects funded which used embryonic stem cells was rather small. Furthermore, the natural science projects were funded alongside policy and regulation-orientated projects. EC and the FP showed – although watered down – commitment to push an emerging Major Innovation in the early stages in this case. Important steps were the classification of stem cell therapies as "Advanced Therapy Medicinal Products" in 2007 by the European Commission Regulation 1394/2007 (ATMP) and the Establishment of the "Committee for Advanced Therapies" (CAT) 2008. The achievements of FP6 (and 7) are the support for a catching-up process of European stem cell research, as well as a trailblazing function for national funding activities (e.g., in Germany or France). FP6 followed up the FP5 funding of technologies for the Super Jumbo Jet, amongst others for a very relevant project, namely the PRECARBI project, whose results have been used in the final phase of the development of the A380 aircraft.

Box 9: Super Jumbo Jet Source: Case study

Super Jumbo Jet:

The PRECARBI project was relevant in the final phase of the development of the A380 aircraft and pertains to the development in materials that could be directly utilised for advanced aircraft structural applications. These materials constitute around 28% of the structural material of the Super Jumbo Jet. The participant organisations were from UK, Germany, Spain, Sweden, France, Switzerland, Greece and Latvia.

Again, projects associated with the mobile phones received both attention and high funding. In FP6 most of mobile phone related projects have been focussed on the development of mobile applications and interfaces than on the development of technical infrastructure or standards, e.g., High-Speed Downlink Packet Access, Multimedia Messaging or WPA2, which had been in development at that time. Looking at the number of projects, mobile phone applications claims the first place, followed by car navigation systems and the Super Jumbo Jet.

An additional source of information on the contributions of FP6 and FP7 to the Major Innovations is the online survey. Experts were asked to assess the R&D related incentives of FP6 (and FP7) participation. Figure 30 (shown a few pages further on, to include also FP7 responses) reflects the experts' judgements concerning R&D, networking and market-related incentives for organisations to participate in FP6 innovation projects.[62] Figure 30 shows that experts in the contexts of all Major Innovations most often emphasise the access to complementary resources which FP6 gave. The incentive to participate in FP6 due to R&D cost sharing or the reduction of uncertainty and risk sharing are less emphasised by experts in personalised medicine and stem cells. Experts in smart grids and LED lighting were especially driven by the fact that participating in FP6 projects would offer them possible access to complementary resources and skills (e.g., keeping up with major technological developments, exploring different technological opportunities as well as learning more about needs for application). In all the observed Major Innovations except photovoltaic panels, FP6 responding experts revealed high expectations concerning networking and the identification of new partners. From the FP6 graph in Figure 30, it becomes obvious that organisations were driven by the idea of networking and finding new partners for R&D projects. This corresponds to the high importance of access to complementary resources and skills. In the cases of personalised medicine and mobile phones, relatively high expectations were noted concerning the promotion of user-producer interaction and the joint creation and promotion of common standards. Experts in field of LED and photovoltaic panels especially revealed high expectations concerning the acceleration of time to market and the control of future market developments. A leading expert in the field of PV solar panel research from a research institution argued that European projects have been important for the development of the PV solar panels, especially at a time when cooperation and networking among photovoltaic players was underdeveloped. Furthermore, FP projects have often been implemented in commercial products. This is in accordance with the results of the online survey where organisations in the field of photovoltaics, as well as smart grids, emphasise that participation in FP6 projects sped up the time to market of the Major Innovation, whereas organisations in the field of LED lighting saw a higher potential of entering new markets from participation in FP6 projects.

Self-explanatory, the most important incentive for organisations to participate in FP6 projects was R&D funding. Especially for organisations in the fields of stem cell treatment, personalised medicine, which were still in early stages of research, this incentive dominated others. Looking at the market incentives, it gets clear that the respondents assigned those incentives less importance than incentives related to funding, networking and R&D cost sharing.

Similarly to FP5 we have not found direct links between the FP6 funded projects and the core development of breakthroughs among the Major Innovations (see the case studies). This can be explained with the fact that the development of the core technologies of most Major Innovations occurred already before the time of FP6 projects. This holds for the Mobile Phone, Car Navigation, Photovoltaic Solar Panels, Linux, Super Jumbo Jet, LED, Smart Grid and Optical Fibers. Although FP6 projects made contributions to incremental technological improvements. In case of Stem Cell Research and Personalised Medicinen it is difficult at present to judge in which way FP5, FP6 and FP7 contributed to their development as they are emerging Major Innovations and it is not clear yet in

[62] It has to be noted that Major Innovations car navigation systems; Linux (open source) and optical fibre have been excluded in the figures depicted in this Chapter, due to the relatively small number of respondents to this question.

which direction they will develop.

FP6 made considerable contributions to the broader diffusion and downstream application of the selected Major Innovations. Except in the photovoltaics case, FP6 was considered to contribute to the identification of new partners, networking and collaborating, exchange of ideas and open innovation. FP6 funding also contributed to a stronger extent to profitable technological innovations in the fields of LED lighting, mobile phone and photovoltaics. In the case of stem cells (where FP6 had committed itself with all due caution) as well as in the case of personalised medicine, FP6 contributed to the conceptual basis for regulatory development and standardisation, e.g., the set-up of common databases funded by FP6, which had been identified as a relevant factor for both personalised medicine and stem cells (see section 4.1).

5.3.3 The role and contribution of FP7 (2007 to 2913) to key technologies underpinning the Major Innovations

FP7 entailed further extension of the budget for funding R&D and introduced new instruments like Joint Technology Initiatives or European Technology Platforms (ETP), which have been targeted mainly towards the coordination of strategic research agendas in Europe. This seems to be a relevant step towards building critical mass in topics, which might result in Major Innovations.

Table 22: EC contribution in millions of euros to, and number of projects (in parentheses) of the Major Innovations in FP7 Source: JIIP

	EC contribution (m€) and number of projects										
	FP7 Total (Number of projects)	Open source	Smart grids	Photo -voltaic	Stem cells	Pers. medicine	LED	Optical fibre	Mobile phones	Car navigation	Super Jumbo Jet
COOPERATION											
Health	4685 (990)	0 (0)	0 (0)	0 (0)	439 (74)	632 (108)	0 (0)	0 (0)	6 (1)	0 (0)	0 (0)
Food, Agri and Bio	1553 (452)	0 (0)	0 (0)	0 (0)	0 (0)	18 (3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
ICT	7159 (2107)	49 (13)	105 (37)	32 (11)	18 (3)	23 (8)	91 (15)	58 (17)	88 (30)	30 (7)	112 (11)
NMP	3081 (777)	0 (0)	9 (1)	77 (20)	48 (12)	36 (5)	96 (16)	0 (0)	4 (1)	0 (0)	32 (4)
Energy	1515 (337)	0 (0)	205 (32)	139 (38)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	10 (1)
Environment	1485 (450)	0 (0)	0 (0)	1 (1)	0 (0)	9 (3)	7 (2)	0 (0)	9 (2)	0 0)	0 (0)
Transport	2196 (695)	0 (0)	0 (0)	12 (2)	0 (0)	0 (0)	5 (2)	0 (0)	8 (5)	29 (30)	544 (80)
Socio-economic sciences	459 (212)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Space	638 (240)	0 (0)	0 (0)	2 (1)	0 (0)	0 (0)	0 (0)	0 (0)	2 (1)	0 (0)	0 (0)
Security	945 (233)	0 (0)	3 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	15 (3)	0 (0)	10 (2)
General Activities	313 (26)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Joint Technology	1473	0	18	0	26	133	8	0	4	0	21

Initiatives	(626)	(0)	(6)	(0)	(1)	(11)	(2)	(1)	(1)	(0)	(14)
IDEAS											
European Research Council	6280 (3803)	0 (0)	1 (1)	31 (21)	223 (125)	82 (37)	16 (11)	5 (3)	9 (5)	0 (0)	3 (2)
PEOPLE											
Marie Curie Actions	4265 (9293)	1 (2)	11 (12)	18 (57)	106 (251)	47 (76)	18 (22)	5 (9)	1 (9)	0 (0)	14 (7)
CAPACITIES											
Research Infrastructures	1515 (335)	0 (0)	0 (0)	9 (1)	0 (0)	22 (3)	3 (1)	0 (0)	42 (1)	0 (0)	3 (1)
Research for the benefit of SMEs	1092 (905)	0 (0)	0 (0)	18 (15)	1 (1)	2 (2)	10 (10)	1 (1)	11 (9)	0 (0)	2 (2)
Regions of Knowledge	120 (81)	0 (0)	0 (0)	2 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Research Potential	350 (194)	0 (0)	0 (0)	3 (1)	12 (5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (1)
Science in Society	234 (162)	0 (0)	0 (0)	0 (0)	1 (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Research policies	28 (25)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
International Cooperation	167 (151)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (1)
EURATOM											
Fusion	5 (4)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Fission	346 (130)	0 (0)	0 (0)	0 (0)	16 (3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
TOTAL	39905 (22228)	50 (15)	353 (91)	344 (169)	890 (477)	1005 (256)	254 (81)	70 (31)	200 (68)	59 (37)	754 (126)

Table 22 shows the EC financial contribution and the number of projects for the Major Innovations in FP7. FP7 has been grouped into four categories: (1) cooperation, (2) ideas, (3) people, and (4) capacities. All Major Innovations received the greatest share of funding from the 'cooperation' category.

When comparing FP7 to FP 5 and 6 it emerges that the EC contribution to the development of personalised medicine rises significantly. It claims the first place, followed by stem cell treatment and again the Super Jumbo Jet. The EC contribution to mobile phone technologies declines from FP5 and 6 towards FP7. In the case of the Super Jumbo Jet, FP7 moved up the supply chain with many projects dedicated to the electronic and engine components of the aircraft, in some projects referring to key enabling technologies like nanotechnology. During the implementation of FP7, the se projects started involving technology transfer or knowledge diffusion. FP7 went more explicitly towards fostering the aeronautic supplier industry, which was also supported by other policy initiatives at national levels (e.g., the 'Spitzencluster Wettbewerb', in Germany[63] and the 'Topsectoren beleid' in the Netherlands[64]). The number of projects geared towards framing

[63] http://www.bmbf.de/de/20741.php

[64] http://www.rijksoverheid.nl/onderwerpen/ondernemersklimaat-en-innovatie/investeren-in-topsectoren

aeronautics policy increased during the implementation of FP7. They aided the technology development and adoption of the A380 within the commercial sector. This shows that the nature of the projects was geared towards taking basic and further applied research forward into commercialisation. Furthermore, a significant number of projects are classified under joint technology initiatives. This shows that many areas of expertise have been leveraged to bring cutting edge technology development to the front, maybe not only for the specific application of the Airbus 380.

Box 10: Car Navigation Source: Case study

Car navigation - eCoMove:
The project eCoMove (Collaborative project, 2010-14), with an EU contribution of €13.7 million, was the largest FP7 project related to car navigation. eCoMove is meant to create an integrated solution for road transport energy efficiency by developing systems and tools to help drivers sustainably eliminate unnecessary fuel consumption (and thus CO^2 emissions), and to help road operators manage traffic in the most energy-efficient way, with a project aim of reducing fuel consumption by 20% overall.

Car navigation - Peacox:
TomTom was also involved in the FP7 project Peacox (persuasive advisor for CO^2-reducing cross-modal trip planning). Other projects in which TomTom appeared involved Tele Atlas. Interestingly, Tele Atlas' main competitor Navteq also participated in the same projects, a clear sign of the pre-competitive nature of the FP projects. The proprietary nature of the development effort needed to bring an idea into a real product and to commercialise this product obviously does not qualify for an FP project from the company's perspective.

Another example – the Major Innovation 'car navigation' shows us how FPs can play a relevant auxiliary role for the occurrence and global enforcement of the Major Innovation. It is evident the EC contribution has been decisive for the occurrence and market success of car navigation systems in Europe. Even if the share of actions for innovation and adoption has increased from FP5 to FP7, the funding was smaller than in the case of other Major Innovations and widespread among corresponding topics. However, FP7 funding application-oriented projects (e.g., the project eCoMove or PEACOX) included the key players in the field of car navigation in Europe, which currently support further development of the Major Innovation car navigation.

The full opening-up of NAVSTAR-GPS infrastructure in 2000 laid an important technological foundation for the quick development of the Major Innovation case 'car navigation'. After several setbacks, a European alternative was not available for a long time. However, at the end of FP7, the development of a serious alternative to the American NAVSTAR-GPS or the Russian GLONASS-system gained momentum (Galileo). The activities currently funded by the FPs might show impacts for a second generation of car navigation and positioning systems. A number of FP7 projects were dedicated to future applications of Galileo and the Galileo GNSS era. In practice, this was the development of devices specifically meant for Galileo, such as GPS receivers, projects preparing the adaption of Galileo / EGNOS for existing functionalities (Galileo Enhanced Driver Assistance, Galileo for Interactive Driving, Enhanced Road Safety, and Vehicle Localisation etc.)[65] Thus, FPs could help to make better use of Galileo and support interoperability of potentially competing or complementary GPS infrastructures in the future.

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[65] This is also the case in Horizon 2020, with a substantial part directed towards next generation GNSS Satellite navigation (1st call 38 million euro, overall period 140 million euro).

Among different incentives for organisations to participate in FP7 in the areas of selected Major Innovations, the respondents of the online survey stated that risk sharing is of minor importance. This does not have to mean automatically that the Risk Sharing Financial Facility played a limited role in the development of Major Innovations, even though the nature of the RSFF (managed by the EIB and applying commercial banking rules for accepting applications for financial support) prohibits a direct link between the FP projects and their results and the RSFF . Looking at Figure 30 one sees that the access to complementary skills,the identification of new partners and the access to R&D cost sharing was of high importance for most Major Innovations. But those factors implicitely contribute also to the risk sharing (see Figure 30). The definition of standards seemed to be more important in the case of car navigation than in the case of other Major Innovations. Similar to the situation in FP6, market-oriented incentives played a less important role.

Figure 30 provides the corresponding picture for the impacts realised by the respondents in the Major Innovations. Except for the car navigation systems, Super Jumbo Jet and LED, they reveal that the FP7 participation was helpful to raise the attention and commitment of the organisation concerning the Major Innovation. Organisations in personalised medicine, smart grids and stem cell treatments also perceived a raise in competitiveness.

We learned that FP5 and FP6 contributed mostly to the Major Innovations by providing access to partners and complementary skills, supporting joint agendas, diffusion of knowledge and preparing standards. FP7 did that, too, but also showed more direct contributions like the development of downstream applications (e.g., in the Jumbo Jet and car navigation).

FP7 also prepared the ground for new Major Innovations. The foundation of the European Research Council might lay the ground for future technological breakthroughs. Joint Technology Initiatives, other 'multi-lateral activities'[66] together with European Technology Platforms, support the coordination of innovation topics at the European level and between the European and national levels. During FP7, European technology platforms relevant for the Major Innovations have been established, e.g., the European Photovoltaic platform – EU PV TP, the Smart Grids or the Platform, Advisory Council for Aviation Research and Innovation in Europe – ACARE. In mobile phones, a Private Public Partnership (PPP) in Advanced 5G networks for the Future Internet (5G) was launched. Among others, photovoltaic energy is covered by the KIC (Knowledge and Innovation Community) for sustainable energy.. FP7 also started cooperating with the European Investment Bank, to provide follow-up investment for projects. That can be of importance to take research results towards applications, also in Major Innovations.

[66] Future & Emerging Technologies(FET) Flagship Initiatives support collaborative Research Projects addressing high risk-ideas as the basis for radically new technologies;

Joint technology Initiatives (JTIs) support large-scale multinational research activities.

Public Private Partnerships (PPPs) coordinate research agenda in fields of strategic importance for European industry or society and launch open calls in FPs.

The European Institute of Technology (EIT) is the first EU initiative to integrate the technology and innovation agenda of all three sides of the Knowledge Triangle (higher education, research and business) by way of so-called Knowledge and Innovation Communities (KICs).

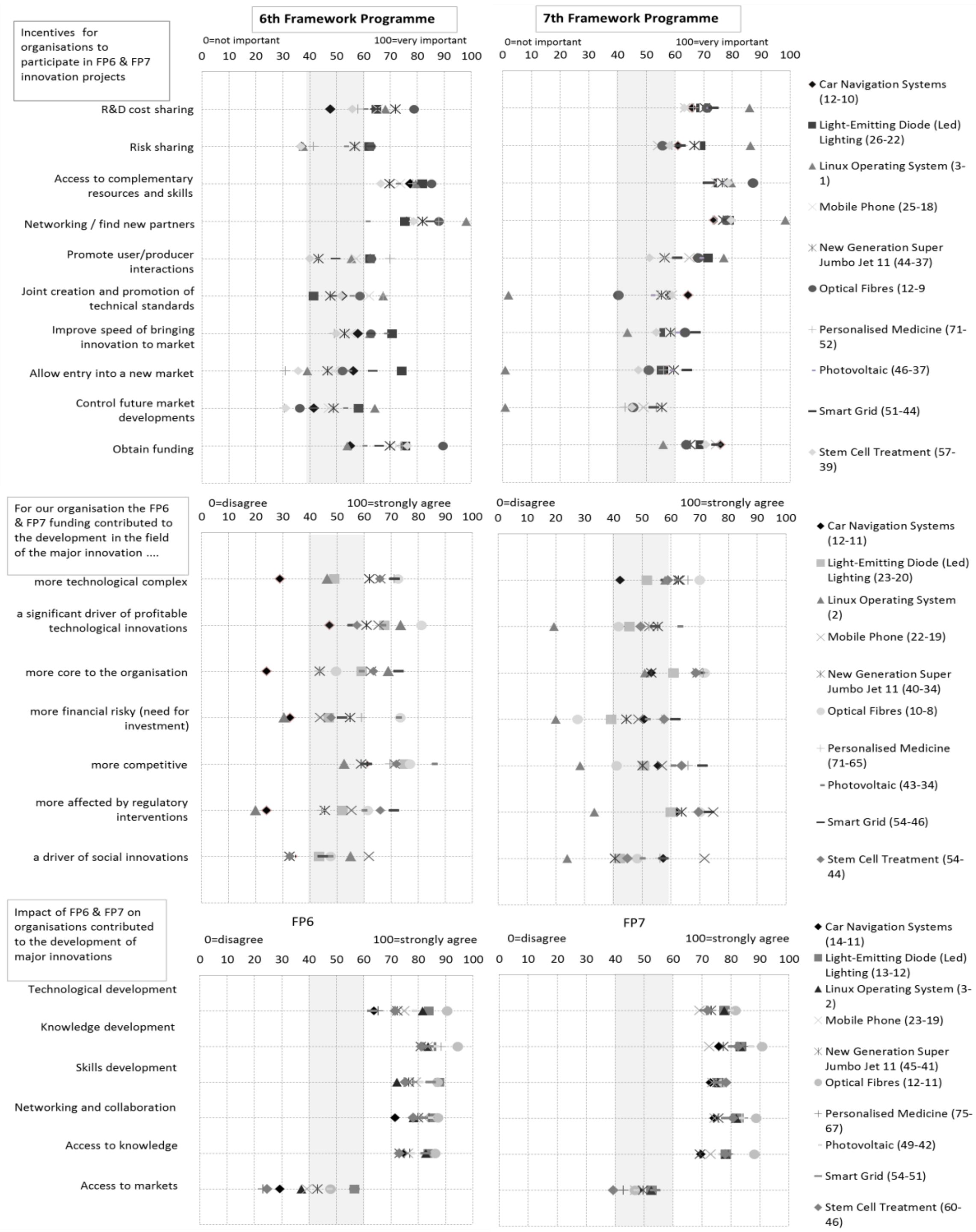

Figure 30: Role and Impacts of FP6 and FP7 for organisations

Two examples of Major Innovation timelines, market uptake and FP funding conclude this paragraph: photovoltaic and LED. They show the long time-lines involved in research and uptake on the market. Figure 31 gives the example of the photovoltaic major innovation, showing the Framework Programme contribution (left axis and blue bars), and the market development in terms of installed PV capacity (right axis and dark dotted line).

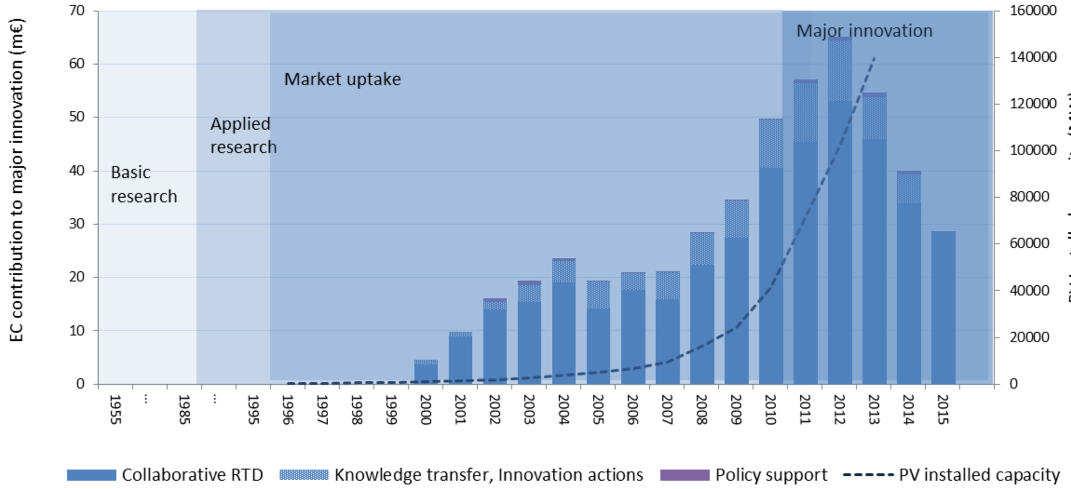

Figure 31: Timeline of photovoltaic major innovation – FP contribution and installed capacity.

Figure 31 shows how Framework Programmes contribute, since FP5, to PV collaborative research having a steep increase shortly after launch of FP7 in 2007 and how the global installed photovoltaic capacity shows at the beginning very gradual increases then after 2009, the diffusion of innovation truly takes off after the European renewable energy policy.

The case of photovoltaic has already demonstrated that although Europe was in leading in creating the photovoltaic industry, the manufacturing has been lost to Asia and especially to China (see also Figure 21). Europe continues to invest in public R&D supporting the photovoltaic technology (e.g., new materials ad incremental innovations) to become more cost-efficient when compared to other (traditional) energy sources. However, being strong in research needs to be complemented with an adequate ecosystem for innovation and exploitation, including manufacturing.

As similar picture is shown on the LED timeline in Figure 32.

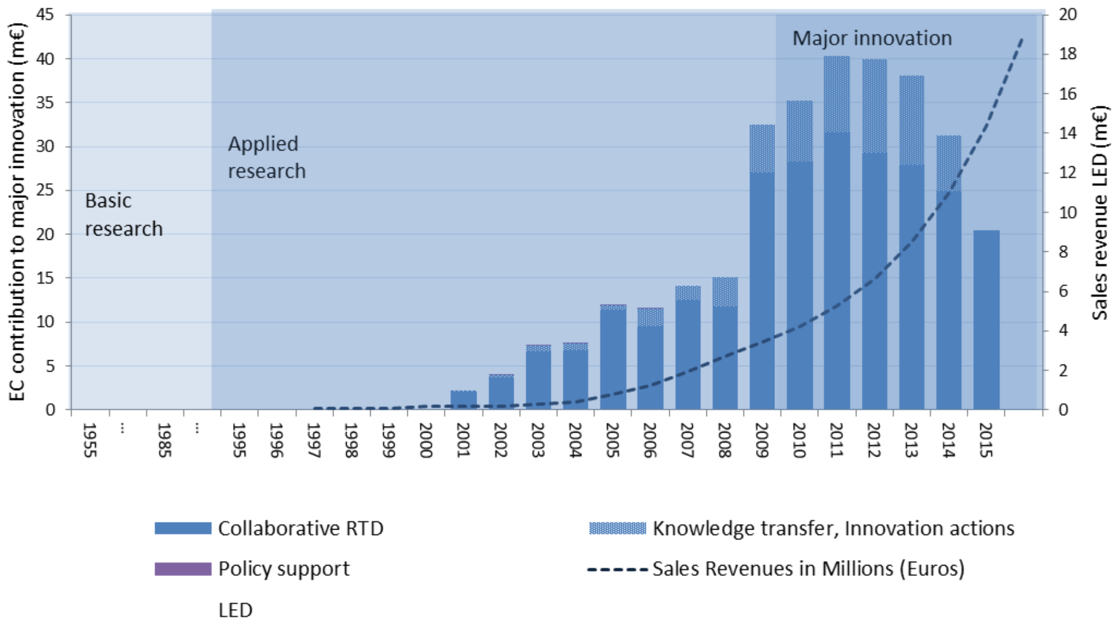

Figure 32: Timeline of LED major innovation – FP contribution and sales.

The research and innovation policy should take the larger ecosystem conditions including exploitation of research results into account when aiming towards Major Innovations.

5.4 Summary of the contributions of the EU Framework Programmes to Major Innovations

The FPs contribute to the Major Innovations mostly by providing access to partners and complementary skills, supporting joint agendas, diffusion of knowledge, preparing standards and the development of downstream applications. This is in line with the pre-competitive nature of FPs 5-6. FP7 brought about a shift towards application-oriented research and innovation and preparing the ground for private-public cooperation in many domains. Most experts in the survey indicate that the innovation would not have been possible without the FP. This does not mean however that there is a one to one relationship between a project and an innovation, in the complex innovation process with the feedback loops, knowledge and capacity built in a project can be used for several innovations that may occur independently from the FP participation. However, Major Innovations can take decades to develop and the time lapse between the R&D and the application can be long. This study is covering only a part of that. As example, FPs 2 and 3 contributed significantly to standards for mobile telephony, but fall outside the scope of this study. Other Major Innovations such as stem cells and personalised medicine, attract large amounts of funding from the FPs, but it is still too early to tell what their impact on the Major Innovation is. Overall, FPs have contributed (to various extents) to developing the already existing innovations further, on top of the already existing core developments in the Major Innovations. For several Major Innovations under scrutiny, first issues to tackle were the **fragmentation** of the international technology community as well as the creation of **interfaces** between different science disciplines. This meets the core elements of FP project funding. Referring to the cases investigated, it can be said that FPs contributed to networking and collaboration as well as to the exchange of ideas in the case of all Major Innovations. Except for the Major Innovation cases LED and Linux, experts interviewed emphasised the significance of the combination of technologies and interdisciplinary cooperation, and in the cases of personalised medicine, photovoltaics, smart grids and stem cells, joint creation with specific partners. Bilateral and network contacts may extend well beyond the lifetime of a project; the value of networks is intangible and very difficult to measure, however. Considering the frame and practice in different sectors, this also included elements of open innovation (personalised medicine, stem cell treatment, photovoltaic panels, car navigation systems and mobile phones). In the cases of car navigation systems, LED lighting, optical fibres and photovoltaic panels, FP participants indicated positive impacts concerning user-producer relations.

Elements of **entrepreneurship and financing follow-up** steps turn out to be crucial (maybe in combination with open innovations), but they were not in the (pre-competitive) range of FP 5 and 6 projects. In FP7, steps have been taken in that direction.

The case study analyses confirm that for all Major Innovations (except for Linux and smart grids), single hotspots and players drove technology development significantly. Thus, the involvement of the **key players** in a (potential) Major Innovation is an issue for FPs. Some other studies stressed the risk that FPs could be dominated by large companies in oligopolistic settings. However, the absence of key players would raise the risk of the FP projects being side-tracked. We saw that FP7 was rather more successful in involving them than the previous FPs.

FP6 and FP7 set much more emphasis on **coordination** of R&D and innovation policy in Member States. This might have been an outcome of the FP accompanying ERA activities or simply favoured by the fact that the all investigated Major Innovations and key players had already been broadly recognised at that time. As has been shown in section 5.2.5, a broad bundle of multilateral ERA activities accompanied FPs, which was relevant for the coordination of strategic research agenda in Europe.

The majority of the experts in the survey noted that the FPs helped to bring Major Innovations more to the **core of the firms'** activities. This was the case for personalised medicine and stem cell treatment, where FP funding was accompanied by awareness and community building activities. It also seemed to work for mobile phones and the upcoming area of mobile applications, and for the optical fibres, photovoltaics and smart grids where new technologies needed to be adapted and taken up in procurement strategies.

As indicated by firms in the cases of mobile phones and personalised medicine (in FP6), as well as to a certain extent by firms in the car navigation case (in FP7), the Framework Programmes increasingly contributed to definitions of common technical **standards**. Furthermore, FP6 and FP7 projects also contributed to conceptual bases for regulatory development, for instance concerning the use of embryonic stem cells or the requirements for advanced medicines. These issues might not have been important for the emergence of Major Innovations, but for were key for a quick development of policy and governance approaches. Overall projects focusing on standardisation or regulatory development just amount to a small fraction of the total sums funded by FPs but these elements are important for a triple helix development in the area of Major Innovations.

Table 20 sums up the contributions of the FPs to the key technologies in the Major Innovations.

Table 23: Evidence for the contribution of several FPs to the development of key technologies for the Major Innovations Source: JIIP

✓✓ evidences ✓ weak evidences × no evidence		Car Navi-gation Systems	LED Light-ing	Linux Oper-ating System	Mobile Phones (MP)	Super Jumbo Jet (A380)	Opti-cal Fibres (OF)	Personal. Medicine (PM)	Photo-voltaic (PV)	Smart Grids (SG)	Stem Cell Treat ment (SCT)
Direct contribution to the initiation and emergence (origin)	FP5 FP6 FP7	× × ×	× × ×	× × ×	× × ×	× × ×	× × ×	× × ×	× × ×	× × ×	× × ×
Direct contribution to the development and introduction of one of the major successes	FP5 FP6 FP7	× × ×	× × ×	× × ×	× × ×	× × ×	× × ×	× × ×	× × ×	× × ×	× × ×
Contribution to the conceptual basis for regulatory development, policy development and standardisation (focus on externalities and synergies)	FP5 FP6 FP7	× ✓ ✓✓	× × ×	× × ×	✓ × ×	✓ × ✓	✓ × ✓	✓ ✓✓ ✓✓	× ✓ ✓	× ✓✓ ✓✓	✓ ✓✓ ✓✓
Contribution to broad	FP5	✓ ✓	✓ ✓	✓✓ ✓	✓ ✓✓	✓ ✓✓	✓ ×	✓ ✓✓	✓ ✓✓	✓ ✓	× ✓

explorations of new technological possibilities	FP6 FP7	✓✓	✓✓	×	✓✓	✓✓	✓	✓✓	✓✓	✓	✓✓
Contribution to the broader diffusion and downstream application of Major Innovations (focus on spill overs, transfer from frontrunners to followers)	FP5 FP6 FP7	× ✓ ✓✓	✓ ✓ ✓✓	× × ×	✓ ✓ ✓✓	✓ ✓✓ ✓✓	✓✓ ✓ ✓	× × ×	× × ×	× × ×	× × ×
Contribution networking and collaborating, exchange of ideas and open innovation (possible focus on next generation innovation)	FP5 FP6 FP7	✓ ✓✓ ✓✓	✓✓ ✓✓ ✓✓	✓ ✓ ✓	✓✓ ✓✓ ✓	✓ ✓✓ ✓✓	× ✓ ✓	✓ ✓✓ ✓✓	✓ ✓✓ ✓✓	✓✓ ✓✓ ✓✓	✓ ✓✓ ✓✓
Contribution to capacity building and strengthening technology competence or sectoral systems piggyback to (light house effects of) Major Innovations	FP5 FP6 FP7	× ✓ ✓✓	✓ ✓ ✓✓	× × ×	✓✓ ✓ ×	✓ ✓✓ ✓✓	✓ ✓ ×	✓ ✓✓ ✓✓	✓ ✓✓ ✓✓	✓ ✓ ✓	✓ ✓✓ ✓✓

Figure 33 sums the possible FP contributions to Major Innovations up in another way: by seeing them in the order of initiation – development – utilisation, and depicting them rippling out from a kernel.

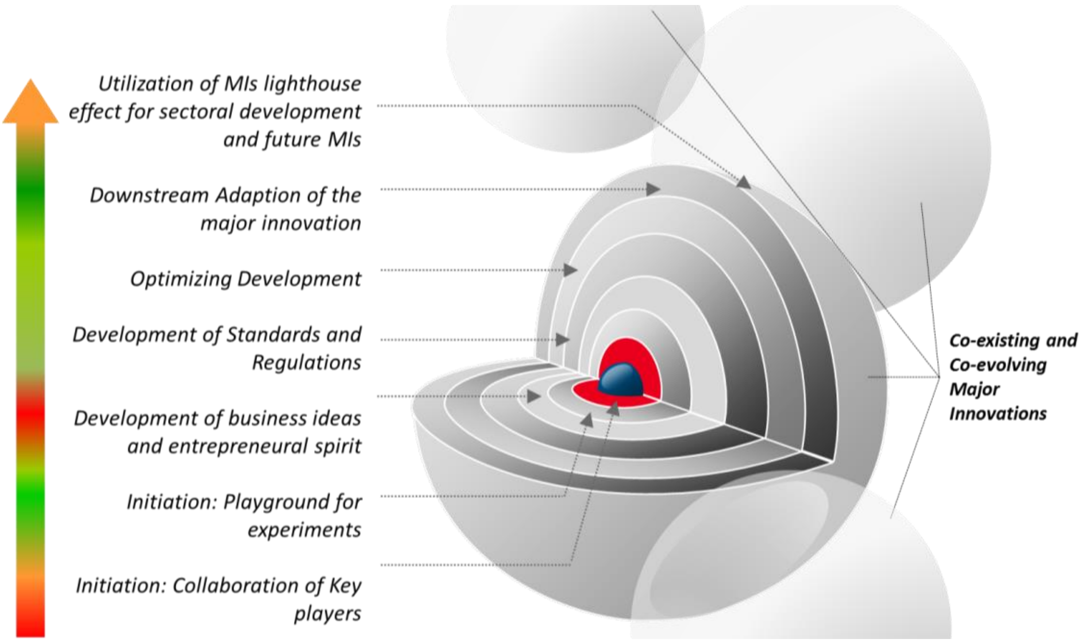

Figure 33: Schematic illustration of potential contributions of FPs to Major Innovations Source: JIIP

After several arguments concerning the encouragement of Major Innovations, the question arises whether Major Innovations could be used for the development of sectorial systems, in the sense of lighthouses that attract other policies and organisations, lining them up towards a joint challenge. An example might be given by the Super Jumbo Jet. Many regions with a long tradition of the aeronautics industry (e.g., in Wales, where the wings of the Airbus 380 are manufactured) show a long tradition in aluminium processing. The Super Jumbo Jet ushered in the new era of broad use of composite materials. In this specific case, the Super Jumbo Jet stands for technological change in the sector, attracting and lining up many contributors. This may also hold for personalised medicine and stem cells where FPs made a contribution to community building and getting other players into the challenge. Ten years ago, even large pharmaceutical firms were reluctant in taking up new opportunities opened by personalised medicine and stem cell research. A potential Major Innovation can put up a challenge that attracts many to contribute.

6 Implications of the study for Horizon 2020 and the evaluation framework

6.1 Horizon 2020

6.1.1 Structure and objectives

Horizon 2020 is the 8th Framework Programme for Research and Innovation of the European Union, launched in 2014 with an indicative total budget for the period 2014-2020 of around 77 billion Euro.[67] It was set out to contribute directly to the objectives of Europe 2020 strategy for "...*smart, sustainable and inclusive growth, highlighting the role of research and innovation as key drivers of social and economic prosperity and of environmental sustainability [...] by providing a common strategic framework for the Union's funding of excellent research and innovation".*[68]

The performance measurement of Horizon 2020 comprises the following indicators[69]:

- increase R&D intensity in the European Union to 3% of GDP in 2020;
- monitor innovation performance of the Member States by developing a new indicator on innovation output[70]; and
- increase the number of researchers in the active population.

Whereas the former Framework Programmes focused on funding research and technological development, Horizon 2020 for the first time bundles together all existing EU funding programmes for research and innovation, including all innovation-related activities of the Competitiveness and Innovation Programme (CIP) as well as the European Institute of Innovation and Technology (EIT).

It is designed to contribute directly to the Innovation Union as the flagship initiative of the Europe 2020[71] strategy to foster Europe's industrial competitiveness, as its activities comprise support for all stages of innovation, from research to market.

Furthermore, by strongly relying on cooperation of Member States initiatives and stakeholders throughout the European Union, it is also intended to contribute to the achievement and functioning of the European Research Area (ERA).

Funding priorities are structured among three pillars (see Table 24), which are implemented over specific actions, specified in respective work packages:

- The *pillar* ***excellent research*** is designed to make Europe an attractive destination for outstanding researchers from around the world by funding elite research, thereby protecting Europe's research scientific capacities;[72]

[67] In current prices;

[68] Regulation (EU) No 1291/2013 of the European Parliament and of the Council establishing Horizon 2020, Introduction, Article 4

[69] Regulation (EU) No 1291/2013 of the European Parliament and of the Council establishing Horizon 2020, Introduction, ANNEX I

[70] COM(2013)0624 Measuring innovation output in Europe: towards a new indicator

[71] Innovation Union: A pocket guide to a Europe 2020 initiative, EU 2013

[72] Austrian Research and Technology Report 2014

- Actions in the *pillar* ***industrial leadership*** should support the acceleration of technological developments and innovation in Europe, focusing on key enabling technologies (KETs)[73] on the one hand, as well as on encouraging innovation in small and medium enterprises (SMEs) and on the access to venture capital for high-risk R&D projects. Emphasis is put on collaborative R&D of industrial and academic partners;
- The *pillar* ***societal challenges*** is supposed to address the policy priorities of the Europe 2020 strategy by research in specific thematic areas.[74]

Table 24: Structure of Horizon 2020 and indicative budgets 2014-20 in millions of Euro

Excellent Science (24 441.1)	Industrial Leadership (17 015.5)	Societal Challenges (29 679)	Spreading excellence in science and widening participation (816.5)
• **European Research Council (ERC)** • **Future and Emerging Technologies (FET)** • **Marie Skłodowska-Curie actions** • **Research Infrastructures**	• Leadership in enabling and industrial technologies (LEIT) • Access to risk finance • Innovation in SMEs	• Health, demographic change and well-being • Food security, sustainable agriculture, marine and maritime research and bioeconomy • Secure, clean and efficient energy • Smart, green and integrated transport • Climate change, resource efficiency and raw material • Inclusive, innovative and reflective societies • Secure societies	• Science with and for societies (462.2) • Non-nuclear direct actions of the Joint Research Centre (JRC) (1 902.6) • European Institute of Innovation and Technology (EIT) (2 711.4)

Source: Regulation (EU) No 1291/2013; Austrian Research Promotion Agency (FFG)

The objectives of “spreading of excellence in science and broadening participation” and “science with and for societies” intersect the other pillars and shall contribute to them by supportive measures comprising specific calls and policy support and coordination actions.[75] The Joint Research Centre (JRC) provides technical and scientific support to the implementation of Horizon 2020, developing measures and indicators to help to realise its goals. The European Institute of Innovation focuses on the integration of the three components of the so-called knowledge triangle. Excellent

[73] In H2020 these are: ICT, micro- and nanotechnologies, advanced materials and manufacturing, biotechnology and space

[74] These are: Health, demographic change and wellbeing; Food security, sustainable agriculture; marine and maritime research and the bio-economy; Secure, clean and efficient energy; Smart, green and integrated transport; Climate action, resource efficiency and raw materials; Inclusive, innovative and secure societies; COM(2011)808, Horizon 2020 - The Framework Programme for Research and Innovation

[75] European Commission: Factsheet on Spreading Excellence and Widening participation; Factsheet on Science with and for Society in Horizon 2020

research should be supported by the implementation of Knowledge and Innovation Communities (KICs) consisting of institutions of higher education, research and business.

6.1.2 (New) Instruments

The main renewal that was established with Horizon 2020 was the objective to support innovation activities in the EU, either by specific innovation support actions or by heavily supporting collaboration of all stakeholders relevant for the innovation system, including universities, industry as well as the policy environment and users.

The main instruments for the implementation of thematic priorities of the pillars *industrial leadership* and *societal challenges* are multiannual workpackages including **funding and support for research** and **innovation actions.** They also include coordination and support actions for the building of multinational consortia and networks as well as for the implementation of ERA Nets and Joint Programming Initiatives to bring forward the further development of the ERA. *Funding of research* actions is targeted to research projects tackling clearly defined challenges, which can lead to the development of new knowledge or a new technology. *Innovation actions* are focused on closer-to-market activities like piloting, testing and prototyping. Funding is dedicated to multinational consortia that can comprise industrial and academic institutions.[76] Regarding the implementation of the thematic priorities, Horizon 2020 is also strongly relying on input and coordinated activities from and with collaborative initiatives like Joint Technology Initiatives, Public-Public-Partnerships[77] and contractual Public-Private-Partnerships, with the latter directly contributing input to the formulation of calls in Horizon 2020 workpackages, based on expertise and needs of its members.

According to the objectives of streamlining and simplification of funding structures in the Framework Programmes, regulations for funding have been brought together in a single system rules.[78]

Access to venture capital in the LEIT work package should be supported by a range of ***debt and equity products*** and advisory services in order to effectively give a boost to the availability of finance for research and innovation activities in Europe. Innovation activities in SMEs should be encouraged via a specifically designed programme, including funding and support measures along different stages of the innovation process, comprising market-feasibility assessment, development and demonstration actions as well as access to risk finance for the commercialisation of products.[79]

The ex ante evaluation[80] proposes continuing support for the RSFF (FP7) intervention at around the same level going forward under Horizon 2020, i.e., for about €1 billion from the EU budget. This sum

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[76] European Commission (2014): Horizon 2020 in brief

[77] E.g., Ambient Assisted Living Joint Programme

[78] This includes the application of unified funding rates. The funding rate for research projects is capped at 100% of refundable projects cost and at 70% for innovation actions (with the exception of 100% for NPOs). A uniform flat-rate of 25% is applied to refund eligible indirect costs. See: European Commission: Factsheet on Rules under Horizon 2020; Regulation (EU) No 1290/2013 of the European Parliament and of the Council of 11 December 2013 laying down the rules for participation and dissemination in "Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020)" and repealing Regulation (EC) No 1906/2006

[79] Horizon 2020 Work Programme 2014-15, Dedicated SME Instrument

[80] Financial instrument facilities supporting access to risk finance for research and innovation in Horizon 2020, Ex ante evaluation, 2013

will be allocated almost entirely for risk-taking through a first-loss piece (FLP) approach on a portfolio basis.

The structure of instruments in the *excellence in science* pillar is different comprising of the ERC and Maria Skłodowska-Curie actions that focus on individual grants dedicated to researchers, applying their own set of rules. The ***ERC***, as institutionalised funding body, provides competitive research grants to talented and creative **individual researchers** focusing on excellent frontier research projects. In contrast, grants of Maria Skłodowska-Curie actions focus on the development and transfer of skills by encouraging cross-border and cross-sectoral mobility of researchers.

Actions of the Work Programme on Future and Emerging Technologies are expected to initiate radically new lines of technology through unexplored collaborations between advanced multidisciplinary science and cutting-edge engineering. Important instruments are the so-called FET Flagship initiatives which are long-term (10 years), large-scale research projects (budget of 1 billion Euro), focusing on multidisciplinary, collaborative research. In Horizon 2020, two flagship initiatives are implemented. The Human Brain Project aims to create a virtual model of the human brain, by heavily relying on high performance computing. The Flagship Graphene aims to push forward the edge of knowledge regarding development and technological applications of this material.[81]

6.2 Implications and recommendations for current and future policy

6.2.1 Scope of the findings and lessons learned

This report analyses ten Major Innovations and the contribution that Framework Programmes have had on them. As a final step, we aim to reflect our findings to the current policy framework and provide suggestions on how the Framework Programmes could better support the development towards future generations of Major Innovations.

As a preceding remark, many of the new instruments and policies in H2020 go in the direction of our recommendations. Given the timeframe of implementation for H2020 we could not assess how effective the new instruments are, and the recommendations below are based on the findings of the analysis of FP5-7. Due to lack of data, activities prior to FP5 could not be taken into account.

First of all, it is important to reiterate that the Framework Programmes until FP7 were focused on supporting **pre-competitive** collaborative research and development activities (Technology Readiness Levels 1-4). Major Innovations, on the other hand, are by definition innovations already successfully introduced to the market (by companies) and are already having important economic or societal impact. Thus, it should be noted that the contribution of the FPs 5 and 6 towards Major Innovations observed in this current study is mainly indirect by nature – supporting enhancement of research and knowledge creation and improved conditions (e.g. research networks, RDI infrastructure, pre-commercial standardisation of technologies, joint agenda-setting) for innovation. From the perspective of the Major Innovation cases, the FPs 5 and 6 have been “catalysers” in reinforcing and integrating the European research landscape paving the way towards Major Innovations. FP7 did this, too, but was also focussed on market needs and uptake, and contributes to the further development and application of technologies.

[81] Horizon 2020 Work Programme 2014-15, Future and Emerging Technologies

Secondly, it should be stressed that based on the case study findings, the **timescale** of the current study (FP5-7) sets certain limitations to the findings. The Major Innovations already showing clear economic or societal impact are results of technology breakthroughs prior to the FP5 (e.g., mobile phone, car navigation system) and then again those Major Innovation where FP support in the analysed funding period has been important, the "real" impacts are yet to be realised (e.g., smart grid, stem cells). The timeframe from technological breakthroughs to Major Innovations is in many cases several decades long (or even longer) and the actual inventions underlying the Major Innovation in question may be even older. The window of opportunity to apply the advancements of technology may not occur directly after the technology has reached a point of maturity but depends on several other factors (e.g., competitiveness of prevailing technology, production costs, market readiness, adequate infrastructure, regulation, etc.). Thus, although FPs may have supported important advancements of technologies laying foundations for future Major Innovations, those impacts are still at least partially to be realised in the future, and previous generations of FPs may have given important impetus to some of the technological breakthroughs leading to Major Innovations, but is not concluded from the findings of the current study. From the evaluation perspective, this notion of timescale of realisation of impacts should be kept in mind.

Thirdly, it should be remarked that Major Innovations do not happen in isolation but rather are shaped by or are **co-evolving** together with the development of other innovations like noted by our family of innovations concept. Technology breakthroughs in one field of technology may lead to a Major Innovation in number of different industrial sectors. This can be noted from several case studies, for example, advancements in ICT were enabling the development of mobile phone or car navigation system and are crucial facilitating factor for the development of smart grids or even personalised medicine. Similarly, the advancements in material science are reinforcing, among other factors, the development of photovoltaics or LED, and a new generation of Super Jumbo Jets. The case studies clearly demonstrated that despite the technological breakthroughs that were important decisive factors bringing Major Innovations about, without companies seeing the business opportunity and end-users (being individuals, companies or public actors) seizing the benefits from innovation, the Major Innovations would not have occurred.

Fourthly and perhaps most importantly, the ten Major Innovation case studies demonstrated the influence of the **context and framework** on success. Major Innovations are very heterogeneous and follow unique paths to large-scale market uptake. In some cases, the main triggering factor leading the innovation to become major has been regulatory change, whereas in some other cases systematic research activities during several decades have finally reached the point to achieve wide-scale market diffusion, like in the cases of LED lightning or fibre optics. Although our study shed some important light on the "black box" of innovation by looking at anomalies and similarities of the ten cases, there are practically as many stories of innovations as there are innovations and there is no one-size-fits-all recipe for future research and innovation policy. Thus, we call for more holistic understanding of Major Innovation as a combination of various innovations, embedded in unique innovation ecosystem that is constantly evolving and shaped by various factors and actors. Among these factors, public policies play an important role. The alignment of research with other relevant policies (like in transport or health) can contribute much to the success of Major Innovations. So this wider perspective requires more broad coordination of policy support (i.e., horizontally in different policy fields and vertically in different levels of governance) in order to address in a more efficient, timely and targeted manner the windows of opportunities to innovation to become major.

Within these lines of thinking, the following paragraphs summarises the main implications for the current European policy for research and innovation and its evaluation.

6.2.2 Implications and recommendations for current and future policy

Improved horizontal and vertical coordination of policies

Taking into account the findings of the analysed Major Innovation cases, it should be clearly stated that due to the complexity of innovation processes, individual FP projects or even FPs by themselves cannot be turned into a systematic pipeline for Major Innovations. Major Innovations are triggered by a multitude of factors, of which Horizon 2020 is one part of a bigger puzzle.

To tackle the complex puzzle of public policy to stimulate (major) innovation three dimensions have to be taken into account:

1) Getting the framework conditions right;
2) Coordination of multilevel governance;
3) Respect sector differences and foster sectoral linkages and cross sector elements.

One of the conclusions of the study is that **other parts of public policy** also matter for the incubation and maturation of Major Innovations. At the EU level, this for instance includes both specific policies and framework conditions. Examples are standardisation and Intellectual Property (IP), lead market initiatives, innovative public procurement, common and open trade policy with third countries, a common currency, and a strong European single market, both for goods and services, to mention a few. But also other sectoral policies, like energy (driving LED and photovoltaics), market liberalisation (driving mobile phones), health (driving personalised medicine and stem cells) and combinations of policies (like transport and energy driving smart grids). Support to research and innovation is a part of the broader public policy-mix, which should be approached as an integral system. The coordination and dialogue between the different policy areas (Directorate Generals) of the EC should be strengthened for this.

The full public policy puzzle is even more complex, it does not only include the EU level but also the **national and the regional levels**. Cluster policies at the national and regional levels, inspired by smart specialisation strategies, may help to boost and nourish Major Innovations. A pro-active integrated and coherent strategy should be in place to encourage and accompany the development and market uptake of Major Innovations. The broader policy design, of creating and nourishing a viable and conducive eco-system in which Major Innovations can emerge and prosper requires therefore much more than Framework Programme policies alone. Stronger interaction and co-ordination is not only required at the EU level (between different institutions and policy domains), but also between the EU and the national and regional levels, to be able to reap the benefits of policy complementarities and avoid unnecessary duplication. Here, some important steps towards reinforcing the European Research Area have already been taken by joint programming activities, joint schemes for mobility of researchers and transnational cooperation in research infrastructures, to mention view. Systemic strategic forward-looking thinking and systematically defining the policy steps needed is part and parcel of a more integral systemic approach to MI-driven public policy formulation and implementation.

Finally, **sector differences** have to be taken into account. Requirements and conditions for the emergence of Major Innovations (be they infrastructure, technology, capital, knowledge, skills, regulation, or standardisation oriented) as well as their innovation cycles, value chains and eco systems differ significantly for different sectors: bringing a new product or service to the market is an entirely different process in aerospace than it is in pharma, energy or ICT. The global competition landscape equally differs significantly per sector, and for instance competition policy can have a major impact on the success in innovation and the return on investment as is, for instance, demonstrated by the photovoltaic case. Next to sectoral differences, there are also sector inter-linkages and cross sector elements that are crucial to innovation. E.g. the development of an innovative car requires innovations in materials, ICT, energy, sensors, as well as infrastructural innovations, innovation-friendly regulations, to name a few. Recent developments such as H2020 with its mission and challenge orientation and the Key Enabling Technologies (and in particular the focus on cross cutting KETs and multi KETs involving for instance DG CONNECT, RTD and GROWTH), are promising steps towards cross domain and more systemic approaches.

Balanced support to creation, enablers and application of Major Innovations

Building on the stepwise improvements of previous FPs and Horizon 2020 already provides a good starting point for further improvements. Horizon 2020 can play different roles in different phases of innovation processes from the early research and development work ("funding and support for research") until later stages of innovation process via piloting and prototype stages ("innovation actions"). Different underlying technologies, industries and market characteristics and systemic dynamics and interdependences significantly limit the scope of blank and bold statements and recipes of "how to cook Major Innovations". When engaging the available instruments, two strategies can be however differentiated:

- Explorative strategies targeted to laying the future foundations for Major Innovations, i.e., aiming for a frontrunner position of Europe in science and technology;
- Exploitative strategies targeted to better utilise the potential of Major Innovation, i.e. aiming for a stronger, more innovative and more competitive European industry, and a better use of its potential to contribute to solving the Grand Societal Challenges.

The existence or development of several technological breakthroughs was highly relevant for most of the Major Innovations observed, albeit that we have demonstrated that they were seldom realised via FP activities in isolation. The European Research Council (ERC) and Horizon 2020 provide a good funding base, together with national sources, for the technological breakthroughs of future Major Innovations.

However, in order to push technological breakthroughs, minimum scales of activity, **critical mass** and (therefore) focus of activities are important. We can learn from previous analyses focusing on critical mass of public R&D programmes in the ERA that several rules of thumb should be considered.[82] Coherent with the analysis of the selected cases of Major Innovations a sector and technology-specific understanding of critical mass is needed. A highly relevant point is the coherence of individual motivations of participants and coordination research agenda and furthermore the directed and targeted pooling of funding, which is more relevant than a high number projects or

[82] Bisgoni F., Bach L., Daimer S., Fisher R., (2011), "Study on the critical mass of public R&D programmes, A potential driver of joint programming".

programmes launched in the area of concern. In view of past experience, this correlates with the size of undertakings and amount of (average) funding for key participants but also the number of national governments being part of joint activities.

Another point, clearly drawn from the case studies, is the notion of **families of innovations**, i.e. how innovations are shaped by and co-evolve with other (related) innovations. It is not a new notion that innovations often happen in the intersections of different types of knowledge. Thus, the “silo” thinking of technologies should increasingly be replaced by policy support that fosters research and technology development across the technologies. Within this line of thinking, the European Commission defined a number of key (enabling) technologies (KETs), which have been promoted extensively since FP7. The KETs are thought to be the backbone of innovations in several industries and H2020 aims to support not only the development of individual KETs but also the cross-cutting activities involving several KETs. These types of cross-technology activities are considered to be highly relevant also from the perspective of the findings of this study. Actions of the Work Programme on Future and Emerging Technologies can support further the development of new (enabling) technologies in cross-cutting areas.

It is important to stress the need for an accompanying, as early as possible, orientation towards **user needs, commercialisation and entrepreneurship**. Based on the findings of several Major Innovations cases, the significance of visionary applications, strongly driven forward by entrepreneurial spirit is a crucial success factor at a certain stage of the innovation process. This does not mean that elements of basic knowledge creation and research driven by academic curiosity should be neglected in favour of an exclusive market-oriented approach, but our study and earlier research shows that if commercialisation and innovation is not in the DNA of a project, the likelihood of such outputs is negligible.

Horizon 2020 takes these considerations into account. It sets clear targets for societal challenges and mission-oriented research and innovation. Existing platforms can be used to bring forward major (families of) innovations. The FP can fund and test various competing (market-oriented) solutions and stimulate selection mechanisms via projects, which pilot and evaluate technological alternatives. The studied Major Innovations also show the significance of non-technological innovation, that is, social innovation (changing behavioural patterns) or design innovation (see the cases of mobile phones or car navigation).

Coordination of the R&D&I and overall public policy agenda is critical. From a future perspective, foresight exercises and road mapping processes are good learning process to underpin policy developments involving all stakeholders across domains. ERA has a broad rage of instruments available, that already may be sufficient to cover all aspects, these instruments could be further improved based on current and past experiences, for instance by further coordination and stimulating the interplay and coherence of the existing instruments such as:

- PPP (including platforms), EIT and KICs to coordinate research and funding agenda;
- JTIs (opening towards SMEs and stakeholders);
- ERA-NET, JPI to coordinate with national policy;
- FET Flagship Instrument (better use and strategically focussing).

Thus, the challenge is to provide increasing transparency and simplicity for potential users and applicants than creating new instruments.Horizon 2020 has room for these forms of innovation.

Table 25 gives an overview of the various European instruments ordered by function.

Table 25: R&D&I processes, functions and instruments

	Function	Instruments
Anticipation	▪ Foresight ▪ Roadmapping	▪ EIT (creation of new KICs in 2016 and 2018) ▪ ETP (European technology platforms) (development of strategies and identification of weak points regarding innovation strategies; helping to create innovation roadmaps) ▪ PPP (private-public partnerships) based on predefined roadmaps contribute to targeted H2020 calls
Initiation: Collaboration of Key players	▪ Coordination of Research Agenda ▪ Integration of Keyplayers ▪ R&D Funding ▪ Supporting, International Cooperation with Third Countries ▪ Creation of interfaces between different disciplines ▪ Exchange of ideas through networking and collaboration	▪ Horizon 2020, stimulates and funds targeted R&D activities ▪ EIT (through the forming of knowledge triangle networks) building targeted networks, e.g. in order to achieve decisive technological breakthroughs or assess technological alternatives. ▪ JPI can coordinate with national strategic research agenda and funding ▪ ETP (European technology platforms) and PPP (private-public partnerships) can mobilise key stakeholders can shape the discussion and coordinate Major Innovation oriented strategies which can be realized within other programmes (e.g., H2020)) ▪ FET-Flagships (visionary, large-scale, science-driven research initiatives, which tackle scientific and technological challenges across scientific disciplines.) ▪ COST funds pan-European and worldwide, bottom-up networks of scientists and researchers across all science and technology fields. Although COST does not fund research itself it can be relevant for open coordination of the research and innovation community managing specific innovation challenges. ▪ ERA-Net coordinate research activities carried out at national or regional level in the Member States and Associated States through (1) the networking of research activities conducted at national or regional level, (2) the mutual opening of national and regional research programmes)
Initiation: Exploration	▪ Investment in large infrastructures ▪ Exploration of new technological possibilities ▪ Enabling/ Involvement of SMEs	▪ Horizon 2020, stimulates and funds targeted R&D-activities ▪ COSME (facilitate and improve access to finance for SMEs through Loan Guarantee Facility and Equity Facility for Growth)
Development of business ideas and entrepreneurial spirit	▪ Funding Innovation activities ▪ Enabling and involvement of SMEs ▪ Translating R&D results into commercial opportunities ▪ Development of entrepreneurial spirit in universities ▪ Development of critical mass in small and medium-sized enterprises	▪ Horizon 2020, stimulates and funds innovation activities ▪ EUREKA (an intergovernmental organisation for market-driven industrial R&D) supports small and medium-sized enterprises, large industry, universities and research institutes ▪ EIT(European Institute of Innovation and Technology) ▪ EIP (European Innovation Partnerships) can coordinate investments into pilot projects ▪ EIP (European Innovation Partnerships) (helping in bringing new products to the market) ▪ COSME (facilitate and improve access to finance for SMEs through Loan Guarantee Facility and Equity Facility for Growth)
Technology Assessment Development of Standards and	▪ Focus on conceptual basis of regulatory development (e.g., common standards, regulations) ▪ Awareness and	▪ EIP (European Innovation Partnerships) supports the early identification and development of standards and norms) ▪ Joint Research Centres (especially IPTS) and DGs support background studies

Regulations	community building activities	
Optimizing Development	▪ Open innovation ▪ investments in demonstration and pilots	▪ EIP (European Innovation Partnerships) (coordination of investments into pilot projects) ▪ Horizon 2020
Downstream Adaption of the Major Innovation	▪ Contribution to a broader diffusion (e.g., focus on spill overs & transfer from frontrunners to followers)	▪ (see above)
Utilization of MIs lighthouse effect for sectoral development and future MIs	▪ Capacity and community building ▪ Strengthening technology competence or sectorial systems ▪ Sectorial technological change	▪ FET-Flagships (visionary, large-scale, science-driven research initiatives, which tackle scientific and technological challenges across scientific disciplines.)

Enhanced monitoring and positioning in global innovation value chains

The analysis of the major Innovations like LED, photovoltaics and stem cells shows the merits of re-inventions, further development and application of technologies from other parts of the world. The Framework Programmes should keep their function as a safe trial area. A European "not-invented-here" syndrome should be avoided. Quite to the contrary, the European research and innovation agenda should better take into account the advancements done elsewhere and assess in how far these can be leveraged for economic growth in the EU by strategic positioning in he global value chain. Several Major Innovations analysed taught us that non-European players have been very successful in building their innovations on top of pre-work carried out in technology hubs elsewhere. Thus, clear mechanisms of taking the technological state-of-the-art into account have to be established, for programme development as well as for the project selection. This requires also adequate policy attention for sufficient venture and other capital to overcome lurking valley of death type of problems, adequate support for start-ups and gazelles, and bringing innovative public procurement policies into practice, to mention just a few.

The case studies also demonstrated, almost by definition, that today's Major Innovations and, especially, the potential Major Innovations of the future may be understood as a **global effort**. In these cases, the strategic exploitation of the FP international cooperation instrument (INCO) shows interesting potential. A good example might be the stem cells case, where locally autonomous efforts appeared to be less promising.

Increased alignment of the research agenda with stakeholders and society

The Major Innovation cases analysed also build our awareness of the importance of the development of regulations and standards in making the innovations major. In several cases, the introduction of **regulations** at the European level has been the triggering event for the development and success of Major Innovations. The coordination between research and other policies within the EC is a challenge – but it has to be taken even wider. Non-governmental actors, such as private and social enterprises, financial sector, venture capital, foundations and other civil society organisations – broadly speaking all stakeholders of the Major Innovations – can play a key role in specific areas, such as health (e.g., personalised medicine/stem cell treatments) and can be instrumental in developing new actions and scaling them up. Previous FPs already stimulated and funded projects, which have been targeted in this direction. Thus accompanying studies focusing on policy, technology assessment, regulations and standards should continue to be an essential element of FP funding.

In many cases, the development and implementation of Major Innovations should be combined with or depend on investments in **large infrastructure**. Large infrastructure development sets standards, brings together private and public entities, and can ensure longer-term benefits for the EU as it will be more difficult to copy than individual applications. Investment in infrastructure however is complex, capital-intensive and knowledge-intensive, but if implemented well, can be very lucrative. A key element in the decision should be based on the assessment whether infrastructure (and their investment) elsewhere in the world could be better leveraged, or whether infrastructure has a strategic value for the EU. It is therefore essential to investigate opportunities for Horizon 2020 in setting further strategic infrastructures, e.g., for smart transport (connected cars), in health/hospitals, in bio-economy, in safety/security. In these cases, a clear coordination between activities funded by the FPs and activities of different Directorates General in the European Commission is needed. The Framework Programmes can support the search for, evaluation of, or selection of alternative infrastructures as an element of a rather holistic approach to bring forward or utilise Major Innovations in Europe. Close co-operation with private and non-governmental actors is important in this context. Private and non-governmental actors are often better placed than governments to point to areas for productive investment or policy action.

We stressed the point that policy also could make use of Major Innovations by utilising so-called **lighthouse** effects of Major Innovations. The reference to major (or promising families of) innovation in other policy areas can be used pro-actively as a vehicle for sectoral policies, the development of supplier SMEs and value chains and smart specialisation strategies at the regional level, including the use of EU Structural Funds. This needs clear visions and strategies, which can be developed during the course of FP projects and accompanying platforms. The efforts currently being carried out in the frame of H2020 to encourage European research and innovation landscape to seek for combinatory funding, such as H2020 combined with European Structural Development Funds (ERDF) or with funding of European Investment Bank, are welcome in order to have sufficient scale for large investments. H2020 already takes important steps forward in improved alignment of public and private investment for innovation. For example the SME Finance Initiative combining H2020, COSME, ESIF, European Investment Bank and European Investment Fund funding, to support the achievement of the innovation objectives of SMEs in all sectors is an initiative aimed to align not only the public investments but also the private investments to mitigate the challenges that European SMEs face when seeking for finance to their innovation activities. Similarly, the Joint Technology Investments (JTIs) and Public Private Partnerships introduced in FP7 and reinforced in H2020 are paving the way towards improved alignment of public and private finance for innovation activities in sectors which are essential to Europe's industrial leadership. Similarly, the new suggestion for Investment Plan for Europe, although being subject to strong criticism from European research community due budget cuts on H2020, could well implemented and with focused agenda of projects, led towards the desired multiplying effect where public investments are triggering even larger private investments.

6.3 Implications and recommendations for evaluation design and implementation

An appropriate approach to innovation and policy involves search, experimentation, monitoring, learning and adaption, all of which need to occur in a context of international transparency to knowledge, trade, investment and competition.

Interim and ex post evaluation at programme level are guided by the regulation that establishes the programme; the evaluations have been largely focusing on the implementation of the programme, and the achievements against the set objectives. Although usually outcomes and outputs are measured, these evaluations are not designed to touch upon real impacts on innovation. Since FP6, the evaluation mechanisms have been spurred at the European as well as the national level.

H2020 puts a stronger emphasis on impacts in the evaluation[83]. The actual implementation of the (interim and ex post) evaluation will determine in how far the impacts will be measured against the expected impacts as stated in the work-programme(s).

The analysis presented in previous chapter shows several implications for standard FP evaluations. As mentioned in Section 5.2.3, the FP evaluation approach has been developed significantly throughout the last years in order to become an efficient management tool. Impacts are measured including various aspects (e.g., participating institutions, innovation activities, bibliometric output, network building or technological transfer as well as researcher mobility). Recent events driven by the financial and economic crisis leading in a decline of the propensity to innovate in Europe during the period of 2009-2012 underpins the importance of these exercises.

A greater shift towards the promotion and exploitation of **results** and thus fostering a drive to (major) innovations should not be at the cost of the clear objectives and methodologies of standard evaluations. However, we saw that standard FP evaluations could be more sensitive towards a number of questions that have not been considered extensively in the past. The frame of standard evaluations gives some room to ask organisations to link specific activities funded to pre-defined or individually specified Major Innovations (families of innovations).

The data collection and analysis presented in previous chapters showed the added value of analysis that is not tied to the programme cycle but aims towards improved understanding of the big picture, the **system**. The "big picture" drawn from interim or ex post evaluations has to be seen as complementary to the standard evaluations and cannot cover immediate needs of public policy and programme implementation.

Key elements for measuring the broader picture of innovation impact are:

1) The **multi level measurements** of impacts: at participant, project, sector, cross sector or programme levels;
2) What exactly is measured as **outcomes or outputs**;
3) Specific elements of **programme implementation**, for instance, are the chosen instruments and rules the most appropriate to achieve maximum impact?;

[83] http://inea.ec.europa.eu/download/legal_framework/regulation_12912013_establishing_h2020.pdf

4) **Contextual elements**, as multi or cross domain regulation and standardisation, access to capital, and capacity;
5) **Time frames**: a major obstacle for measuring impact on innovation from FPs the elapsed time between a project, or set of project and the occurrence of an innovation, this can vary between several months and decades, largely depending on the sector (ICT applications are usually closer to the market while drug development can take 15 years or more).

The analysis of the selected cases of Major Innovations showed that (after the initial FP-funded activities) firms or small groups of key players decided to pursue ideas and technologies outside the FP (financed by internal, external private or national public sources). In order to learn more about the background (and the options of the FP management to react on that), it is essential to ensure that the FP-funded project is embedded in the **organisations' strategies** and future perspectives.

The measurement should probably take place at all **levels**. As this and other studies demonstrate, innovations and especially large or Major Innovations are complex processes, and cases of a one-to-one relationship between an FP project and an innovation will rarely happen. More likely clusters of results and outcomes of projects can lead to innovations, and this can be across domains (for instance new imaging techniques are needed for innovative diagnoses of diseases). At the same time assessment at participant level can also shed light on the innovation impact of a project (participation) on innovation (and the innovative capacity) within firms. Studies as the Innovation Impact study analysed to which degree a project participation has contributed to a new or improved product or service, and subsequently mapped this onto the Community Innovation Survey to analyse the impact on the innovative behaviour and for instance sales of a firm and across sectors.

With regards to the measurement itself, **patents** are often used as output measures that indicate innovation levels or potential. Although for certain cases this may be an accurate measurement (and probably one of the few that contain external 'objective' data) especially with new techniques in triangulating inventors to (indirectly) relate them to projects (overcoming the attribution problem), we need to point out that various studies have demonstrated that for many FP projects patents and other IPR are not the preferred way to protect results from a project. Other means of protection such as secrecy, speed to market, embedding in services are often seen as more efficient (of course depending on the sector). This implies that although patent analysis is needed and adds value to an evaluation, it should not be taken as an indication by itself for innovation across the many different actions in an FP.

With specific elements of programme implementation, we mean for instance the different instruments. Various studies have shown that the **size** and scope of a project has an impact on its outcomes. Bigger is however not necessarily better in terms of outputs and outcomes, instead an optimum size of budget and number of participants can be found to result in an optimum output. This optimum strongly relates to the type of research/technology and the sector (the budget allocation per project participant is for instance a more relevant indicator than an overall project budget).

Another example is to measure the critical mass needed to develop innovations. The Major Innovation cases show the relevance of a critical mass as well as the combination of the right partners for technology breakthroughs and their successful applications to Major Innovations. The existing instruments introduced to coordinate ERA (e.g., ETP, JTI, JPI, KICs, PPPs, etc.), seem relevant in the aim of improved support of critical, but targeted, mass of development efforts considered relevant for potentially high impact innovations. Thus, FP evaluations should also consider the coherence and impacts of the **ERA** multilateral activities.

In addition, the current study shows that other **non-technological** drivers or barriers play a major role in the success or failure of Major Innovations. We have provided examples of regulation, standardisation and other (non R&D&I) policies, both inside and outside the EU. The impact of these non-technological factors should be taken into account when measuring impacts, not just at the ex ante stage (where this more often the practice) but also in the ex post evaluations.

The selected cases of Major Innovations demonstrated the high relevance of contextual (e.g., sector specific) factors and the role of a single triggering event which decided the success of Major Innovations. The European Commission is recommended to undertake regular in depth **sectoral** analyses and foresights. This type of analysis is highly relevant to understand systemic changes, future developments and needs. The insight gained helps to steer programming and accompanies evaluations in the key areas of FP activity. Recent developments show an encouraging increased activity in foresight through for instance expert workshops. It would be recommendable to avoid an ad hoc approach, but instead design a consistent approach and methodology to be implemented over a long period of time, which will allow detecting trends, and systematically improve and better interpret results. This manner, complementary to ex ante evaluations, the EC could make better use of targeted foresight activities.

Standard interim or ex post evaluation methods will probably not be appropriate to overcome the obstacle of elapsed time to market. Other means as **foresight** (in support of ex ante assessments, but also to measure results against the earlier foresights) and ongoing and long term monitoring of innovations as a result of the projects (long after the funding period has ended) will be more effective as a means to establish evidence for (potential) innovation impacts.

As indicated, an **object-oriented** approach (reasoning from the innovation itself) as taken in the current study is worth exploring. Databases referring to the innovation subject (e.g., firms) are very common and implemented in Eurostat and OECD official statistics. However, it seems that there is little knowledge and insufficient data from the perspective of the innovation object (e.g., a Major Innovation). Thus, it is recommended to take up a broader effort building and coordinating the conceptual ground as well as an object-oriented innovation database to complement subject-oriented data and analysis into the future research plans.

For example, the establishment of a SFINNO type data basis at EU level (“ECINNO”) could be an option for a follow-up system of innovations with EC contribution, which would also guarantee the continuous thinking and learning of the programme managers on the level of innovations. Another option is to conduct innovation surveys for instance biannually, for example, focusing by turns to different programmes and also to different innovations (technological, service, social etc.), specifically related to the FP participants (not as a copy of the CIS).

The analyses conducted provide the proof of the **case approach** as an adequate instrument to discuss the position and role of FPs in the larger frame. The case study approach however has some important limitations (resource and time consuming, certain level of unavoidable ambiguity and subjectivity of the results), which should be considered. Innovation subject-oriented case studies however could provide interesting complementary knowledge to innovation policy evaluation, e.g., selected parts aimed to create more strategic, longer-term perspectives targeted towards improved understanding of how innovations actually come about rather than geared towards a precise assessment of policy contribution.

The challenge of measuring innovation impacts from publicly funded programmes is obviously not limited to the EU level. The innovation policies of governments have in recent years increasingly focused on encouraging system innovation performance. Much can be learned from governmental and funding agencies in **countries** and their practices. As an example, we can mention the practical change in the Tekes evaluation procedures. The study 'Exploring roles of Tekes fuelling Finnish Innovation'[84] has analysed the contribution of Tekes programmes to innovations. After this study, Tekes added to ex post evaluations also case innovation examples which complement and concretise traditional ex post evaluation process and reporting. Another example relates to reflective monitoring as applied in the Netherlands. As the approach to innovation at a systemic level is extremely complex, with no party having all knowledge and capacity required to fully plan and steer the process. Reflective monitoring is based on the idea that the design and implementation of innovation programmes is strongly linked to a collective learning process. So it's not just about the more or less traditional functions of monitoring, such as measuring, describing and evaluating, but especially also about learning and reflection.

To increase the opportunities and propensity to innovate at a project level, we have to note that Major Innovations do not happen at project level. Projects and smaller innovations can nevertheless be feeders and contributors to Major Innovations. We can make a few **recommendations for the evaluation and review process**:

1) **Tailored project evaluation** and guidance at early stages:
    a. The motivation and objectives when submitting a project proposal are directly linked to its outcomes as earlier studies demonstrate[85]; for instance when a project has not (truly) set out clear objectives to commercialise (which is more than words, and can be identified by the partnership, the realism, workplan and approach for instance), the chances of producing exploitable results are around 0%, not even 'accidentally'. Apart from clear criteria, the selected evaluator teams must include capabilities to judge the exploitation potential;
    b. Along the same lines, expertise in venture capital, private equity and other types of investments is needed at the evaluation stage. All described Major Innovations require major (private) investments at some stage. Many projects may have excellent outcomes from a scientific or technological point of view, but at the same time do not deliver a financeable result, which often requires much more than a patent or IPR. Inclusion at early stages of finance experts will allow for detecting weaknesses and early steering and modification in a proposal/project in this respect. Traditional banks are often out of reach for highly innovative companies with risky projects;
2) Cross and domain external relevance:
    c. Contextual issues as regulation, standardisation, policies outside the specific domain, can be critical for the success or failure of an innovation, as demonstrated in this study. Insight in the implications of these must be ensured at the proposal evaluation stage;

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[84] http://www.tekes.fi/globalassets/julkaisut/funder_activator_networker_investor.pdf

[85] see the innovation Impact study that analysed 8000 project participations

d. Along the same lines, potential exploitation outside a specific domain and vice versa, relevant developments outside that domain, have to be taken into account, stimulated and evaluated where appropriate in order to establish the cross fertilisation needed to foster Major Innovations (for instance developing a particle filter developed for a car exhaust system may also be exploitable in air conditioning systems in an airplane);

1) *Risk and failure*: Finally, we would like to underline that the innovation process is one frequently marked with high risk and failure. The FPs in their current set up don not contain instruments that allow implicitly for project failure (without consequence). Such instruments would increase the attractiveness to highly risky projects. Instruments that allow for a 'Try fast fail fast' approach in certain domains, with short review cycles and clear exit procedures would benefit highly innovative projects. In addition a closer link and matching criteria between existing risk financing instruments (such as the RSFF) and the FP (H2020) projects would benefit the development of FP project results.

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8 Annex A: Case Studies in a Nutshell

The following section condenses relevant characteristics of the Major Innovations in short tables. These tables can be used by the reader as complementary background information for Chapters 3 and 4.

Table 26: Novelty of Major Innovations

Source: JIIP, based on case studies

	Technological novelty/newness	First application	Key technological breakthroughs	Large scale usage
Car Navigation Systems	Car navigation systems based on various innovations (CPU and GPS navigation hardware, sensors, digital maps, screen technology and software, audio, video, other communication) is a radical and disruptive product innovation, replacing physical maps and the effort and ability to read maps.	**1985:** ETAK Navigator in Los Angeles and the Homer, designed by Steven Lobezzoo	* **GPS – global positioning system based on satellites and GPS receivers** * **Memory** (from CD-ROM to flash) **for map storage/retrieval** * **Text-to-speech * Graphical User Interface** (GUI) and * **Heads-up display** * **Turn-by-turn guidance and * Dead reckoning** * **Map matching * Digitalisation** (digital maps, geocoding) * **RDS-TMC / Live traffic** * **Time-To-First-Fix** (TTFF) * **Screen technologies** * **Bluetooth * Wifi, GPS phone, smartphone, 3G, 4G, navigation apps** * **Galileo, HAD, self-driving car**	**since 2000**
LED Lighting	The development of blue and white LED represents a scientific and technological breakthrough and a radical innovation based in particular on decades of scientific research efforts related to material physics. Subsequently it has revolutionised lighting and lighting industry (new to global market). LED can be seen as a disruptive technology.	**Early and mid-1990s:** discovery and commercialisation of blue and white LED by two groups of competing Japanese researchers	* **Light emission:** semiconductor materials, technologies and processes (e.g., growing gallium nitride crystals) * **Light management:** Development of phosphor coatings to encapsulate the LED chip or the bulb cover in order to translate the blue light into white light * **Heat management** * **Electronics:** LED bulb package needs compact, economical and functional AC-DC converters	**since the mid-1990s** (final breakthrough of LEDs in general lighting market is not reached yet)
Linux Operating System	In the early 1990s Linux as free and open source software was a unique in its kind and diffused fast.	**1991:** First version of the Linux kernel is released to the Internet	* **Improvements in ICT applications** * **Free source operating system:** The end users have freedom in using, studying, sharing and modifying that software	**since 2000:** Linux based digital advices (computers, laptops, smartphones, etc.) are entering the market
Mobile Phones (MP)	Mobile phone, together with the entire mobile telecommunication system, forms a radical and complex technological system, which replaces the traditional call communication system based on analogue phone technology.	**1956:** First fully automatic mobile telephone system created by Swedish Televerket **1973:** First hand-held cell phone demonstrated by Motorola"	* **Advanced network technologies** (e.g., HSDPA; WiMAX) * **Advanced software technologies** (e.g., MSN for cell phones, in phone video editing, etc.) * **Advanced handset component technologies** (e.g., camera, touch screen for phones, etc.) * **Digitalisation of mobile communication technologies.**	**Increasingly since the half 1990s.**
Super Jumbo Jet (A380)	The novelty of the innovation comes from quite a few aspects. These are: use of lightweight composite materials, noise reduction and high fuel efficiency, enormous transportation capacity and variability.	**2007:** Introduction of Airbus A380	* **Advanced Materials** (e.g., lightweight composite materials) * **Advanced engine technologies** (e.g., zero splice engine intake liner) * **Advanced cockpit technologies** (e.g., interactive displays, advanced management systems, improved navigation modes)	**since 2007:** 50 Airbuses have been delivered to Airlines so far. Total orders for the A380 stand at 318 as of August 2014, Thus far, around 143 have been delivered globally.

	Technological novelty/newness	First application	Key technological breakthroughs	Large scale usage
Optical Fibres (OF)	Utilisation of basic optical phenomenon such as refraction and reflection led to quantum computers of the present day, which is considered to be a novel innovation.	**1970:** invention of low-loss optical fibres	* **Semiconductor lasers** * **Microprocessors** * **Communication networks**	**since 1990s**
Personalised Medicine (PM)	New classes of medicine, which are very expensive, but can be effectively used because of related diagnostic testing. Therefore major convergence of genetic data, pharma, medical technology, social media, and infrastructures is needed to achieve the vision of PM.	**2000:** Start of drug related diagnostic tests	* **Genomic profiling** (e.g., genome sequencing, DANN chip, RNA chip, etc.) * **Improvements in diagnostic technologies** (e.g., biomarkers, targeted molecular imaging, etc.) * **Improvements in ICT and medical device technologies** (e.g., Software and data management, cyber security, nanotechnology devices) * **Biobanking**	PM approaches are in most areas still under development and far from complete deployment. First applications can be seen in oncology.
Photovoltaic (PV)	As an invention PV technology is not new. However, recent major technological advancements (e.g., thin film solar panels) have made cost of solar power comparable with that of electricity from fossil fuels.	**1954:** Installation of first photovoltaic solar panel	* **Crystalline silicon modules** * **Heterojunction** * **Thin films** * **Multi-junction cells** * **Concentrated photovoltaics**	**Since approximately 10 years. Research in materials is still ongoing, and large-scale adoption has not occurred yet.**
Smart Grids (SG)	Part of the technology required is already available or has been used in other domains, but it is the integration of all of them (combines innovations from many areas, all KETs (except biotechnology) plus ICT) and the extreme conditions of very high voltages and currents what makes the SG complicated.	**2005:** Telegestore project by ENEL S.p.A. (Italy)	* **Integrated communication technologies** * **Sensing and measurement technologies** * **Superconductivity, storage, power electronic and diagnostic technologies** * **Advanced control methods** * **Improved interface and information systems**	Smart grids are still under development and far from complete deployment. Deployment will be adapted to circumstances.
Stem Cell Treatment (SCT)	Stem cell treatment can be characterised as a product innovation that differs significantly from previous treatment methods. Even putatively connatural applications for different organs or sub-groups of patients significantly deviate from each other.	**1955:** First successful bone marrow transplant	* **Cell therapy** * **Tissue engineering** * **Diagnostic technologies** * **Supporting technologies** (e.g., Stem cell preservation methods; methods of collection processing and testing, etc.) * **Biobanking**	SCT approaches are in most areas still under development and far from complete deployment. First applications can be seen in the reproduction and transplantation field of tissue stem cells.

Table 27: Application areas, business models and key actors of Major Innovations Source: Case studies

	Geographical location of innovation hubs	Application areas	Business models	Key actors	Market drivers
Car Navigation Systems	* **Japan** * **US** * **Europe**	* **Built-in 'in-dash' GPS navigation systems (automotive embedded navigation)** * **GPS-based Portable Navigation Devices (PNDs) (portable navigation)** * **Smartphones with GPS navigation (mobile phone navigation)**	* **Until recently closed innovation model:** core R&D happening in-house (applied to the in-dash segment and the PND segment) * **Moore's Law and the opening of the NAVSTAR satellite system to civilian use:** Entering of newcomers from the software, PDA and GPS companies * **Recently players of each segment** (the in-dash segment and the PND segment) **are interchangeably active in the other sector** (e.g., TomTom, GM OnStar). * **Entering of various new players on the Satnav market via the apps segment:** Google, Nokia, and a number of smaller app and map makers, offering free and paid Satnav solutions.	**The key actors are market participants in the following three sub-markets or market segments of today's car navigation market:** * 'in-dash' GPS navigation systems (both built-in in new cars and as 'aftermarket' product) * GPS-based Portable Navigation Devices (PNDs) (portable navigation) * smartphones with app-enabled GPS navigation	* **Revenues and profits made by suppliers** (due to strong consumer demand) * **Ease of use** (portability) **and price** (especially in the case of the popularity of the PND and recently the uptake of smartphone-enabled navigation apps) * **Reduction of vehicle mileage** (associated with a reduction in fuel costs) * **Lower insurance claims of 12%.**
LED Lighting	* **Asia:** Taiwan, Japan, South Korea and China * **Europe:** home of two of the globally leading LED firms (Philips and Osram)	* **Indicator lamps** * **Car tail light** * **Flash- and traffic lighting** * **LCD backlighting** * **HB-LED headlights** * **General illumination** * **Smart lighting systems**	**LED lighting led to a new industry creation:** * Enabled new entrants (small start-ups) to the market by creating LED-based products and challenging the existing companies. * Creation of joint ventures, alliances and consortia between the big players and the new entrants.	* **Electronic companies and their private research laboratories** * **University research institutes** * **Small niche companies**	* **Material logic:** discovery of the material logic of gallium nitride and therefore the bright light emitting diodes * **Market logic:** huge market potential of gallium nitride for different applications * **Competitive logic:** competition in the race of improvements of gallium nitride production process between individual researchers and research groups and companies
Linux Operating System	* **Europe:** Germany * **Asia:** Korea, Taiwan, Japan	* **Digital devices** (e.g., Computers, Laptops, Smartphone, Tablets; Supercomputers, etc.) * **Development and subsequent sales of standard or customised versions of Linux** * **Provision of consultancy and additional services** (e.g., training, installation, technical support) * **Certification of a Linux-based OS**	**Open innovation Bazaar model:** Linux as open source software is developed and improved over the internet in view of public. In practice, anyone is freely licensed to use, copy, study, and change the software of the Linux kernel in any way, and the source code is openly shared so that people are encouraged to voluntarily improve the design of the software.	* **Paid programmers** (80%) * **Anybody else who wants to improve the design of the software**	* **Dominance of Linux together with Apache in the webserver market** * **Compatibility of Mac OS X with Linux** * **demand of firms:** Free and open source software for products strengthen the innovation capacity of firms.

Mobile Phone (MP)	* Europe: Sweden, Finland (in early phase also Germany, France and Netherlands) * Asia: Korea, China, Taiwan * USA	* In addition to phone calls, SMS, MMS, email, Internet, infrared and Bluetooth communication, business applications, gaming, photography and video players, navigational systems applications enabling interactive learning, new business concepts, alleviating social and health care services or mitigation of poverty.	* Since early phase first manufacturing of mobile phones and cellular networks (component industries with globalising value chains), software business and telecommunication operators, gradually accelerating growth of application businesses (see Application areas) and internet * **Shift from mobile-cellular phones to smart phones:** smart phone development led gradually to the change of the entire mobile phone markets * **Shift of mobile phone business to application business:** growing the importance of application business (e.g., Apple's creation of common ecosystem for Apple Corp)	* Mobile phone, related component and cellular network manufacturers, software and application developers, regulators, users and consumers, close PPP, user-community collaboration and user-producer relationship.	* Liberalisation of the European telecom market * Need for flexible and fast mobile communication of individuals, businesses, public administrations, media etc. independent of location. * Enabling technology for numerous new and creative business concepts by various mobile applications based on voice, videos, movies, etc.
Super Jumbo Jet (A380)	* **Europe:** France, UK, Germany, The Netherlands, Finland * **US**	* **Avionic Components** * **Communications (Airborne)** * **Flight and Data Management** * **Imaging and Visual Systems** * **Indicators and Instruments** * **Navigation Aids (Airborne)** * **Warning Systems**	**Creation of niche market:** A380 was created to target the international traffic (long haul intra-continental flights) and therefore to face high-traffic, high-volume routes (high congestion and need to overcome a number of flying challenges).	Companies like: * **Rolls-Royce** (United Kingdom) * **Honeywell** (USA) * **Fokker Aerospace Group** (Netherlands) * **Thales Avionics** (France)	* **Increasing demand for larger aircrafts** * **Advances in materials and manufacturing** * **Advances in ICT technologies**
Optical Fibres (OF)	* **Asia:** China, Japan * **US** * **Europe:** Italy, France, UK	* **Medical area** (e.g., light guides, imaging tools and also as lasers for surgeries) * **Defence/Government** (e.g., hydrophones for seismic and SONAR uses, wiring in aircraft, etc.) * **Data Storage** (e.g., data transmission and storage) * **Industrial/Commercial application area** (e.g., sensory devices to make temperature, pressure and other measurements) * **Broadcast/CATV application area** (e.g., wiring CATV, HDTV, internet, video on-demand) * **Telecommunications** * **Networking** (connects users and servers in a wide spectrum of network)	**Consolidated fibre market:** * Competitive rivalry within the industry * not much of threat expected from new entrants or substitute products.	* **Component and system Suppliers** (e.g., raw material producers, manufacturing equipment, transceivers, connectors, harness suppliers) * **Optical Fibre and Cable Producers**	* **Material drivers** (e.g., small size and lightweight, wide temperature range, noise immunity, etc.) * **Material availability** * **Power demand** * **Security** (in the sense of secured communication)

Personalised Medicine (PM)	* **US** * **Europe:** Germany, UK, France	* **Drug development** * **Diagnostics** * **Biomarkers** * **Medical technologies and infratructures**	**Changes in business models:** *Transformation of blockbuster medication model into a PM model * Entrance of new small biotech start-ups * growing importance of diagnostic companies	* **Big pharma companies** * **Universities and small biotechs** * **Diagnostic companies** * **Technology companies**	* **New science and knowledge gained in areas like genomics and proteomics** * **Evident failure rate of drugs in use today** * **More effective and efficient prevention and treatment contributes to managing the cost of health care** * **New business opportunities (product differentiation and new product opportunities)**
Photovoltaic (PV)	* **Asia:** China * **Europe:** Germany, Belgium Netherlands, France, Switzerland * **America:** USA	* Production of electricity for homes and businesses * Production of electricity for the grid	The market is currently still driven by public policy. The more the market is protected, the more it will develop. However, in near future the photovoltaic is expected to be competitive when compared to other energy sources.	Key actors are companies in the fields of: * **materials and components** * **silicon and cells** * **modules production** * **balance of system** * **PV systems** * **power sales**	* **PV market in most European countries is policy-driven** * **Environmental benefits** * **In future, more cost-efficient and more available alternative to other energy forms (fossil fuels)**
Smart Grids (SG)	* Europe: Germany, Switzerland-Sweden, France, Spain * America: USA * Asia: Japan (and China now entering)	* Utilities (grid) * Homes and businesses (smart-homes and distributed generation) * Household appliances	Europe: led by regulation America: (USA), led by grid improvement In some cases, not so clear benefits for utilities	* **Multinational enterprises/institutions** * **Regulatory bodies and standardisation bodies** * **Utilities**	* **Improvement of the efficiency of the current electric grid** (e.g., reducing significantly greenhouse gas emissions) * **Achieving more secure and sustainable energy in the future**
Stem Cell Treatments (SCT)	* **US** * **Europe:** Germany, UK	* **Clinical stem cell treatment** * **Drug development and disease modelling** * **(Re)programming of tissue cells** * **Identification/treatment of cancer stem cells**	*Stem cells value chain is **located in public domain (clinical laboratories and treatment)** to a large extent ***lab-equipment suppliers** provide specific facilities for stem cell research * Firms developing **stem cell based test systems** for pharmaceutical firms *Entrance of new small biotech start-ups	* **Medical facilities/university research institutes/private research groups** * **Biotech start-ups** * **Pharma companies** * **Hospitals/clinical laboratories** * **Equipment suppliers**	Reduction of drug development costs

Table 28: Regulations, standardisations, IPR and public policy of Major Innovations

Source: Case studies

	Regulation	Standardisation	Public policy	Intellectual property rights
Car Navigation Systems		**Standards have been important in establishing the car navigation field:** * **Initially set by individual companies** (as first movers) * **CARiN Database Format** (CDF) (1997 by Philips): a proprietary navigation map format * **With maturity of industry** (since 2000) **stronger importance of standards: Radio communication standards, Transport Protocol Experts Group** (TPEG) protocol (a new international standard for transmitting multimodal traffic and travel information), **Navigation Data Standard** (NDS, map vendor independent format that allows for incremental map updates)	* **Opening up of the NAVSTAR satellite system for civilian purposes** (2000) * **Public R&D&I support to the development of car navigation systems:** Mostly indirect and non-car navigation specific but related to the development of many of its main underlying innovations including GPS positioning technology and the NAVSTAR satellite system (mainly through US military investment), processor technology (CPU, GPS), screens, GUI, bluetooth, RDS, memory storage devices and digital maps	**Patents and proprietary ownership have played an important role right from the beginning of car navigation systems** (new car navigation specific findings such as map matching technology were patented in the 1980s)
LED Lighting	* **Ban of the use of inefficient technologies** (in particular incandescent lightbulbs) * **Stricter legislation on energy efficiency requirements and on entire building infrastructures**	* **Considerable differences of safety, performance standards related to LEDs across countries:** Some of the available standards and test methods for LED lighting products have been considered as insufficient and as an obstacle for the development of the industry.	* **Government LED R&D funding:** There seems to be a correlation between countries' national LED R&D programmes and its level of innovative activity (more patents came from funded projects)	* **Play important role due to the breadth and complexity of LED technologies** * **Implement strong entry barriers for companies**
Linux Operating System			* Embracement of adopting open source software by many different levels of government in Europe and beyond (EC dedicated a strategy on the use of OSS within its institutions) * Rise of possible focus on support of development of OSS due to negative incentives for firms to invest in OS research	Linux is licensed under the GNU General Public License (GPL), which builds on the principle of copyleft.
Mobile Phone (MP)	* **Regulation protecting the safety of user:** health effects, phone use in vehicles * **Regulation on roaming charges affecting consumer tariffs** * **Regulation on the usage of natural resources used in manufacturing mobile phones** * **Regulation on emerging environmental wastes**	* **3rd Generation Partnership Project (3GPP):** Setting Mobile phone system specifications * **GSM:** Harmonisation of frequency bands; enables global roaming, reduces the complexity of the radio design, and reduces interference with adjacent services and helps managing cross-border interference	* **European policy:** liberalisation of the telecommunication markets; support of a large number of projects through successive R&D programmes; promotion of platforms such as ETPs, JPIs; * Some important mobile phone technologies and GSM standard development were supported already by the 4th EU FP project, and then various mobile phone, cellular network technologies, and applications by 5th to 7th FP programmes.	* **Play important role due to the strong growing and R&D intensive area** * **Patent wars are a common phenomenon in this area**

	Regulation	Standardisation	Public policy	Intellectual property rights
Super Jumbo Jet (A380)	* **EU Emissions Trading Scheme (ETS):** Curbing rising greenhouse gas pollution from aviation and fight climate change * **Plans to introduce charges for carbon emissions**	* **International Civil Aviation Organisation Standards and Recommended Practices (ICAO SARPs):** Regulations related to airports and aircraft code F (such as Airbus A380) * **Civil aviation authorities of different countries:** individual interim aerodrome requirements based on ICAO SARPs.	EC sustainable development strategy: * **Modernise the air traffic management system** * **Reduce the environmental performance of aircraft** * **Economic mechanisms for trading emission rights provide incentives for greener operations**	Airbus filed **more than 380 patent applications** in the fields of aerodynamics, cabin design, engine integration, flight controls, aircraft systems, manufacturing techniques and the advanced lightweight composite materials while the A380 was being developed.
Optical Fibres (OF)	* **Commission Recommendation 2010/572/EU:** Through the Next Generation Access Networks (NGA) all Europeans should be enabled to access fast broadband by 2013 and very fast broadband by 2020	Key standards of optical fibres: * **FOA Standard FOA-1:** Test in order to measure the loss of an installed fibre optic cable plant * **FOA Standard FOA-2:** Test of loss of a fibre cable (singlemode or multimode), including connectors on each end * **FOA Standard FOA-3:** Test of optical power at the end of a fibre optic cable * **FOA Standard FOA-4:** Test of Fibre Optic Cable Plants	* **Need to for the development of broadband policies** * **Need for the protection of the net neutrality principle**	* **Play a key role in expanding the product portfolio in the field of optical fibres:** Europe lead with respect to the number of granted patents, followed by Canada and the US.
Personalised Medicine (PM)	* **European Medicines Agency (EMA):** * **European Personalised Medicine Association & European Association for Predictive, Preventive and Personalised Medicine** * **Member states:** regulatory and legal locus for diagnostic products and even for companion diagnostics lies with the member states		Public policy issues with regard to PM are: * * **Usage of secondary patient and biospecimens** * **Creation of clear and reasonable pathways for approval of PM diagnostics and therapeutics, and for co-development of drugs and diagnostics** * **Creating incentives through IP policies** *	IPs will play a considerable role in developing and commercialising personalised medicine products and treatments. With this regard, changes in the IP law should be considered.
Photovoltaic (PV)	EC energy roadmap 2007: setting of energy and emissions targets and 10% of renewable resource energy Climate and Energy package 2009: Renewable Energy Sources (RES) Directive 2009/28/EC: installers of photovoltaic solar panels in the EU must be certified	The wide variety of PV panel technologies and specifications make it difficult to implement standards in the market. Experts and industry professionals have repeatedly asked for standards although due to the wide range of different types of panels this might be difficult.	The PV solar panel industry is very sensitive to public policy and support from policy makers and to legislating high incentives to stimulate development of their domestic solar markets (e.g., German feed-in tariff (FIT) model). Long-term public support is needed in order for PV panels to succeed.	In order to design and produce their products, companies constantly patent the results of their R&D. The number of PV patent applications at the European Patent Office rose from about 1 000 in 1997 to over 2 000 in 2002

	Regulation	Standardisation	Public policy	Intellectual property rights
Smart Grids (SG)	* **Electric sector traditionally highly regulated** * **EC energy policy: Sets regulations to secure a sustainable energy provision** * **EC's framework should facilitate investments in SGs**	* **European standardisation process of smart grids (start 2009):** The EC issued a mandate to CEN, CENELEC and ETSI (ESOs) aimed at smart utility meters (electricity, gas, water and heat) involving communication, interoperability, security and consumption * **Other standards:** Related to the implementation of high-level smart grid services and functionalities	* **Need of establishment of clear and consistent policies, regulations and plans for electricity systems:** Forming incentives for innovative investment in smart grids * **Need of greater public engagement:** Educating all relevant stakeholders about the need for smart grids and the benefits they offer	IPR mainly plays a role with regard to the equipment manufacturers of smart grids.
Stem Cell Treatment (SCT)	* **EC legislation on advanced-therapy medicines (2008):** definition of 'advanced-therapy medicinal products (ATMPs)'; * **Committee for Advanced Therapies (CAT):** assess the quality, safety and efficacy of ATMPs, * **Commission directive 2009/120/EC:** technical requirements * **Regulations on embryonic stem cells:** differ in the different European countries	* **EMA:** Provision of guidelines for the development of stem cell treatments (concerning (1) production/manufacturing, (2)quality control, (3) pre-clinical and (4) clinical aspects) * **International Stem Cell Initiative:** Studies on standardised characterisations of stem cells have been used to establish the key generic properties of each of these stem cells.	* **Funding policies:** highly important in the development of stem cell treatments. * **UK:** UK Stem Cell Initiative (UKSCI) adopted a ten-year for stem cell research programme in the UK * **Japan:** A clear communicated political commitment towards stem cells research; harmonisation of the existing regulatory system with the new conditions of stem cells research and development of stem cell treatments (e.g., the approval procedures of new medications/treatments)	It can be in some ways hard in drafting patent claims for stem cells as they are complex living systems and not describable by a fixed chemical structure like pharmaceuticals, proteins or nucleic acid molecules. This unpredictability of stem cells becomes also a major challenge for patent claims on medical applications.

9 Annex B: Case studies

(provided in separate documents)

9.1 Car Navigation Systems (CNS)

9.2 LED Lighting (LED)

9.3 Linux Operating System (LOS)

9.4 Mobile Phone (MP)

9.5 Super Jumbo Jet (A380)

9.6 Optical Fibres (OF)

9.7 Personalised Medicine (PM)

9.8 Photovoltaic (PV)

9.9 Smart Grids (SG)

9.10 Stem Cell Treatment (SCT)

10 Annex C: Survey results

Table B 1: Completed and partially completed surveys by Major Innovation; absolute figures and percentage in parenthesis Source: JIIP, based on online survey

	Total number of respondents (in %)	Car Navigation Systems	Light-Emitting Diode (Led) Lighting	Linux Operating System	Mobile Phone	Super Jumbo Jet 11	Optical Fibres	Personalised Medicine	Photovoltaic	Smart Grid	Stem Cell Treatment
Fully completed survey	581 (100%)	23 (4.0%)	43 (7.4%)	13 (2.2%)	67 (11.5%)	78 (13.4%)	20 (3.4%)	101 (17.4%)	67 (11.5%)	74 (12.7%)	95 (16.4%)
Partially completed surveys	670 (100%)	26 (3.9%)	39 (5.8%)	10 (1.5%)	90 (13.4%)	186 (27.8%)	13 (1.9%)	96 (14.3%)	55 (8.2%)	60 (9.0%)	95 (14.2%)
All surveys	1251 (100%)	49 (3.9%)	82 (6.6%)	23 (1.8%)	157 (12.5%)	264 (21.1%)	33 (2.6%)	197 (15.7%)	122 (9.8%)	134 (10.7%)	190 (15.2%)

Table B 2: Major Innovations by organisation type; absolute figures and percentage in parenthesis

Source: JIIP, based on online survey

	Total number (in %)	Car Navigation Systems	Light-Emitting Diode (Led) Lighting	Linux Operating System	Mobile Phone	Super Jumbo Jet 11	Optical Fibres	Personalised Medicine	Photovoltaic	Smart Grid	Stem Cell Treatment
Fully completed survey											
Higher educational institute	154 (100%)	3 (1.9%)	4 (2.6%)	3 (1.9%)	19 (12.3%)	20 (13.0%)	8 (5.2%)	34 (22.1%)	18 (11.7%)	13 (8.4%)	32 (20.8%)
Private research organisation	64 (100%)	2 (3.1%)	8 (12.5%)	4 (6.3%)	5 (7.8%)	6 (9.4%)	2 (3.1%)	10 (15.6%)	7 (10.9%)	7 (10.9%)	13 (20.3%)
Industrial company	191 (100%)	9 (4.7%)	21 (11.0%)	2 (1.0%)	24 (12.6%)	35 (18.3%)	5 (2.6%)	24 (12.6%)	24 (12.6%)	31 (16.2%)	16 (8.4%)
Public organisation	81 (100%)	3 (3.7%)	4 (4.9%)	2 (2.5%)	7 (8.6%)	8 (9.9%)	0 (0.0%)	15 (18.5%)	13 (16.0%)	7 (8.6%)	22 (27.2%)
Other organisation	58 (100%)	5 (8.6%)	5 (8.6%)	1 (1.7%)	8 (13.8%)	4 (6.9%)	3 (5.2%)	9 (15.5%)	3 (5.2%)	14 (24.1%)	6 (10.3%)
Total of respondents (%)	548 (100%)	22 (4.0%)	42 (7.7%)	12 (2.2%)	63 (11.5%)	73 (13.3%)	18 (3.3%)	92 (16.8%)	65 (11.9%)	72 (13.1%)	89 (16.2%)
Partially completed surveys											
Higher educational institute	113 (100%)	0 (0.0%)	7 (6.2%)	2 (1.8%)	13 (11.5%)	29 (25.7%)	3 (2.7%)	20 (17.7%)	9 (8.0%)	5 (4.4%)	25 (22.1%)
Private research organisation	42 (100%)	2 (4.8%)	2 (4.8%)	1 (2.4%)	7 (16.7%)	11 (26.2%)	1 (2.4%)	9 (21.4%)	2 (4.8%)	2 (4.8%)	5 (11.9%)
Industrial company	123 (100%)	6 (4.9%)	9 (7.3%)	1 (0.8%)	18 (14.6%)	51 (41.5%)	2 (1.6%)	9 (7.3%)	12 (9.8%)	9 (7.3%)	6 (4.9%)
Public organisation	73 (100%)	5 (6.8%)	6 (8.2%)	1 (1.4%)	10 (13.7%)	12 (16.4%)	1 (1.4%)	12 (16.4%)	2 (2.7%)	9 (12.3%)	15 (20.5%)
Other organisation	46 (100%)	2 (4.3%)	3 (6.5%)	0 (0.0%)	5 (10.9%)	15 (32.6%)	0 (0.0%)	4 (8.7%)	8 (17.4%)	8 (17.4%)	1 (2.2%)
Total of respondents (%)	397 (100%)	15 (3.8%)	27 (6.8%)	5 (1.3%)	53 (13.4%)	118 (29.7%)	7 (1.8%)	54 (13.6%)	33 (8.3%)	33 (8.3%)	52 (13.1%)
All surveys (completed and partially completed)											
Higher educational institute	267 (100%)	3 (1.1%)	11 (4.1%)	5 (1.9%)	32 (12.0%)	49 (18.4%)	11 (4.1%)	54 (20.2%)	27 (10.1%)	18 (6.7%)	57 (21.3%)
Private research organisation	106 (100%)	4 (3.8%)	10 (9.4%)	5 (4.7%)	12 (11.3%)	17 (16.0%)	3 (2.8%)	19 (17.9%)	9 (8.5%)	9 (8.5%)	18 (17.0%)
Industrial company	314 (100%)	15 (4.8%)	30 (9.6%)	3 (1.0%)	42 (13.4%)	86 (27.4%)	7 (2.2%)	33 (10.5%)	36 (11.5%)	40 (12.7%)	22 (7.0%)
Public organisation	154 (100%)	8 (5.2%)	10 (6.5%)	3 (1.9%)	17 (11.0%)	20 (13.0%)	1 (0.6%)	27 (17.5%)	15 (9.7%)	16 (10.4%)	37 (24.0%)
Other organisation	104 (100%)	7 (6.7%)	8 (7.7%)	1 (1.0%)	13 (12.5%)	19 (18.3%)	3 (2.9%)	13 (12.5%)	11 (10.6%)	22 (21.2%)	7 (6.7%)
Total of respondents (%)	945 (100%)	37 (3.9%)	69 (7.3%)	17 (1.8%)	116 (12.3%)	191 (20.2%)	25 (2.6%)	146 (15.4%)	98 (10.4%)	105 (11.1%)	141 (14.9%)

Table B 3: Frequency and importance of FP projects conducted by Major Innovations; absolute figures and percentage in parenthesis

Source: JIIP, based on online survey

	Total number (in %)	Car Navigation Systems	Light-Emitting Diode (Led) Lighting	Linux Operating System	Mobile Phone	New Generation Super Jumbo Jet 11	Optical Fibres	Personalised Medicine	Photovoltaic	Smart Grid	Stem Cell Treatment
	Number of respondents who conducted FP5, FP6, FP7 projects										
Projects conducted in FP5	69 (100%)	10 (14.5%)	2 (2.9%)	3 (4.3%)	35 (50.7%)	6 (8.7%)	4 (5.8%)	1 (1.4%)	5 (7.2%)	2 (2.9%)	1 (1.4%)
Projects conducted in FP6	379 (100%)	8 (2.1%)	24 (6.3%)	12 (3.2%)	73 (19.3%)	99 (26.1%)	8 (2.1%)	34 (9.0%)	34 (9.0%)	24 (6.3%)	63 (16.6%)
Projects conducted in FP7	803 (100%)	31 (3.9%)	56 (7.0%)	8 (1.0%)	49 (6.1%)	159 (19.8%)	21 (2.6%)	162 (20.2%)	83 (10.3%)	108 (13.4%)	126 (15.7%)
Total	1251 (100%)	49 (3.9%)	82 (6.6%)	23 (1.8%)	157 (12.5%)	264 (21.1%)	33 (2.6%)	197 (15.7%)	122 (9.8%)	134 (10.7%)	190 (15.2%)
	Number of respondents who conducted a certain amount of Framework Programme projects										
1 FP project conducted	161 (100%)	3 (1.9%)	22 (13.7%)	3 (1.9%)	15 (9.3%)	30 (18.6%)	3 (1.9%)	29 (18.0%)	19 (11.8%)	9 (5.6%)	28 (17.4%)
2-3 FP project conducted	187 (100%)	10 (5.3%)	12 (6.4%)	3 (1.6%)	19 (10.2%)	27 (14.4%)	9 (4.8%)	32 (17.1%)	15 (8.0%)	32 (17.1%)	28 (15.0%)
4-5 FP project conducted	81 (100%)	4 (4.9%)	4 (4.9%)	1 (1.2%)	10 (12.3%)	7 (8.6%)	4 (4.9%)	9 (11.1%)	13 (16.0%)	16 (19.8%)	13 (16.0%)
5-10 FP project conducted	74 (100%)	3 (4.1%)	1 (1.4%)	1 (1.4%)	11 (14.9%)	9 (12.2%)	3 (4.1%)	15 (20.3%)	11 (14.9%)	13 (17.6%)	7 (9.5%)
>10 FP project conducted	123 (100%)	8 (6.5%)	3 (2.4%)	2 (1.6%)	27 (22.0%)	17 (13.8%)	4 (3.3%)	19 (15.4%)	12 (9.8%)	12 (9.8%)	19 (15.4%)
Total	626 (100%)	28 (4.5%)	42 (6.7%)	10 (1.6%)	82 (13.1%)	90 (14.4%)	23 (3.7%)	104 (16.6%)	70 (11.2%)	82 (13.1%)	95 (15.2%)
	Number of respondents who consider the participation in the FP(s) projects as important in the development of innovations specific to the organisation										
Important	433 (100%)	18 (4.2%)	29 (6.7%)	9 (2.1%)	50 (11.5%)	61 (14.1%)	20 (4.6%)	69 (15.9%)	56 (12.9%)	57 (13.2%)	64 (14.8%)
Not important	127 (100%)	7 (5.5%)	10 (7.9%)	2 (1.6%)	20 (15.7%)	18 (14.2%)	3 (2.4%)	19 (15.0%)	10 (7.9%)	12 (9.4%)	26 (20.5%)
I do not know.	95 (100%)	2 (2.1%)	6 (6.3%)	2 (2.1%)	13 (13.7%)	22 (23.2%)	0 (0.0%)	21 (22.1%)	4 (4.2%)	12 (12.6%)	13 (13.7%)
Total	655 (100%)	27 (4.1%)	45 (6.9%)	13 (2.0%)	83 (12.7%)	101 (15.4%)	23 (3.5%)	109 (16.6%)	70 (10.7%)	81 (12.4%)	103 (15.7%)
	Number of respondents who think that the development of their innovation would not have been possible without the FP funding										
Would have been possible	173 (100%)	4 (2.3%)	14 (8.1%)	2 (1.2%)	28 (16.2%)	25 (14.5%)	6 (3.5%)	25 (14.5%)	18 (10.4%)	23 (13.3%)	28 (16.2%)
Would not have been possible	312 (100%)	14 (4.5%)	17 (5.4%)	8 (2.6%)	29 (9.3%)	46 (14.7%)	10 (3.2%)	58 (18.6%)	38 (12.2%)	38 (12.2%)	54 (17.3%)
Total	485 (100%)	18 (3.7%)	31 (6.4%)	10 (2.1%)	57 (11.8%)	71 (14.6%)	16 (3.3%)	83 (17.1%)	56 (11.5%)	61 (12.6%)	82 (16.9%)

Table B 4: Evident and potential impact of Major Innovations; arithmetic mean (0=disagree; 100=strongly agree) and number of respondents in parenthesis

Source: JIIP, based on online survey

	Evident impact			
	R&D Impact	Economic Impact	Societal Impact	Environmental Impact
Car Navigation Systems	65.62 (34)	63.56 (34)	61.73 (33)	56.45 (33)
Light-Emitting Diode (Led) Lighting	65.48 (65)	70.81 (63)	61.45 (62)	71.16 (61)
Linux Operating System	70.81 (16)	70.06 (16)	54.56 (16)	37.25 (12)
Mobile Phone	73.7 (115)	79.09 (113)	87.79 (110)	49 (109)
Super Jumbo Jet 11	60.8 (135)	62.65 (126)	49.78 (121)	55.48 (123)
Optical Fibres	80.69 (29)	82.88 (26)	87.41 (27)	67.3 (27)
Personalised Medicine	71.34 (141)	61.16 (131)	65.99 (135)	41.22 (120)
Photovoltaic	68.72 (92)	68.23 (92)	68.18 (90)	74.51 (91)
Smart Grid	68.72 (101)	61.23 (95)	55.45 (94)	64.67 (95)
Stem Cell Treatment	68.75 (146)	53.39 (135)	62.31 (134)	38.29 (125)
Arithmetic mean (total number)	68.65 (874)	65.03 (831)	64.92 (822)	54.38 (796)
	Potential impact			
Car Navigation Systems	75.5 (30)	72.33 (30)	75.65 (31)	75.27 (30)
Light-Emitting Diode (Led) Lighting	71.16 (55)	80.22 (54)	70.84 (55)	78.48 (54)
Linux Operating System	66.75 (16)	81.57 (14)	54.14 (14)	50.08 (12)
Mobile Phone	78.66 (102)	81.37 (101)	86.08 (101)	64.64 (100)
Super Jumbo Jet 11	70.87 (130)	69.51 (124)	55.76 (123)	62.46 (124)
Optical Fibres	82.59 (27)	85.58 (26)	86.64 (25)	78.19 (26)
Personalised Medicine	80.27 (128)	77.87 (124)	82.73 (123)	52.03 (117)
Photovoltaic	77.6 (83)	83.06 (85)	82.46 (84)	85.92 (83)
Smart Grid	77.48 (88)	79.43 (88)	73.1 (89)	79.52 (87)
Stem Cell Treatment	78.85 (130)	70.11 (128)	77.88 (127)	44.88 (120)
Arithmetic mean (total number)	76.68 (789)	76.73 (774)	75.41 (772)	64.89 (753)

Table B 5: Relevant R&D conditions for the development of Major Innovations; arithmetic mean (0=not relevant; 100=highly relevant) and number of respondents in parenthesis

Source: JIIP, based on online survey

	R&D conditions				
	Implementation of technological novelty	Combination (convergence) of several technologies	Interdisciplinary cooperation	Ability of the innovation to be applied across different market segments	Joint creation of knowledge through cooperation with specific partners
Car Navigation Systems	72,72 (32)	80,44 (32)	74,97 (32)	68,19 (31)	71,38 (32)
Light-Emitting Diode (Led) Ligh	71,75 (59)	67,24 (58)	66,44 (59)	71,28 (57)	70,09 (54)
Linux Operating System	75,86 (14)	65,5 (12)	50,85 (13)	61 (13)	64,23 (13)
Mobile Phone	81,5 (105)	79,75 (102)	68,88 (101)	72,86 (102)	72,27 (99)
Super Jumbo Jet 11	74,89 (119)	79,38 (121)	77,38 (120)	64,66 (112)	73,33 (119)
Optical Fibres	80,17 (24)	72,08 (24)	75,83 (24)	68 (23)	75,55 (22)
Personalised Medicine	79,75 (135)	79,68 (135)	84,6 (135)	65,7 (132)	81,04 (134)
Photovoltaic	78,15 (84)	76,57 (84)	76,56 (84)	69,84 (83)	83,78 (83)
Smart Grid	73,56 (95)	82,87 (94)	82,05 (94)	75,57 (93)	80,58 (92)
Stem Cell Treatment	82,31 (138)	82,69 (138)	84,59 (138)	67,81 (134)	81,58 (134)
Arithmetic mean (total number)	77,88 (805)	78,9 (800)	77,85 (800)	68,96 (780)	77,5 (782)

Table B 6: Relevant public support conditions for the development of Major Innovations; arithmetic mean (0=not relevant; 100=highly relevant) and number of respondents in parenthesis

Source: JIIP, based on online survey

	Public support conditions					
	Public R&D funding for basic research (science)	Public R&D funding for applied research and development	Other public financial instruments (soft loans. tax incentives)	Seed money (e.g. business angels etc.) for start-ups	Venture capital and private investment	Banks loans / credits
Car Navigation Systems	67.65 (31)	80.94 (31)	58.5 (30)	61.17 (29)	60.41 (29)	56.43 (30)
Light-Emitting Diode (Led) Ligh	68.4 (58)	70.76 (59)	55.59 (54)	55.5 (54)	57.19 (54)	49.87 (53)
Linux Operating System	59.58 (12)	67.67 (12)	50.55 (11)	58.64 (11)	54.73 (11)	34.11 (9)
Mobile Phone	62.95 (100)	73.95 (99)	53.26 (95)	61.77 (96)	68.37 (95)	52.92 (92)
Super Jumbo Jet 11	64.27 (116)	74.61 (117)	57.79 (112)	49.65 (109)	53.01 (105)	55.39 (103)
Optical Fibres	79 (24)	83.04 (24)	63.42 (24)	72.21 (24)	69.46 (24)	48.48 (23)
Personalised Medicine	78.73 (132)	83.11 (132)	60.91 (126)	69.26 (126)	69.61 (126)	48.37 (123)
Photovoltaic	79.09 (79)	84.47 (79)	68.62 (78)	68.32 (78)	71.81 (78)	62.27 (73)
Smart Grid	65.02 (93)	76.65 (93)	65.43 (94)	63 (91)	66.62 (91)	59.6 (85)
Stem Cell Treatment	85.29 (133)	83.58 (133)	65.2 (127)	69.8 (132)	67.62 (133)	46.05 (128)
Arithmetic mean (total number)	72.57 (778)	78.85 (779)	61.02 (751)	63.33 (750)	65.14 (746)	52.56 (719)

Table B 7: Relevant market conditions for the development of the Major Innovations; arithmetic mean (0=not relevant; 100=highly relevant) and number of respondents in parenthesis

Source: JIIP, based on online survey

	Market conditions							
	Opportunity to open up a new market / introduce a novelty on an existing market	Changes in end user behavior	Strong public demand	Strong private demand	Existing regulatory and legal environment	Existing standards (e.g. procedures, guidelines, protocols etc.)	Industrial structural change (creation of industries/ disappearance of others)	Development of a complete eco system (e.g. suppliers, consumers, regulatory bodies, private persons, etc.)
Car Navigation Systems	69.32 (31)	69.45 (31)	59.26 (31)	66.77 (31)	67.47 (30)	69.84 (31)	59.3 (30)	60.87 (30)
Light-Emitting Diode (Led) Ligh	71.67 (55)	64.14 (58)	64.72 (57)	64.38 (58)	62.67 (55)	50.67 (52)	61.91 (55)	62.52 (56)
Linux Operating System	72.08 (13)	55.83 (12)	35.92 (13)	49.92 (13)	35.7 (10)	52.67 (12)	53.73 (11)	51.75 (12)
Mobile Phone	83.44 (99)	84.15 (99)	62.38 (100)	75.95 (100)	60.66 (100)	67.78 (99)	69.81 (97)	73.97 (98)
Super Jumbo Jet 11	62.09 (113)	53.75 (112)	49.09 (111)	57.93 (110)	60.9 (108)	58.01 (110)	53.58 (109)	58.58 (107)
Optical Fibres	76.13 (24)	59.79 (24)	66.65 (23)	70.23 (22)	50.86 (22)	55.43 (23)	60 (24)	69.08 (24)
Personalised Medicine	74.92 (131)	75.69 (131)	72.03 (132)	66.77 (127)	65.04 (127)	65.7 (130)	59.58 (127)	65.67 (124)
Photovoltaic	77.62 (78)	66.9 (78)	71.38 (80)	71.15 (79)	73.98 (80)	66.92 (78)	72.65 (77)	75.13 (80)
Smart Grid	74.16 (95)	74.42 (93)	64.51 (93)	62.44 (93)	75.33 (93)	70.87 (93)	60.61 (90)	71.17 (92)
Stem Cell Treatment	71.14 (133)	61.21 (131)	70.96 (133)	61.44 (133)	71.45 (133)	69.41 (132)	64.41 (131)	61.81 (129)
Arithmetic mean (total number)	73.2 (772)	68.14 (769)	64.51 (773)	65.33 (766)	66.33 (758)	64.88 (760)	62.42 (751)	66.22 (752)

Table B 8: Most current innovation hubs of Major Innovations; absolute figures and percentage in parenthesis

Source: JIIP, based on online survey

	Most current innovation hubs												
	Total number (in%)	EU 28	Other European countries	USA/Canada	Other North American countries	Australia	South America	China	India	Japan	South Korea	Rest of Asia Pacific	Russia	Middle East
Car Navigation Systems	31 (100%)	21 (67.7%)	0 (0.0%)	5 (16.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (12.9%)	1 (3.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Light-Emitting Diode (Led) Lighting	53 (100%)	24 (45.3%)	1 (1.9%)	9 (17.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (3.8%)	0 (0.0%)	13 (24.5%)	4 (7.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Linux Operating System	13 (100%)	8 (61.5%)	0 (0.0%)	4 (30.8%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (7.7%)	0 (0.0%)
Mobile Phone	97 (100%)	27 (27.8%)	1 (1.0%)	45 (46.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	8 (8.2%)	0 (0.0%)	2 (2.1%)	14 (14.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Super Jumbo Jet 11	113 (100%)	78 (69.0%)	2 (1.8%)	20 (17.7%)	0 (0.0%)	1 (0.9%)	0 (0.0%)	8 (7.1%)	0 (0.0%)	2 (1.8%)	2 (1.8%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Optical Fibres	24 (100%)	8 (33.3%)	1 (4.2%)	9 (37.5%)	0 (0.0%)	1 (4.2%)	0 (0.0%)	3 (12.5%)	0 (0.0%)	0 (0.0%)	2 (8.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Personalised Medicine	128 (100%)	47 (36.7%)	0 (0.0%)	76 (59.4%)	0 (0.0%)	1 (0.8%)	0 (0.0%)	2 (1.6%)	0 (0.0%)	0 (0.0%)	2 (1.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Photovoltaic	78 (100%)	50 (64.1%)	0 (0.0%)	14 (17.9%)	0 (0.0%)	2 (2.6%)	1 (1.3%)	6 (7.7%)	1 (1.3%)	3 (3.8%)	1 (1.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Smart Grid	91 (100%)	53 (58.2%)	0 (0.0%)	30 (33.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (4.4%)	0 (0.0%)	1 (1.1%)	2 (2.2%)	0 (0.0%)	0 (0.0%)	1 (1.1%)
Stem Cell Treatment	132 (100%)	31 (23.5%)	0 (0.0%)	80 (60.6%)	1 (0.8%)	1 (0.8%)	0 (0.0%)	4 (3.0%)	0 (0.0%)	13 (9.8%)	1 (0.8%)	1 (0.8%)	0 (0.0%)	0 (0.0%)
Total	760 (100%)	347 (45.7%)	5 (0.7%)	292 (38.4%)	1 (0.1%)	6 (0.8%)	1 (0.1%)	37 (4.9%)	1 (0.1%)	38 (5.0%)	29 (3.8%)	1 (0.1%)	1 (0.1%)	1 (0.1%)

Table B 9: Most current production places of Major Innovations; absolute figures and percentage in parenthesis

Source: JIIP, based on online survey

	Most current production places									
	Total number (in%)	EU 28	Other European countries	USA/Canada	Other North American countries	Australia	China	India	Japan	South Korea	Rest of Asia Pacific
Car Navigation Systems	27 (100,0%)	11 (40.7%)	0 (0.0%)	5 (18.5%)	0 (0.0%)	0 (0.0%)	7 (25.9%)	0 (0.0%)	3 (11.1%)	1 (3.7%)	0 (0.0%)
Light-Emitting Diode (Led) Lighting	51 (100,0%)	6 (11.8%)	1 (2.0%)	1 (2.0%)	0 (0.0%)	0 (0.0%)	30 (58.8%)	0 (0.0%)	7 (13.7%)	4 (7.8%)	2 (3.9%)
Linux Operating System	13 (100,0%)	6 (46.2%)	0 (0.0%)	7 (53.8%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Mobile Phone	96 (100,0%)	3 (3.1%)	0 (0.0%)	12 (12.5%)	0 (0.0%)	0 (0.0%)	65 (67.7%)	0 (0.0%)	0 (0.0%)	15 (15.6%)	1 (1.0%)
Super Jumbo Jet 11	108 (100,0%)	80 (74.1%)	3 (2.8%)	15 (13.9%)	0 (0.0%)	0 (0.0%)	8 (7.4%)	0 (0.0%)	1 (0.9%)	1 (0.9%)	0 (0.0%)
Optical Fibres	24 (100,0%)	6 (25.0%)	0 (0.0%)	7 (29.2%)	0 (0.0%)	0 (0.0%)	11 (45.8%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Personalised Medicine	120 (100,0%)	33 (27.5%)	0 (0.0%)	72 (60.0%)	0 (0.0%)	1 (0.8%)	11 (9.2%)	0 (0.0%)	1 (0.8%)	2 (1.7%)	0 (0.0%)
Photovoltaic	78 (100,0%)	8 (10.3%)	0 (0.0%)	3 (3.8%)	0 (0.0%)	0 (0.0%)	64 (82.1%)	1 (1.3%)	2 (2.6%)	0 (0.0%)	0 (0.0%)
Smart Grid	88 (100,0%)	28 (31.8%)	0 (0.0%)	35 (39.8%)	0 (0.0%)	1 (1.1%)	19 (21.6%)	0 (0.0%)	1 (1.1%)	3 (3.4%)	1 (1.1%)
Stem Cell Treatment	125 (100,0%)	23 (18.4%)	0 (0.0%)	76 (60.8%)	1 (0.8%)	0 (0.0%)	12 (9.6%)	0 (0.0%)	9 (7.2%)	2 (1.6%)	2 (1.6%)
Total	730 (100,0%)	204 (27.9%)	4 (0.5%)	233 (31.9%)	1 (0.1%)	2 (0.3%)	227 (31.1%)	1 (0.1%)	24 (3.3%)	28 (3.8%)	6 (0.8%)

Table B 10: Most current markets of Major Innovations; absolute figures and percentage in parenthesis

Source: JIIP, based on online survey

	Most current markets														
	Total number (in%)	EU 28	Other European countries	USA/Canada	Other North American countries	Australia	South America	China	India	Japan	South Korea	Rest of Asia Pacific	Russia	Middle East	Africa
Car Navigation Systems	733 (100,0%)	16 (59.6%)	0 (1.9%)	9 (17.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (17.3%)	0 (0.0%)	1 (1.9%)	1 (0.0%)	0 (0.0%)	2 (0.0%)	18 (0.0%)	1 (0.0%)
Light-Emitting Diode (Led) Lighting	29 (100,0%)	31 (41.7%)	1 (0.0%)	9 (50.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	9 (8.3%)	0 (0.0%)	1 (0.0%)	0 (0.0%)	0 (0.0%)	0 (1.9%)	0 (0.0%)	0 (0.0%)
Linux Operating System	52 (100,0%)	5 (19.6%)	0 (0.0%)	6 (33.0%)	0 (1.0%)	0 (0.0%)	0 (0.0%)	1 (43.3%)	0 (2.1%)	0 (0.0%)	0 (0.0%)	0 (1.0%)	1 (0.0%)	0 (0.0%)	0 (0.0%)
Mobile Phone	12 (100,0%)	19 (28.7%)	0 (0.0%)	32 (16.7%)	1 (0.0%)	0 (3.7%)	0 (0.0%)	42 (25.0%)	2 (0.9%)	0 (0.0%)	0 (0.0%)	1 (8.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Super Jumbo Jet 11	97 (100,0%)	31 (12.5%)	0 (0.0%)	18 (37.5%)	0 (0.0%)	4 (0.0%)	0 (0.0%)	27 (41.7%)	1 (0.0%)	0 (0.0%)	0 (4.2%)	9 (4.2%)	0 (0.9%)	0 (14.8%)	0 (0.9%)
Optical Fibres	108 (100,0%)	3 (28.5%)	0 (0.8%)	9 (66.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	10 (4.1%)	0 (0.0%)	0 (0.0%)	1 (0.0%)	1 (0.0%)	1 (0.0%)	16 (0.0%)	1 (0.0%)
Personalised Medicine	24 (100,0%)	35 (46.2%)	1 (1.3%)	82 (7.7%)	0 (0.0%)	0 (0.0%)	0 (1.3%)	5 (39.7%)	0 (1.3%)	0 (1.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Photovoltaic	123 (100,0%)	36 (43.8%)	1 (0.0%)	6 (36.0%)	0 (0.0%)	0 (0.0%)	1 (0.0%)	31 (13.5%)	1 (1.1%)	1 (3.4%)	0 (0.0%)	0 (1.1%)	0 (0.0%)	0 (1.3%)	0 (0.0%)
Smart Grid	78 (100,0%)	39 (19.8%)	0 (0.8%)	32 (65.3%)	0 (0.0%)	0 (0.0%)	0 (1.7%)	12 (9.9%)	1 (0.8%)	3 (0.8%)	0 (0.0%)	1 (0.8%)	0 (0.0%)	1 (1.1%)	0 (0.0%)
Stem Cell Treatment	89 (100,0%)	24 (32.6%)	1 (0.5%)	79 (38.5%)	0 (0.1%)	0 (0.5%)	2 (0.4%)	12 (20.6%)	1 (0.8%)	1 (1.0%)	0 (0.3%)	1 (1.8%)	0 (0.0%)	1 (0.0%)	0 (0.0%)
Total	121 (100,0%)	239 (55.2%)	4 (0.0%)	282 (31.0%)	1 (0.0%)	4 (0.0%)	3 (0.0%)	151 (6.9%)	6 (0.0%)	7 (3.4%)	2 (3.4%)	13 (0.0%)	0 (0.3%)	0 (2.5%)	0 (0.1%)

Table B 11: Most important funding schemes of Major Innovations; arithmetic mean (0=not important; 100=very important) and number of respondents in parenthesis

Source: JIIP, based on online survey

	Regional and national RTDI funding	Funding of large scale infrastructures	European research framework programme (FP 1.2.3.4.5.6.7) funding	Other international RTDI funding (ESA etc.)	Other European funding sources (e.g. structural fund. cohesion fund. etc)	Other funding
Car Navigation Systems	72.48 (31)	71.42 (31)	84.74 (31)	61.47 (30)	58.24 (29)	
Light-Emitting Diode (Led) Lighting	70.63 (52)	63.1 (49)	73.14 (51)	49.53 (45)	47.07 (43)	35.6 (5)
Linux Operating System	59.69 (13)	61.15 (13)	76.67 (12)	62.17 (12)	53.8 (10)	
Mobile Phone	58.84 (96)	65.74 (95)	69.58 (95)	51.48 (90)	47.2 (89)	85.83 (6)
New Generation Super Jumbo Jet 11	64.21 (107)	68.24 (107)	75.41 (107)	57.87 (101)	55.53 (101)	48.7 (10)
Optical Fibres	75.67 (24)	65.83 (23)	76 (24)	45.7 (23)	37.04 (24)	33.75 (4)
Personalised Medicine	77.67 (126)	71.15 (125)	87.54 (125)	67.33 (116)	65.83 (118)	57.86 (14)
Photovoltaic	81.35 (78)	66.58 (76)	88.1 (77)	63.58 (73)	64.46 (74)	28.71 (7)
Smart Grid	76.94 (89)	74.06 (89)	83.15 (89)	62.72 (87)	70.03 (88)	31.8 (5)
Stem Cell Treatment	82.21 (131)	71.02 (132)	87.92 (133)	71.18 (119)	69.4 (121)	59.46 (13)
Total	73.33 (747)	69.03 (740)	81.45 (744)	61.39 (696)	60.33 (697)	48.58 (67)

Table B 12: The role of innovations conducted by respondents' organisations on the development of the Major Innovations; arithmetic mean (0=disagree; 100=strongly agree) and number of respondents in parenthesis

Source: JIIP, based on online survey

	It has a core role.	It has a supportive role.	It features a stand-alone character.	It is different from other innovations in the major innovation family
Car Navigation Syst	68.74 (19)	74 (16)	43.47 (15)	51.33 (3)
Light-Emitting Diode	59.74 (34)	66 (34)	49.83 (30)	32.75 (4)
Linux Operating Sys	49.44 (9)	55.38 (8)	48.43 (7)	93.33 (3)
Mobile Phone	49.16 (62)	59.33 (58)	44.63 (48)	41.18 (11)
New Generation Sup	62.35 (62)	66.03 (60)	45.69 (55)	66.69 (13)
Optical Fibres	84.28 (18)	50.65 (17)	51.56 (18)	26 (3)
Personalised Medic	74.13 (82)	68 (72)	46.78 (65)	69.35 (17)
Photovoltaic	63.53 (62)	66.5 (56)	50.12 (51)	60.67 (15)
Smart Grid	73.37 (68)	66.75 (55)	43.27 (52)	35.67 (18)
Stem Cell Treatmen	68.06 (78)	60.69 (67)	45.33 (60)	58.77 (22)
Total	65.85 (494)	64.32 (443)	46.47 (401)	54.93 (109)

Table B 13: Funding schemes used for the development of stand-alone, core and supportive innovations conducted by the respondents' organisations in the fields of Major Innovations; absolute figures and percentage in parenthesis

Source: JIIP, based on online survey

	Total number incl. double counts (in%)	Regional and national RTDI funding	EU Framework Programme (FP 5, FP 6, FP 7)	Other European funding sources (e.g. structural fund, cohesion fund, etc)	Other international RTDI funding (ESA etc.)	Other funding	No subsidies were used.
Car Navigation Systems	22 (100%)	6 (2727.3%)	15 (6818.2%)	0 (0.0%)	1 (454.5%)	0 (0.0%)	0 (0.0%)
Light-Emitting Diode (Led) Ligh	61 (100%)	20 (3278.7%)	31 (5082.0%)	2 (327.9%)	2 (327.9%)	5 (819.7%)	1 (163.9%)
Linux Operating System	7 (100%)	1 (1428.6%)	5 (7142.9%)	0 (0.0%)	0 (0.0%)	1 (1428.6%)	0 (0.0%)
Mobile Phone	86 (100%)	19 (2209.3%)	45 (5232.6%)	4 (465.1%)	4 (465.1%)	12 (1395.3%)	2 (232.6%)
New Generation Super Jumbo	111 (100%)	29 (2612.6%)	57 (5135.1%)	4 (360.4%)	9 (810.8%)	7 (630.6%)	5 (450.5%)
Optical Fibres	33 (100%)	9 (2727.3%)	16 (4848.5%)	3 (909.1%)	2 (606.1%)	3 (909.1%)	0 (0.0%)
Personalised Medicine	150 (100%)	43 (2866.7%)	69 (4600.0%)	8 (533.3%)	4 (266.7%)	24 (1600.0%)	2 (133.3%)
Photovoltaic	93 (100%)	34 (3655.9%)	44 (4731.2%)	0 (0.0%)	2 (215.1%)	9 (967.7%)	4 (430.1%)
Smart Grid	101 (100%)	31 (3069.3%)	52 (5148.5%)	8 (792.1%)	1 (99.0%)	7 (693.1%)	2 (198.0%)
Stem Cell Treatment	137 (100%)	48 (3503.6%)	59 (4306.6%)	11 (802.9%)	3 (219.0%)	14 (1021.9%)	2 (146.0%)
Total	801 (100%)	240 (2996.3%)	393 (4906.4%)	40 (499.4%)	28 (349.6%)	82 (1023.7%)	18 (224.7%)

Table B 14: Funding schemes for the development of stand-alone, core and supportive innovations conducted by the respondents' organisations in the fields of Major Innovations; absolute figures and percentage in parenthesis

Source: JIIP, based on online survey

	Total number incl. double counts (in%)	Regional and national RTDI funding	EU Framework Programme (FP 5, FP 6, FP 7)	Other European funding sources (e.g. structural fund, cohesion fund, etc)	Other international RTDI funding (ESA etc.)	Other funding	No subsidies were used.
Higher educational institute							
Car Navigation Systems	1 (100%)	0 (0.0%)	1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Light-Emitting Diode (Led) Ligh	12 (100%)	4 (33.3%)	5 (41.7%)	1 (8.3%)	0 (0.0%)	2 (16.7%)	0 (0.0%)
Linux Operating System	1 (100%)	0 (0.0%)	1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Mobile Phone	25 (100%)	7 (28.0%)	11 (44.0%)	2 (8.0%)	0 (0.0%)	5 (20.0%)	0 (0.0%)
New Generation Super Jumbo	32 (100%)	8 (25.0%)	17 (53.1%)	2 (6.3%)	2 (6.3%)	1 (3.1%)	2 (6.3%)
Optical Fibres	12 (100%)	4 (33.3%)	6 (50.0%)	0 (0.0%)	0 (0.0%)	2 (16.7%)	0 (0.0%)
Personalised Medicine	63 (100%)	18 (28.6%)	27 (42.9%)	6 (9.5%)	2 (3.2%)	10 (15.9%)	0 (0.0%)
Photovoltaic	21 (100%)	8 (38.1%)	12 (57.1%)	0 (0.0%)	1 (4.8%)	0 (0.0%)	0 (0.0%)
Smart Grid	25 (100%)	11 (44.0%)	11 (44.0%)	2 (8.0%)	1 (4.0%)	0 (0.0%)	0 (0.0%)
Stem Cell Treatment	52 (100%)	19 (36.5%)	21 (40.4%)	4 (7.7%)	1 (1.9%)	5 (9.6%)	2 (3.8%)
Total	244 (100%)	79 (32.4%)	112 (45.9%)	17 (7.0%)	7 (2.9%)	25 (10.2%)	4 (1.6%)
Private research organisation							
Car Navigation Systems	5 (100%)	2 (40.0%)	2 (40.0%)	0 (0.0%)	1 (20.0%)	0 (0.0%)	0 (0.0%)
Light-Emitting Diode (Led) Ligh	4 (100%)	1 (25.0%)	3 (75.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Linux Operating System	4 (100%)	1 (25.0%)	2 (50.0%)	0 (0.0%)	0 (0.0%)	1 (25.0%)	0 (0.0%)
Mobile Phone	7 (100%)	2 (28.6%)	4 (57.1%)	0 (0.0%)	0 (0.0%)	1 (14.3%)	0 (0.0%)
New Generation Super Jumbo	12 (100%)	3 (25.0%)	3 (25.0%)	2 (16.7%)	2 (16.7%)	2 (16.7%)	0 (0.0%)
Optical Fibres	5 (100%)	1 (20.0%)	3 (60.0%)	1 (20.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Personalised Medicine	12 (100%)	2 (16.7%)	7 (58.3%)	0 (0.0%)	0 (0.0%)	3 (25.0%)	0 (0.0%)
Photovoltaic	12 (100%)	4 (33.3%)	6 (50.0%)	0 (0.0%)	0 (0.0%)	2 (16.7%)	0 (0.0%)
Smart Grid	11 (100%)	3 (27.3%)	5 (45.5%)	2 (18.2%)	0 (0.0%)	1 (9.1%)	0 (0.0%)
Stem Cell Treatment	12 (100%)	3 (25.0%)	7 (58.3%)	0 (0.0%)	0 (0.0%)	2 (16.7%)	0 (0.0%)
Total	84 (100%)	22 (26.2%)	42 (50.0%)	5 (6.0%)	3 (3.6%)	12 (14.3%)	0 (0.0%)
Industrial company							
Car Navigation Systems	9 (100%)	2 (22.2%)	7 (77.8%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Light-Emitting Diode (Led) Ligh	28 (100%)	8 (28.6%)	15 (53.6%)	1 (3.6%)	1 (3.6%)	2 (7.1%)	1 (3.6%)
Linux Operating System	1 (100%)	0 (0.0%)	1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Mobile Phone	32 (100%)	6 (18.8%)	18 (56.3%)	0 (0.0%)	2 (6.3%)	4 (12.5%)	2 (6.3%)
New Generation Super Jumbo	46 (100%)	12 (26.1%)	24 (52.2%)	0 (0.0%)	4 (8.7%)	4 (8.7%)	2 (4.3%)
Optical Fibres	6 (100%)	2 (33.3%)	3 (50.0%)	1 (16.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Personalised Medicine	26 (100%)	7 (26.9%)	15 (57.7%)	1 (3.8%)	0 (0.0%)	2 (7.7%)	1 (3.8%)
Photovoltaic	33 (100%)	11 (33.3%)	15 (45.5%)	0 (0.0%)	0 (0.0%)	3 (9.1%)	4 (12.1%)
Smart Grid	42 (100%)	10 (23.8%)	23 (54.8%)	3 (7.1%)	0 (0.0%)	5 (11.9%)	1 (2.4%)
Stem Cell Treatment	20 (100%)	8 (40.0%)	10 (50.0%)	1 (5.0%)	0 (0.0%)	1 (5.0%)	0 (0.0%)
Total	243 (100%)	66 (27.2%)	131 (53.9%)	7 (2.9%)	7 (2.9%)	21 (8.6%)	11 (4.5%)
Public organisation							
Car Navigation Systems	5 (100%)	2 (40.0%)	3 (60.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Light-Emitting Diode (Led) Ligh	7 (100%)	3 (42.9%)	4 (57.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Linux Operating System	1 (100%)	0 (0.0%)	1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Mobile Phone	7 (100%)	1 (14.3%)	3 (42.9%)	1 (14.3%)	0 (0.0%)	2 (28.6%)	0 (0.0%)
New Generation Super Jumbo	9 (100%)	3 (33.3%)	5 (55.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (11.1%)
Optical Fibres	0 (0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Personalised Medicine	19 (100%)	8 (42.1%)	6 (31.6%)	0 (0.0%)	1 (5.3%)	4 (21.1%)	0 (0.0%)
Photovoltaic	18 (100%)	8 (44.4%)	7 (38.9%)	0 (0.0%)	1 (5.6%)	2 (11.1%)	0 (0.0%)
Smart Grid	7 (100%)	2 (28.6%)	3 (42.9%)	1 (14.3%)	0 (0.0%)	0 (0.0%)	1 (14.3%)
Stem Cell Treatment	35 (100%)	14 (40.0%)	12 (34.3%)	4 (11.4%)	1 (2.9%)	4 (11.4%)	0 (0.0%)
Total	108 (100%)	41 (38.0%)	44 (40.7%)	6 (5.6%)	3 (2.8%)	12 (11.1%)	2 (1.9%)

Table B 15: Preferred partners regarding the development of the stand-alone, core and supportive innovations conducted by the respondents' organisations in the field of Major Innovations; absolute figures and percentage in parenthesis

Source: JIIP, based on online survey

	Total number incl. double counts (in%)	Other firms belonging to the same firm group	Customers/clients	Consultants	Suppliers	Universities	Research institutes	Competing companies/organisations	Other
Domestic partners									
Car Navigation Systems	14 (100%)	1 (7.1%)	4 (28.6%)	0 (0.0%)	3 (21.4%)	2 (14.3%)	2 (14.3%)	2 (14.3%)	0 (0.0%)
Light-Emitting Diode (Led) Ligh	49 (100%)	5 (35.7%)	10 (71.4%)	4 (28.6%)	6 (42.9%)	10 (71.4%)	10 (71.4%)	4 (28.6%)	0 (0.0%)
Linux Operating System	10 (100%)	0 (0.0%)	2 (14.3%)	2 (14.3%)	0 (0.0%)	3 (21.4%)	3 (21.4%)	0 (0.0%)	0 (0.0%)
Mobile Phone	62 (100%)	6 (42.9%)	13 (92.9%)	5 (35.7%)	5 (35.7%)	15 (107.1%)	13 (92.9%)	4 (28.6%)	1 (7.1%)
New Generation Super Jumbo	76 (100%)	10 (71.4%)	13 (92.9%)	5 (35.7%)	9 (64.3%)	18 (128.6%)	14 (100.0%)	7 (50.0%)	0 (0.0%)
Optical Fibres	19 (100%)	3 (21.4%)	2 (14.3%)	2 (14.3%)	3 (21.4%)	6 (42.9%)	2 (14.3%)	1 (7.1%)	0 (0.0%)
Personalised Medicine	147 (100%)	10 (71.4%)	20 (142.9%)	10 (71.4%)	15 (107.1%)	43 (307.1%)	35 (250.0%)	9 (64.3%)	5 (35.7%)
Photovoltaic	104 (100%)	14 (100.0%)	17 (121.4%)	5 (35.7%)	12 (85.7%)	21 (150.0%)	25 (178.6%)	10 (71.4%)	0 (0.0%)
Smart Grid	134 (100%)	17 (121.4%)	27 (192.9%)	13 (92.9%)	15 (107.1%)	27 (192.9%)	25 (178.6%)	9 (64.3%)	1 (7.1%)
Stem Cell Treatment	113 (100%)	11 (78.6%)	8 (57.1%)	8 (57.1%)	7 (50.0%)	37 (264.3%)	34 (242.9%)	5 (35.7%)	3 (21.4%)
Total number incl. double counts (in%)	728 (100%)	77 (550.0%)	116 (828.6%)	54 (385.7%)	75 (535.7%)	182 (1300.0%)	163 (1164.3%)	51 (364.3%)	10 (71.4%)
European partners									
Car Navigation Systems	51 (100%)	3 (5.9%)	10 (19.6%)	3 (5.9%)	8 (15.7%)	10 (19.6%)	11 (21.6%)	6 (11.8%)	0 (0.0%)
Light-Emitting Diode (Led) Ligh	126 (100%)	18 (35.3%)	20 (39.2%)	6 (11.8%)	17 (33.3%)	28 (54.9%)	26 (51.0%)	11 (21.6%)	0 (0.0%)
Linux Operating System	13 (100%)	1 (2.0%)	1 (2.0%)	1 (2.0%)	1 (2.0%)	4 (7.8%)	3 (5.9%)	2 (3.9%)	0 (0.0%)
Mobile Phone	159 (100%)	19 (37.3%)	18 (35.3%)	11 (21.6%)	17 (33.3%)	38 (74.5%)	36 (70.6%)	19 (37.3%)	1 (2.0%)
New Generation Super Jumbo	190 (100%)	14 (27.5%)	26 (51.0%)	8 (15.7%)	30 (58.8%)	40 (78.4%)	43 (84.3%)	28 (54.9%)	1 (2.0%)
Optical Fibres	55 (100%)	5 (9.8%)	6 (11.8%)	2 (3.9%)	9 (17.6%)	15 (29.4%)	12 (23.5%)	6 (11.8%)	0 (0.0%)
Personalised Medicine	218 (100%)	25 (49.0%)	22 (43.1%)	10 (19.6%)	18 (35.3%)	65 (127.5%)	52 (102.0%)	21 (41.2%)	5 (9.8%)
Photovoltaic	162 (100%)	15 (29.4%)	19 (37.3%)	3 (5.9%)	21 (41.2%)	39 (76.5%)	43 (84.3%)	21 (41.2%)	1 (2.0%)
Smart Grid	174 (100%)	15 (29.4%)	23 (45.1%)	22 (43.1%)	23 (45.1%)	35 (68.6%)	30 (58.8%)	22 (43.1%)	4 (7.8%)
Stem Cell Treatment	133 (100%)	7 (13.7%)	11 (21.6%)	5 (9.8%)	15 (29.4%)	41 (80.4%)	42 (82.4%)	8 (15.7%)	4 (7.8%)
Total number incl. double counts (in%)	1281 (100%)	122 (239.2%)	156 (305.9%)	71 (139.2%)	159 (311.8%)	315 (617.6%)	298 (584.3%)	144 (282.4%)	16 (31.4%)
Non-European partners									
Car Navigation Systems	2 (100%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (50.0%)	0 (0.0%)	1 (50.0%)	0 (0.0%)
Light-Emitting Diode (Led) Ligh	23 (100%)	6 (300.0%)	2 (100.0%)	0 (0.0%)	10 (500.0%)	1 (50.0%)	2 (100.0%)	2 (100.0%)	0 (0.0%)
Linux Operating System	3 (100%)	0 (0.0%)	1 (50.0%)	1 (50.0%)	0 (0.0%)	1 (50.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Mobile Phone	40 (100%)	7 (350.0%)	7 (350.0%)	2 (100.0%)	4 (200.0%)	9 (450.0%)	6 (300.0%)	5 (250.0%)	0 (0.0%)
New Generation Super Jumbo	28 (100%)	4 (200.0%)	5 (250.0%)	0 (0.0%)	6 (300.0%)	3 (150.0%)	5 (250.0%)	5 (250.0%)	0 (0.0%)
Optical Fibres	13 (100%)	1 (50.0%)	1 (50.0%)	0 (0.0%)	4 (200.0%)	3 (150.0%)	2 (100.0%)	2 (100.0%)	0 (0.0%)
Personalised Medicine	69 (100%)	4 (200.0%)	6 (300.0%)	2 (100.0%)	7 (350.0%)	21 (1050.0%)	19 (950.0%)	8 (400.0%)	2 (100.0%)
Photovoltaic	35 (100%)	0 (0.0%)	9 (450.0%)	2 (100.0%)	5 (250.0%)	6 (300.0%)	11 (550.0%)	2 (100.0%)	0 (0.0%)
Smart Grid	26 (100%)	2 (100.0%)	4 (200.0%)	3 (150.0%)	3 (150.0%)	4 (200.0%)	6 (300.0%)	3 (150.0%)	1 (50.0%)
Stem Cell Treatment	56 (100%)	3 (150.0%)	7 (350.0%)	3 (150.0%)	7 (350.0%)	18 (900.0%)	13 (650.0%)	3 (150.0%)	2 (100.0%)
Total number incl. double counts (in%)	295 (100%)	27 (1350.0%)	42 (2100.0%)	13 (650.0%)	46 (2300.0%)	67 (3350.0%)	64 (3200.0%)	31 (1550.0%)	5 (250.0%)

Table B 16: Drivers for the development of the stand-alone, core and supportive innovations conducted by the respondents' organisations in the field of Major Innovations; arithmetic mean (0=not important; 100=very important) and number of respondents in parenthesis

Source: JIIP, based on online survey

	Past R&D conducted in-house	Past R&D conducted in a European Framework project	Past R&D conducted within a national program	Past R&D conducted within a (cooperative) project exclusively funded from an internal budget	Building on (realized potential in the course of) previous activities	Observation of a market niche. customer request	Outcompetition of existing products and/or firms	Customers demand	Suppliers demand	Strategic considerations (e.g. new knowledge. new market areas. etc.)
Car Navigation Systems	77 (13)	78.4 (15)	68.15 (13)	56.36 (11)	70.85 (13)	57.08 (12)	52.55 (11)	60.62 (13)	57.75 (12)	66.15 (13)
Light-Emitting Diode (Led) Lighting	75.39 (33)	62.97 (30)	62.28 (32)	62.3 (27)	70.93 (30)	63.38 (26)	60.54 (26)	69.57 (28)	40.85 (26)	76.13 (30)
Linux Operating System	86 (6)	71.33 (6)	46.67 (6)	57.6 (5)	72.25 (4)	82.33 (3)	65 (4)	39.75 (4)	40.5 (4)	84.75 (4)
Mobile Phone	68.5 (46)	72.33 (48)	57.64 (45)	41.27 (37)	67.26 (42)	57 (38)	46.32 (34)	66.39 (38)	44.06 (31)	68.68 (40)
Super Jumbo Jet 11	82 (61)	72.07 (59)	68.89 (54)	59.41 (51)	74.64 (56)	55.72 (54)	43.33 (43)	71.74 (53)	33.85 (48)	64.13 (53)
Optical Fibres	78.78 (18)	52.44 (18)	52.12 (17)	42.69 (16)	67.75 (16)	49.25 (16)	39.21 (14)	56.73 (15)	23.92 (12)	69.67 (15)
Personalised Medicine	83.16 (73)	71.49 (71)	66.37 (68)	46.25 (64)	68.82 (66)	54.17 (65)	39.84 (56)	51.66 (65)	30.72 (58)	68.19 (68)
Photovoltaic	78.82 (55)	73.46 (52)	66.81 (52)	55.89 (46)	72.9 (51)	64.24 (51)	48.67 (43)	59.32 (50)	43.7 (43)	73.73 (51)
Smart Grid	71.49 (59)	68.05 (59)	60.36 (58)	49.55 (55)	64.26 (50)	61.34 (53)	45.1 (52)	54.35 (51)	45.48 (50)	71.81 (54)
Stem Cell Treatment	86.81 (68)	64.62 (66)	69.63 (60)	49.07 (58)	68.58 (59)	49.94 (52)	40.5 (50)	46.08 (53)	27 (48)	60.8 (55)

Table B 17: Impact of the development of the stand-alone, core and supportive innovations of Major Innovations conducted by the respondents' organisations on R&D activities; arithmetic mean (0=low impact; 100=high impact) and number of respondents in parenthesis

Source: JIIP, based on online survey

	Increased number of research staff	Improved/enlarged scope of scientific/technological/managerial skills and capabilities	Reorientation of R&D strategy	Improved access to complementary expertise (e.g. R&D partnerships and networks)	Trans-national mobility of researchers	Establishment/reorientation of training. vocational training/life-long learning	Improved visibility as a competent R&D-partner	New or improved products/production processes/services	Reorientation of commercial strategy	Creation of spin-off companies
Car Navigation Systems	63.86 (14)	77.4 (15)	47.8 (15)	72.85 (13)	44.18 (11)	55.82 (11)	76.23 (13)	66.85 (13)	48.46 (13)	31 (12)
Light-Emitting Diode (Led) Lighting	48.77 (31)	70.16 (32)	52.9 (31)	67.63 (30)	49.23 (30)	43.25 (28)	74.66 (29)	70.42 (31)	53.23 (31)	32.17 (29)
Linux Operating System	64.4 (5)	84 (6)	74.8 (5)	85.4 (5)	36.5 (4)	30 (5)	81.4 (5)	77.5 (4)	60.33 (3)	36.33 (3)
Mobile Phone	57.23 (44)	71.69 (45)	55.72 (43)	73.09 (44)	55.73 (41)	44.84 (37)	74.02 (41)	65.29 (41)	46.66 (38)	37.18 (39)
Super Jumbo Jet 11	54.86 (58)	76.52 (60)	52.71 (55)	70.22 (55)	50.07 (55)	43.1 (50)	78.32 (59)	65.23 (57)	39.96 (48)	24.77 (47)
Optical Fibres	66.76 (17)	76.56 (18)	61.76 (17)	68.12 (17)	37.25 (16)	31.31 (16)	73.38 (16)	58.93 (15)	35.15 (13)	38.86 (14)
Personalised Medicine	66.54 (70)	77.58 (71)	57.18 (67)	75.94 (69)	63.63 (65)	58 (65)	73.56 (70)	70 (69)	41.05 (60)	28.9 (59)
Photovoltaic	63.46 (54)	74.44 (57)	62 (53)	70.65 (54)	51.94 (53)	47.69 (48)	75.2 (54)	64.62 (52)	48.56 (48)	25.85 (46)
Smart Grid	60.07 (59)	74.29 (59)	59.58 (59)	74.07 (59)	46.3 (57)	50.59 (54)	76.51 (57)	74.64 (55)	59.42 (53)	29.2 (51)
Stem Cell Treatment	60.86 (65)	75.6 (65)	59.32 (63)	70.71 (62)	56.73 (62)	54.25 (59)	72.02 (62)	66.27 (60)	35.85 (54)	33.81 (54)
Total	60.31 (417)	75.12 (428)	57.46 (408)	72.18 (408)	52.76 (394)	49.01 (373)	74.95 (406)	67.79 (397)	45.67 (361)	30.45 (354)

Table B 18: Impact of the development of the stand-alone, core and supportive innovations of Major Innovations conducted by the respondents' organisations on organisational and societal activities; arithmetic mean (0=low impact; 100=high impact) and number of respondents in parenthesis

Source: JIIP, based on online survey

	New or improved standards	Savings in resources (e.g. time. costs)	Increased license incomes	Increased turnover	Enhanced productivity	Improved market share/entering new markets	Increased overall employment	Improvement in the health system	Improvement in the educational system	Ensuring resource security (raw materials. energy)	Other environmental impacts
Car Navigation Systems	42.14 (14)	38.67 (12)	22.92 (12)	44.91 (11)	38.82 (11)	49.56 (9)	47.9 (10)	34.3 (10)	38.9 (10)	26.1 (10)	56.73 (11)
Light-Emitting Diode (Led) Lighting	45.45 (29)	51.79 (29)	28.14 (28)	57 (29)	51.07 (30)	59.34 (29)	46.42 (31)	26.81 (27)	35.85 (27)	40.15 (26)	44.35 (26)
Linux Operating System	46.25 (4)	29.75 (4)	36.67 (3)	45.67 (3)	15.33 (3)	52.67 (3)	24.33 (3)	5.67 (3)	36 (4)	8 (3)	24.5 (4)
Mobile Phone	52.47 (38)	44.59 (37)	36.2 (35)	47.51 (35)	47.61 (38)	60.22 (37)	54.43 (37)	41.35 (37)	46.67 (39)	36.26 (35)	44.85 (33)
Super Jumbo Jet 11	44.4 (48)	42.9 (48)	28.22 (50)	46.74 (46)	42.96 (45)	47.09 (46)	53.17 (54)	31.68 (47)	41.1 (48)	41.8 (49)	45.76 (51)
Optical Fibres	40.92 (12)	54.09 (11)	32.5 (12)	44 (14)	34.18 (11)	45.67 (12)	54 (15)	31.54 (13)	50.57 (14)	27.77 (13)	25 (13)
Personalised Medicine	54.17 (63)	48.68 (60)	28.02 (56)	42.33 (57)	53.69 (58)	46.65 (54)	58.84 (62)	69.22 (67)	61.37 (62)	32.69 (55)	26.67 (54)
Photovoltaic	33.89 (47)	40.92 (49)	22.77 (44)	44.91 (45)	39.51 (47)	52.86 (44)	49.63 (48)	18.25 (44)	38.28 (46)	46.04 (49)	52.02 (47)
Smart Grid	45.45 (53)	47.55 (53)	27.84 (50)	57.7 (53)	54.69 (52)	60.53 (51)	51.9 (51)	27.88 (50)	43.02 (52)	52.06 (52)	55.77 (52)
Stem Cell Treatment	55.28 (50)	48.64 (50)	31.76 (49)	36.83 (52)	45.63 (49)	36.54 (52)	50.04 (56)	61.04 (57)	54.65 (55)	30.51 (47)	25.63 (49)
Total	47.17 (358)	46.08 (353)	28.79 (339)	46.72 (345)	47.02 (344)	50.74 (337)	52.22 (367)	41.77 (355)	47.09 (357)	38.94 (339)	41.34 (340)

Table B 19: Important drivers for of respondents' organisation to participate in FP projects; arithmetic mean (0=not important; 100=very important) and number of respondents in parenthesis

Source: JIIP, based on online survey

	R&D cost sharing	R&D risk sharing	Access to complementary resources and skills	Reach a critical mass of resources and skills	Keeping up with major technological developments	Exploring different technological opportunities	Gain a window into 'state of the art' technology	Show up technological competences
Car Navigation Systems	65.19 (21)	57.37 (19)	75.27 (22)	59.11 (18)	76.86 (21)	79.05 (20)	68.75 (20)	70.67 (21)
Light-Emitting Diode (Led) Lighting	67.03 (39)	65.28 (39)	75.68 (40)	62.97 (39)	69.98 (40)	76.15 (40)	74.43 (40)	77.23 (40)
Linux Operating System	66.7 (10)	51.44 (9)	71.09 (11)	57.11 (9)	63.33 (9)	70.45 (11)	74.67 (9)	69.22 (9)
Mobile Phone	64.2 (56)	55.13 (54)	74.83 (60)	66.05 (59)	78.25 (60)	73.13 (61)	77.82 (57)	73.43 (58)
Super Jumbo Jet 11	71.55 (74)	62.76 (68)	73.67 (76)	66.55 (69)	77.84 (73)	72.59 (71)	77.11 (74)	74.95 (73)
Optical Fibres	73.89 (18)	50.5 (16)	84.95 (19)	69.44 (18)	73.83 (18)	81.39 (18)	71.06 (17)	66.12 (17)
Personalised Medicine	65.3 (82)	56.11 (74)	77.52 (83)	70.32 (81)	76.43 (81)	76.32 (78)	70.17 (76)	69.7 (77)
Photovoltaic	68.26 (58)	59.84 (55)	75.74 (58)	66.73 (55)	73.75 (57)	73.38 (61)	68.42 (59)	71.97 (58)
Smart Grid	71.56 (64)	61.75 (65)	73.82 (66)	62.95 (65)	77.61 (64)	74.06 (63)	74.35 (62)	69.68 (60)
Stem Cell Treatment	60.81 (84)	50.48 (75)	74.65 (85)	66.35 (77)	70.51 (81)	70.77 (78)	70.76 (78)	65.47 (76)
Total	66.94 (506)	57.8 (474)	75.41 (520)	66 (490)	74.92 (504)	74.05 (501)	72.91 (492)	71.06 (489)

Table B 20: Important drivers for of respondents' organisation to participate in FP projects; arithmetic mean (0=not important; 100=very important) and number of respondents in parenthesis

Source: JIIP, based on online survey

	Networking/find new partners	Promote user/producer interactions	Joint creation and promotion of technical standards	Improve speed of bringing innovation to market	Allow entry into a new market	Control future market developments	Obtain funding
Car Navigation Systems	77.67 (21)	68.06 (17)	63.84 (19)	63.44 (16)	59.88 (17)	54 (17)	73.9 (20)
Light-Emitting Diode (Led) Lighting	77.55 (40)	67.33 (36)	51.03 (35)	59.74 (35)	60.44 (36)	54.55 (33)	70.67 (39)
Linux Operating System	80.44 (9)	47.67 (6)	40.67 (6)	48.67 (6)	28.43 (7)	38.67 (6)	59.33 (9)
Mobile Phone	77.44 (61)	61.08 (52)	59.35 (54)	58.77 (53)	53.67 (52)	46.86 (49)	71.38 (58)
Super Jumbo Jet 11	79.11 (72)	50.71 (63)	52.23 (65)	55.95 (65)	53.74 (65)	52.05 (62)	67.81 (67)
Optical Fibres	83.05 (20)	58.94 (17)	41.47 (15)	56.13 (16)	45.35 (17)	37.64 (14)	73.12 (17)
Personalised Medicine	80.49 (82)	58.21 (68)	56.27 (73)	58.63 (76)	52.87 (71)	41.02 (65)	70.61 (76)
Photovoltaic	75 (59)	61.31 (54)	52.67 (51)	62.42 (55)	57.15 (55)	53.06 (52)	69.4 (58)
Smart Grid	80.17 (66)	58 (60)	56.39 (61)	66.46 (61)	63.88 (58)	49.64 (58)	73.11 (56)
Stem Cell Treatment	79.28 (80)	46.95 (63)	56.22 (68)	52.28 (69)	43.29 (65)	39.97 (66)	72.88 (75)
Total	78.82 (510)	57.22 (436)	54.86 (447)	58.85 (452)	53.87 (443)	47.26 (422)	70.83 (475)

Table B 21: Comparison of an average R&D project to an FP project; arithmetic mean (0=disagree; 100=strongly agree) and number of respondents in parenthesis

Source: JIIP, based on online survey

	The stand-alone/core/supportive innovation compared to an average R&D project had...					
	...high internal project cost.	...high degree of scientific and technical risk.	...high degree of commercial risk.	...scientific and technical complexity.	...long and intensive research and development phase.	...new technological aspects incorporated.
Car Navigation Systems	46.48 (21)	56.18 (22)	48.77 (22)	69.3 (23)	66.77 (22)	74.52 (23)
Light-Emitting Diode (Led) Lighting	48.33 (39)	64.23 (39)	52.53 (38)	74.05 (39)	67.92 (39)	79.92 (39)
Linux Operating System	35.67 (9)	58 (11)	55.9 (10)	72.36 (11)	71.8 (10)	75.75 (8)
Mobile Phone	48.51 (61)	56.02 (61)	47.83 (59)	71.74 (61)	65.57 (61)	76.78 (60)
Super Jumbo Jet 11	53.36 (76)	63.24 (76)	49.93 (72)	74.26 (76)	73.88 (76)	76.07 (72)
Optical Fibres	45.94 (16)	74.2 (20)	47.72 (18)	79.95 (20)	77.15 (20)	77.78 (18)
Personalised Medicine	51.74 (84)	56.53 (85)	37.04 (77)	76 (87)	74.77 (84)	76.54 (82)
Photovoltaic	55.65 (57)	65.34 (59)	56.48 (58)	74.89 (62)	75.23 (61)	76.38 (61)
Smart Grid	51.38 (64)	58.31 (65)	53.08 (64)	73.41 (66)	67.49 (67)	75.59 (66)
Stem Cell Treatment	53.71 (86)	60.09 (86)	41.29 (78)	73.59 (88)	70.74 (86)	74.81 (84)
Total	51.38 (513)	60.5 (524)	47.68 (496)	74.06 (533)	71.24 (526)	76.27 (513)

Table B 22: Impacts of the FP project on the respondents' organisation; arithmetic mean (0=disagree; 100=strongly agree) and number of respondents in parenthesis

Source: JIIP, based on online survey

	Technological development	Knowledge development	Skills development	Networking and collaboration	Access to knowledge	Access to markets
Car Navigation Systems	74.95 (22)	77.05 (22)	74.65 (23)	75.91 (23)	72.27 (22)	44 (17)
Light-Emitting Diode (Led) Lighting	79.86 (37)	84.66 (38)	79.87 (38)	83 (38)	80.16 (37)	53.92 (36)
Linux Operating System	71.78 (9)	76.22 (9)	72.56 (9)	74.8 (10)	76.4 (10)	23.29 (7)
Mobile Phone	71.18 (60)	78.55 (60)	76.53 (58)	79.59 (58)	75.39 (57)	42.79 (53)
Super Jumbo Jet 11	72.89 (76)	78.55 (76)	75.89 (73)	77.45 (75)	70.36 (76)	46.55 (67)
Optical Fibres	81.2 (20)	90.95 (20)	80.35 (20)	87.75 (20)	88.2 (20)	43.17 (18)
Personalised Medicine	72.13 (86)	85.66 (87)	77.26 (88)	84.17 (89)	78.78 (88)	39.66 (80)
Photovoltaic	78.82 (65)	85.92 (66)	78.31 (65)	83.05 (64)	76.02 (64)	46.57 (58)
Smart Grid	69.48 (67)	81.55 (69)	77.85 (67)	79.35 (69)	79.5 (66)	53.98 (64)
Stem Cell Treatment	71.93 (88)	82.05 (88)	77.34 (85)	79.84 (88)	76.43 (84)	34.06 (72)
Total	73.58 (530)	82.37 (535)	77.32 (526)	80.78 (534)	76.7 (524)	44.06 (472)

Table B 23: Would the development of the stand-alone, core and supportive innovation conducted by the respondents' organisation have been possible without the EU Framework Programme project(s)?; absolute figures and percentage in parenthesis

Source: JIIP, based on online survey

	Total number (in%)	Yes.	No.
Car Navigation Systems	13 (100%)	4 (30.8%)	9 (69.2%)
Light-Emitting Diode (Led) Lighting	25 (100%)	13 (52.0%)	12 (48.0%)
Linux Operating System	6 (100%)	1 (16.7%)	5 (83.3%)
Mobile Phone	43 (100%)	22 (51.2%)	21 (48.8%)
Super Jumbo Jet 11	57 (100%)	21 (36.8%)	36 (63.2%)
Optical Fibres	15 (100%)	6 (40.0%)	9 (60.0%)
Personalised Medicine	67 (100%)	19 (28.4%)	48 (71.6%)
Photovoltaic	48 (100%)	15 (31.3%)	33 (68.8%)
Smart Grid	53 (100%)	22 (41.5%)	31 (58.5%)
Stem Cell Treatment	63 (100%)	24 (38.1%)	39 (61.9%)
Total	390 (100%)	147 (37.7%)	243 (62.3%)

Table B 24: Change in view of the respondents' organisation on the field of Major Innovations between the start of the first EU Framework Programme project and the end of the last EU Framework Programme project; arithmetic mean (0=disagree; 100=strongly agree) and number of respondents in parenthesis

Source: JIIP, based on online survey

	For our organisation, the field of MI has become...						
	...more technological complex.	...a significant driver of profitable technological innovations (applications).	...more core to the organisation (higher attention, institutionally anchored etc.).	...more financial risky (need for investment).	...more competitive.	...more affected by regulatory interventions.	...a driver of social innovations.
Car Navigation Systems	43.52 (21)	43.79 (19)	54.89 (19)	50.5 (18)	54.11 (18)	62.2 (20)	51.12 (17)
Light-Emitting Diode (Led) Lighting	50.71 (35)	46.03 (33)	65.5 (34)	43.77 (31)	53.88 (32)	62.49 (35)	42.61 (31)
Linux Operating System	53.67 (9)	24.13 (8)	62.11 (9)	39.5 (8)	55.78 (9)	64.63 (8)	42.43 (7)
Mobile Phone	67.8 (59)	50.13 (54)	72.27 (60)	51.95 (55)	59.05 (55)	70.26 (57)	67.37 (57)
Super Jumbo Jet 11	61.71 (68)	54.45 (66)	56.09 (65)	44.67 (64)	46.97 (61)	61.94 (64)	37.24 (59)
Optical Fibres	71.53 (17)	51.29 (14)	71.59 (17)	33.86 (14)	46.2 (15)	74.38 (16)	48.75 (16)
Personalised Medicine	66.78 (83)	53.57 (82)	70.98 (84)	54.93 (80)	62.7 (80)	67.52 (77)	52.52 (77)
Photovoltaic	64.05 (57)	65.64 (55)	73.97 (58)	53.53 (49)	59.57 (54)	62.96 (55)	48.65 (48)
Smart Grid	61.06 (68)	54.02 (64)	68 (65)	64.13 (64)	71.34 (64)	70.17 (63)	55.39 (59)
Stem Cell Treatment	61.38 (79)	49.01 (74)	69.85 (81)	60.61 (74)	63.73 (73)	65.46 (76)	40.94 (65)
Total	62.05 (496)	52.56 (469)	67.8 (492)	53.34 (457)	59.56 (461)	66.17 (471)	49.57 (436)

Table B 25: Impact of FP6 project on the respondents' organisation; arithmetic mean (0=disagree; 100=strongly agree) and number of respondents in parenthesis

Source: JIIP, based on online survey

	Technological development	Knowledge development	Skills development	Networking and collaboration	Access to knowledge	Access to markets
Car Navigation Systems	63.75 (4)	81.75 (4)	75.5 (4)	71.5 (4)	74.75 (4)	29.33 (3)
Light-Emitting Diode (Led) Lighting	83.77 (13)	87.31 (13)	87.69 (13)	85.15 (13)	83.69 (13)	56.67 (12)
Linux Operating System	81.6 (5)	83.6 (5)	72.2 (5)	78.2 (5)	82.8 (5)	37.33 (3)
Mobile Phone	74.91 (23)	83.48 (23)	79.17 (23)	82.13 (23)	76.3 (23)	39.19 (21)
Super Jumbo Jet 11	72.4 (30)	81 (30)	76.57 (28)	79.93 (29)	73.3 (30)	43.2 (25)
Optical Fibres	90.6 (5)	94.4 (5)	87 (5)	87.2 (5)	86.2 (5)	47.8 (5)
Personalised Medicine	65.31 (13)	88.43 (14)	78.14 (14)	83.93 (14)	76.86 (14)	23.15 (13)
Photovoltaic	77.75 (16)	85.75 (16)	80 (16)	83.69 (16)	76.69 (16)	46.63 (16)
Smart Grid	63.08 (13)	83.57 (14)	84.43 (14)	81.57 (14)	82.64 (14)	56.67 (12)
Stem Cell Treatment	71.61 (28)	81.1 (29)	75.26 (27)	78.07 (29)	73 (28)	24.62 (26)
Total	73.45 (150)	83.88 (153)	79.13 (149)	81.23 (152)	76.91 (152)	39.63 (136)

Table B 26: Impact of FP7 project on the respondents' organisation; arithmetic mean (0=disagree; 100=strongly agree) and number of respondents in parenthesis

Source: JIIP, based on online survey

SEVENTH FRAMEWORK PROGRAMME	Technological development	Knowledge development	Skills development	Networking and collaboration	Access to knowledge	Access to markets
Car Navigation Systems	78.62 (13)	75.77 (13)	73 (14)	74.21 (14)	69.62 (13)	47.91 (11)
Light-Emitting Diode (Led) Lighting	77.75 (24)	83.28 (25)	75.8 (25)	81.88 (25)	78.25 (24)	52.54 (24)
Linux Operating System	77.75 (2)	83.28 (2)	75.8 (2)	81.88 (3)	78.25 (3)	52.54 (2)
Mobile Phone	69.17 (23)	72.48 (23)	73.59 (22)	74.48 (21)	72.95 (20)	47 (19)
Super Jumbo Jet 11	73.2 (45)	77.36 (45)	75.3 (44)	75.73 (45)	69.31 (45)	49.66 (41)
Optical Fibres	81.5 (12)	90.67 (12)	77.33 (12)	88.75 (12)	88 (12)	46.82 (11)
Personalised Medicine	73.34 (73)	85.12 (73)	77.09 (74)	84.21 (75)	79.15 (74)	42.87 (67)
Photovoltaic	79.23 (48)	86.14 (49)	77.77 (48)	83 (47)	75.79 (48)	46.55 (42)
Smart Grid	70.94 (53)	80.69 (54)	76.15 (52)	78.41 (54)	78.31 (51)	53.82 (51)
Stem Cell Treatment	72.08 (60)	82.51 (59)	78.31 (58)	80.71 (59)	78.14 (56)	39.39 (46)
Total	74.02 (353)	82.05 (355)	76.59 (351)	80.5 (355)	76.65 (346)	46.6 (314)

Table B 27: Comparison of impacts of FP5-FP7 projects on the respondents' organisation; arithmetic mean (0=disagree; 100=strongly agree) and number of respondents in parenthesis

Source: JIIP, based on online survey

SEVENTH FRAMEWORK PROGRAMME	FP5	FP6	FP7
Technological development	68.44 (27)	73.45 (150)	74.02 (353)
Knowledge development	78.11 (27)	83.88 (153)	82.05 (355)
Skills development	76.81 (26)	79.13 (149)	76.59 (351)
Networking and collaboration	81.93 (27)	81.23 (152)	80.5 (355)
Access to knowledge	76.19 (26)	76.91 (152)	76.65 (346)
Access to markets	35.27 (22)	39.63 (136)	46.6 (314)

Table B 28: Important factors for respondents' organisations in participating in FP6 projects; arithmetic mean (0=not important; 100=very important) and number of respondents in parenthesis

Source: JIIP, based on online survey

	R&D cost sharing	R&D risk sharing	Access to complementary resources and skills	Reach a critical mass of resources and skills	Keeping up with major technological developments	Exploring different technological opportunities	Gain a window into 'state of the art' technology	Show up technological competences
Car Navigation Systems	47.75 (4)	37 (3)	77.5 (4)	58.25 (4)	85.25 (4)	90 (3)	80 (3)	71.5 (4)
Light-Emitting Diode (Led) Lighting	64.77 (13)	62 (13)	81.92 (13)	69.5 (12)	71 (13)	70.77 (13)	74.38 (13)	76.15 (13)
Linux Operating System	68.2 (5)	37.75 (4)	79.5 (6)	60.75 (4)	71.6 (5)	67.67 (6)	88.75 (4)	71.6 (5)
Mobile Phone	65.4 (20)	57.32 (19)	73.64 (22)	64.48 (23)	80.61 (23)	72.17 (23)	82.68 (22)	73.68 (22)
New Generation Super Jumbo Jet 11	71.97 (31)	56.81 (27)	69.71 (31)	58.31 (26)	74.97 (29)	76.52 (27)	76.63 (30)	72.2 (30)
Optical Fibres	78.8 (5)	62.75 (4)	85.2 (5)	86.2 (5)	82 (5)	76.6 (5)	54.75 (4)	62.5 (4)
Personalised Medicine	57.92 (12)	41.42 (12)	78.5 (12)	63.33 (12)	76.33 (12)	77.73 (11)	75.73 (11)	74.55 (11)
Photovoltaic	60.07 (15)	52.93 (15)	72.14 (14)	64.5 (14)	72.53 (15)	68.8 (15)	69.29 (14)	71.2 (15)
Smart Grid	64.21 (14)	62.69 (13)	81.57 (14)	63.79 (14)	78.79 (14)	80.71 (14)	78.08 (13)	70.54 (13)
Stem Cell Treatment	55.93 (28)	36.85 (27)	66.57 (28)	60.28 (25)	64.65 (26)	67 (25)	68.58 (26)	61.38 (26)
Total	63.73 (147)	51.41 (137)	73.94 (149)	63.33 (139)	74.3 (146)	73.22 (142)	75 (140)	70.43 (143)

Table B 29: Important factors for respondents' organisations in participating in FP6 projects; arithmetic mean (0=not important; 100=very important) and number of respondents in parenthesis

Source: JIIP, based on online survey

	Networking/find new partners	Promote user/producer interactions	Joint creation and promotion of technical standards	Improve speed of bringing innovation to market	Allow entry into a new market	Control future market developments	Obtain funding
Car Navigation Systems	76 (4)	62.67 (3)	52.25 (4)	58 (3)	56.33 (3)	41.67 (3)	55 (3)
Light-Emitting Diode (Led) Lighting	75.46 (13)	62.36 (11)	41.36 (11)	70.55 (11)	74.27 (11)	58.1 (10)	75.62 (13)
Linux Operating System	98.2 (5)	55.67 (3)	67.33 (3)	62.5 (2)	39.25 (4)	64.33 (3)	54 (6)
Mobile Phone	79.22 (23)	57.35 (20)	62.15 (20)	55.26 (19)	49.11 (19)	47.25 (20)	72.68 (22)
New Generation Super Jumbo Jet 11	82.04 (27)	43.38 (24)	47.83 (24)	53.08 (26)	46.72 (25)	48.96 (24)	69.93 (28)
Optical Fibres	88 (5)	63 (4)	58.67 (3)	62.8 (5)	52.2 (5)	36.33 (3)	89.5 (4)
Personalised Medicine	88 (11)	69.89 (9)	67.36 (11)	49.2 (10)	31.11 (9)	30.67 (9)	74.36 (11)
Photovoltaic	60.8 (15)	42.2 (15)	54.93 (14)	67.73 (15)	54.13 (15)	52.47 (15)	59.67 (15)
Smart Grid	84.71 (14)	49.62 (13)	49.92 (12)	62.69 (13)	63.38 (13)	41.67 (12)	65.82 (11)
Stem Cell Treatment	78.59 (27)	40 (24)	51.77 (26)	49.96 (25)	35.83 (23)	31.17 (24)	76.44 (27)
Total	79.45 (144)	50.38 (126)	53.81 (128)	57.29 (129)	49.17 (127)	44.22 (123)	70.63 (140)

Table B 30: Important factors for respondents' organisations in participating in FP7 projects; arithmetic mean (0=not important; 100=very important) and number of respondents in parenthesis

Source: JIIP, based on online survey

SEVENTH FRAMEWORK PROGRAMME	R&D cost sharing	R&D risk sharing	Access to complementary resources and skills	Reach a critical mass of resources and skills	Keeping up with major technological developments	Exploring different technological opportunities	Gain a window into 'state of the art' technology	Show up technological competences
Car Navigation Systems	66 (12)	61.09 (11)	74.62 (13)	57.7 (10)	70.83 (12)	74.42 (12)	65.83 (12)	76 (12)
Light-Emitting Diode (Led) Lighting	69.08 (25)	68.92 (25)	75.12 (26)	60.77 (26)	70.58 (26)	79.15 (26)	75.73 (26)	78.08 (26)
Linux Operating System	86 (3)	86.33 (3)	79.67 (3)	73.67 (3)	75.5 (2)	96.33 (3)	77.33 (3)	93.5 (2)
Mobile Phone	63.7 (23)	54.17 (23)	74.44 (25)	67.96 (24)	77.5 (24)	77.04 (25)	73.57 (23)	78.78 (23)
New Generation Super Jumbo Jet 11	70.57 (42)	66.75 (40)	76.61 (44)	71.05 (42)	79.3 (43)	69.91 (43)	77.33 (43)	76.4 (42)
Optical Fibres	71.2 (10)	55.67 (9)	87.09 (11)	65.7 (10)	68.1 (10)	87.2 (10)	78.3 (10)	64.2 (10)
Personalised Medicine	66.57 (70)	58.95 (62)	77.35 (71)	71.54 (69)	76.45 (69)	76.09 (67)	69.23 (65)	68.89 (66)
Photovoltaic	71.12 (43)	62.43 (40)	76.89 (44)	67.49 (41)	74.19 (42)	74.87 (46)	68.16 (45)	72.23 (43)
Smart Grid	73.37 (49)	61.82 (51)	71.45 (51)	63.12 (50)	77.18 (49)	72.75 (48)	73.17 (48)	70 (46)
Stem Cell Treatment	63.25 (56)	58.15 (48)	78.61 (57)	69.27 (52)	73.27 (55)	72.55 (53)	71.85 (52)	67.6 (50)
Total	68.39 (333)	61.43 (312)	76.38 (345)	67.62 (327)	75.27 (332)	74.84 (333)	72.19 (327)	72.02 (320)

Table B 31: Important factors for respondents' organisations in participating in FP7 projects; arithmetic mean (0=not important; 100=very important) and number of respondents in parenthesis

Source: JIIP, based on online survey

	Networking/find new partners	Promote user/producer interactions	Joint creation and promotion of technical standards	Improve speed of bringing innovation to market	Allow entry into a new market	Control future market developments	Obtain funding
Car Navigation Systems	73.75 (12)	67.8 (10)	64.6 (10)	63.4 (10)	57.45 (11)	55.6 (10)	75.83 (12)
Light-Emitting Diode (Led) Lighting	78.88 (26)	71.42 (24)	56.7 (23)	56.26 (23)	55.38 (24)	54.95 (22)	68.44 (25)
Linux Operating System	98.5 (2)	77 (1)	2 (1)	43.5 (2)	1 (1)	1 (1)	56 (1)
Mobile Phone	74.88 (25)	65 (20)	59.05 (21)	58.48 (21)	59.76 (21)	49.06 (18)	74.36 (22)
New Generation Super Jumbo Jet 11	76.95 (44)	56.37 (38)	55.33 (40)	58.58 (38)	59.59 (39)	55.43 (37)	65.39 (38)
Optical Fibres	77.92 (12)	68.1 (10)	40.22 (9)	63.44 (9)	50.8 (10)	45.33 (9)	64 (11)
Personalised Medicine	79.32 (71)	56.42 (59)	54.31 (62)	60.06 (66)	56.03 (62)	42.68 (56)	69.97 (65)
Photovoltaic	79.84 (44)	68.67 (39)	51.81 (37)	60.43 (40)	58.28 (40)	53.3 (37)	72.79 (43)
Smart Grid	78.55 (51)	60.76 (46)	58.38 (48)	67.09 (47)	64.07 (44)	52.56 (45)	74.55 (44)
Stem Cell Treatment	79.62 (53)	51.23 (39)	58.98 (42)	53.59 (44)	47.38 (42)	45 (42)	70.88 (48)
Total	78.52 (340)	60.81 (286)	55.73 (293)	59.77 (300)	56.68 (294)	49.55 (277)	70.75 (309)

Table B 32: Comparison of important factors for respondents' organisations when participating in FP5 – FP7 projects; arithmetic mean (0=disagree; 100=strongly agree) and number of respondents in parenthesis

Source: JIIP, based on online survey

	FP5	FP6	FP7
R&D cost sharing	66.58 (26)	63.73 (147)	68.39 (333)
Reduction of uncertainty due to Risk sharing	47.4 (25)	51.41 (137)	61.43 (312)
Access to complementary resources and skills	70.88 (26)	73.94 (149)	76.38 (345)
Reached a critical mass of resources and skills i	59.42 (24)	63.33 (139)	67.62 (327)
Keeping up with major technological developm	74 (26)	74.3 (146)	75.27 (332)
Exploring different technological opportunities	68.35 (26)	73.22 (142)	74.84 (333)
Gain a window into 'state of the art' technology	70.68 (25)	75 (140)	72.19 (327)
Networking / find new partners	79.15 (26)	79.45 (143)	78.52 (320)
Promote user/producer interactions	50.29 (26)	50.38 (144)	60.81 (340)
Joint creation and promotion of technical stand	50.15 (24)	53.81 (126)	55.73 (286)
Improve speed of bringing innovation to marke	55.43 (26)	57.29 (128)	59.77 (293)
Potential entry into a new market	43.45 (23)	49.17 (129)	56.68 (300)
Control future market developments	35.36 (22)	44.22 (127)	49.55 (294)
Obtain funding	72.88 (22)	70.63 (123)	70.75 (277)

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[KI-02-16-068-EN-N]

This study identifies the key elements explaining how some Major Innovations came about in Europe and in the world, and evaluates the specific contribution of the European Union Framework Programmes for Research, Technological developments and Demonstration Activities to their development. The results support policy evaluation and development as well as the understanding of areas for further improvement to enhance impacts.

This study was conducted by an external contractor (Jiip - The Joint Institute for Innovation Policy) from December 2013 to March 2015. It is one of evidence gathering exercises undertaken for the overall ex post evaluation of the FP7 (2007-2013) and for the Interim Evaluation of H2020.

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ISBN 978-92-79-51532-3